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CICLO XXX

DEVELOPMENT AND TESTING OF A NEW METHOD TO COMBINE ENVIRONMENTAL MANAGEMENT TOOLS TO IMPROVE LIFE CYCLE MANAGEMENT PERFORMANCE AT INDUSTRIAL LEVEL

Coordinatore: Ch.mo Prof. Paolo Colombo
Supervisore: Ch.mo Prof. Antonio Scipioni

Dottorando: Andrea Loss

Learn from yesterday, live for today, hope for tomorrow.
The important thing is to not stop questioning.
(Albert Einstein)

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RESEARCH ABSTRACT

Environmental sustainable development topic is increasingly at the centre of international interest. During the last decades, environmental issues have evolved from pollution and depletion of natural resources towards global issues such as climate change. Industrial organizations are exposed to risks that could undermine their market competitiveness: operative risks, financial risks, compliance risks and Market risks. In this global context, industries need of a robust Environmental Strategy for improving their competitiveness and proactively manage related risks and opportunities. In the last years, the concept of life cycle environmental management has increased its importance stressing the need of organizations manage all the environmental impacts generate by their activities and products along all values chains with a life cycle perspective. The management of life cycle performance is a multiperspectives issue and requires the use of multiple Environmental Management Tools (EMTs) to be addressed. The scientific community has responded developing many methods for multiple EMTs use.

From scientific literature review several limits of current method for multiple EMTs use emerged that are circumscribable in six different critical areas: 1. environmental impact assessment, 2. Resources consumption assessment, 3. performance evaluation, 4. ecoinnovation (Eco Design, Eco Efficiency), 5. strategic decision making and 6. strategy & management. These limitations do not allow companies to have a robust and complete management of its life cycle environmental performance and therefore limit the opportunity to develop strategies that reduce the environmental impacts of the organization and its products. The present research focuses on the development and application at industrial level of a new method to combine environmental management tools (EMTs) to improve the life cycle environmental performance of industries. To do so the specific objectives of the research were the develop of a new method to combine EMTs to overcome identified criticalities and test its applicability and effectiveness to improve life cycle environmental management performance in a real industrial case study.

The methodology of the research took into consideration the Environmental Management Drivers (EMDs), the Environmental Management Barriers (EMBs), the integration/combination mechanisms, the available EMTs, and the limits of already existing methods in the definition of the new method and the single case study method to address and discuss its applicability and effectiveness at industrial level.

The development of the new method Organizational Environmental Sustainability System (OES2) is addressed in the first part of the research. The method has been developed combining seven different ISO EMTs: Organizational Life Cycle Assessment (ISO/TS 14072), Product Life Cycle Assessment (ISO 14040-44), Environmental Performance Evaluation (ISO 14031), Ecodesign (ISO/TR 14062), Ecoefficiency (ISO 14045), Environmental Management System (ISO 14001) and Communication & labelling tools (ISO 14025-24-21). In order to face all identified gaps and improve the operatively implementation of the method the concept of STEM (Supportive Tools to Environmental Management) has been introduced. Eight different STEMs have been implemented by OES2 method giving operative support to all implemented EMTs: Multiscale LCA (MLCA), a new mathematical model that correlates all the assessment scales (organizational, product, process); the Environmental Inventory Database (EID) and Environmental Results Database (ERD), that permits to automatize the data collection and the result management processes; the Eco Environmental Keyperformance Analyzer (Eco-EKA), that permits to perform the performance evaluation and the performance tracking with a multi scale perspective, the EcoDesign Simulation Dashboard (Eco-DSD), that permits to provide a work space to designers to simulate new ecodesign project and compare the environmental performance, the Indicator of Work Environmental Efficiency (IWEE), that allows to assess the level of ecoefficiency of industrial processes and provides solutions to improve the process management, the Strategic Environmental Decision Making module (SEDM module), that supports and increases the use of statistical and mathematical approaches to support decision making processes, and finally the Environmental

Sustainability Strategy Model (ESSM), that supports the validation of environmental strategy at product and organizational level.
The applicability and effectiveness of OES2 method to improve life cycle environmental management performance, is presented in the second part of the thesis. The industrial application has been conducted in Acqua Minerale San Benedetto S.p.A., one of the most important player in the beverage sector in the world. Six different tests have been performed in order to stress OES2 method in all six critical areas of environmental management. Results of the applicability of OES2 method have shown the importance to assess environmental impacts with a multiscale approach, the importance to introduce STEMs in order to support the operative implementation of EMTs and the importance to combine EMTs in order to achieve a comprehensive environmental management approach. The OES2 methods has improved the life cycle environmental management performance of San Benedetto S.p.A. in all the six critical areas.
The research activities were carried out at the Department of Industrial Engineering of the Padova University and at the company Acqua Minerale San Benedetto S.p.A. (mainly production site of Scorzè).
The results of the research activities are summarized in 6 chapters.
Introduction: introduces the issues of environmental management and the need to use methods to combine EMTs. The scope of the research, the objectives, the dissertation structure and the research methodology are described.
Chapter 1: first part of material & methods, it reports on the scientific literature review to identify limits of available methods and required characteristics to be consider for the development of the new method: Environmental Management Drivers (EMDs), the Environmental Management Barriers (EMBs), the integration/combination mechanisms, the available EMTs, and the already existing methods for multiple EMTs use.
Chapter 2: second part of material & methods, it reports on the development of the OES2 methods and the methodological development of STEMs.
Chapter 3: presents the results of the industrial application tests carried out in San Benedetto S.p.A. focusing the attention on how the OES2 method permits to solve the identified gaps on life cycle environmental management performance of the organization.
Chapter 4: presents the discussion on the results with reference to already published methods for multiple EMTs use and objectives of the research.
Chapter 5: reports on research contributions and perspectives for future researches.
Keywords: Combination of environmental management tools, Life Cycle Management, Organizational Life Cycle Assessment, Industrial environmental sustainability, Multiscale assessment, LCA applied to large products portfolio.

List of most used abbreviations

EMTs: Environmental Management Tools
EMDs: Environmental Management Drivers
EMBs: Environmental Management Barriers
LCA: Life Cycle Assessment
OLCA: Organizational Life Cycle Assessment
LCM: Life Cycle Management
LCT: Life Cycle Thinking
EMS: Environmental Management System
EPE: Environmental Performance Evaluation
STEMs: Supportive Tools to Environmental Management
OES2: Organizational Environmental Sustainability System
MLCA model: Multiscale LCA model
EID: Environmental Inventory Database
ERD: Environmental Results Database
Eco-EKA: Eco Environmental KPI Analyzer
Eco-DSD: Eco Design Simulation Dashboard
IWEE: Indicator of Work Environmental Efficiency
SEDM module: Strategic Environmental Decision Making module
ESSM Environmental Sustainability Strategy Model
BIS: Business Informatic Systems
ISO: International Standard Organization
EOPIs: Environmental Operative Performance Indicators
IOPIs: Inventory Operative Performance Indicators
IPLE: Index of Potential Loss of Ecoefficiency
CF: Carbon Footprint
OEF: Organisation Environmental Footprint
PEF: Product Environmental Footprint

Summary

INTRODUCTION

Highlights:

- **Background to the research**
- **Scope of the research**
- **Research objectives**
- **Research method and methodology**
- **Structure of the dissertation**

1. Introduction to the research

Environmental sustainable development topic is increasingly at the centre of international interest (World Bank, 2017, WMO, 2017; UNFCCC, 2016; UNEP, 2016; EC, 2014; USEPA, 2013). Rahman et al. (2012) defines being environmentally sustainable as doing business in a way that reduces waste, conserves energy and promotes environmental health - preventing damage to the natural environment. The environmental sustainability is one of the three pillars on which the sustainability concept is based on, following the triple bottom line model (UNEP, 2011) diffused at industrial level (Kannegiesser et al., 2015). During the last decades, environmental issues have evolved from pollution and depletion of natural resources towards global issues such as climate change. Climate change is one of the most daunting challenges human kind has ever faced (Balint et a., 2017) and requires the adoption of prompt and effective innovations in industrial sector (De Stefano et al., 2016). This phenomenon is changing the global climate, producing persistent mutations such as: global temperature increasing, modification in rainfall, sea level raising, glaciers melting, increasing in extreme climatic events probability, etc. (IPCC, 2013). Natural resources conservation is another key aspect of sustainable development (Rimos et al., 2014) but in the last decades anthropogenic activates have determined resource depletion making scarce resources such as: freshwater (WWAP, 2012; UNEP, 2008), fossil oil (Brown et al., 2014; Rozenberg et al., 2010), land (UNEP, 2014; EC, 2012), minerals and metals (Henckens et al., 2016; Henckens et al., 2014). The last key aspect regarding to environmental sustainable development is the mitigation of the negative effects related to industrial polluting emissions in the different environmental sub-compartments (e.g. air, water, soil). These emission in many cases are responsible of negative effects on human health (Wang et al., 2016; Tanaka, 2015) and of biodiversity lost (Lafuite et al., 2017; Cardinale et al., 2012). Several political and scientific initiatives are taking place at international level to face issues related to environmental sustainability. At political level, the most significant example is represented by the 21st Conference of Parties (COP21) held in Paris during 2015 is one of the most significant international event on climate change fighting where 195 countries have adopted the first universal and legally binding agreement on the world climate. The agreement sets out a comprehensive action plan to bring the world back on track to avoid dangerous climate change by limiting global warming well below 2ºC (EC, 2016). Another significant example can be found in the 2030 Agenda for Sustainable Development (UN, 2015a; UN, 2015b) and in the 7th Environmental Action Program (EAP) that is the policy document that defines the European Union's policy on the environment until 2020 and that is the foundation for the programming until 2050 (EC, 2013a). Instead at the scientific level, the United Nations Environment Program (UNEP) and SETAC (Society of Environmental Toxicology and Chemistry) are two of the most important organizations that promote initiatives for methodological improvement, increasing case studies application of environmental management practices. Examples of initiatives are: Life Cycle Initiative with flagship projects that start from methodological aspects related to environmental impact assessment to projects on life cycle management (SETAC, 2017); WULCA an international working group for the creation of a consensual and consistent framework to assess, compare and disclose the environmental performance of products and organizations regarding freshwater use (Pfister et al., 2017). However, some contradictions at international level exist and the rescission of climate agreements by the US on June 2017 is the most relevant evidence where political coiches overlook the overwhelming scientific evidence on climate change (Savo et al., 2016). According to some scientists, the US exit could reinforce the Paris accord because their facade membership would weaken the commitment (Kemp, 2017). However, in this global context, industrial organizations are exposed to risks that could undermine their market competitiveness (WEF, 2017).

Figure 1 The Global risks landscape (WEF, 2017)

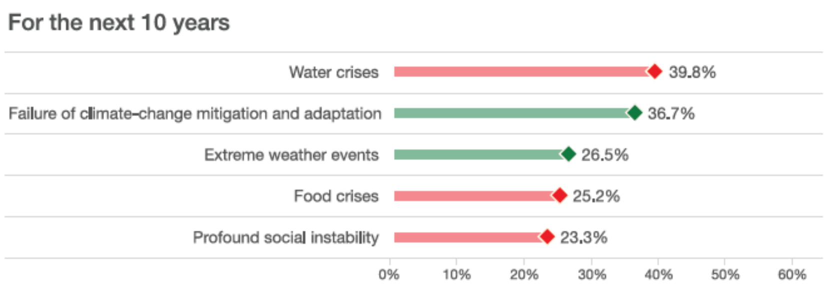


Figure 2 The Global risks perception of future (WEF, 2016)

In fact, it is important to notice as in the global risks landscape elaborated from the World Economic Forum (figure 1) environmental related aspects are among the most impactful and likely (score over the average). Furthermore, as shows in figure 2, in the next 10 years is foreseen that the relevance of climate change and water crises (exacerbate from climate change) will increase in terms of impact and likelihood (WEF, 2016).

Figure 1 shows as aspects related to environment and resources have a key role for industrial competitiveness generating diverse types of industrial risks (Gasbarro et al., 2017; Elijido-Ten, E. O., 2017):

- Operative risks: industrial risks related to access and availability of strategic resources;
- Financial risks: industrial risks related to energy and resources shock price;
- Compliance risks: industrial risks related to change in regulation and administrative procedures;
- Market risks: industrial risks related to corporate responsibility and reputation on the market.

Operative risks are connected to changes on strategic resources availability and may be the effect of changing environmental regulation (Pinkse et al., 2016) or of depletion processes (Mudd, 2010). Current examples of operational risks are related to access to water in many world regions that have become scarce in the last years for overexploitation and for climate change effects (WWAP, 2012). In the specific, Northey et al. (2017) have putted the attention as the access to water is a potential binding factor for mineral extraction industries. Another example can be related to access to minerals and metals such as: lead-zinc (Mudd et al., 2017), copper (Sieger, 2017), indium (Werner et al., 2017). Financial risks are instead related mainly to two aspects: increase of production cost and reduction of marginality due to increase of resources costs (Gasbarro et al., 2017) and to bad society rating to access to financial loans (Deutsche Bank, 2017; Wittneben et al., 2009) or to risk premium rates (Busch et al., 2007). Examples can be related to effects of energy shock price on China's metal market (Zhang et al., 2016) or on United States industries (Lee et a., 2002). Another example can be related to effects of other commodities shock price on Australian industries (Knop et al., 2014) or on by-product metal sector (Redlinger et al., 2016). Compliance risks can have profound impact on business growth and profitability and can take the form of regulation emissions of products or processes such as carbon taxes of EU ETS schemes (Fan et al., 2017; Wolf et al., 2011). Examples of compliance risks are related to resources lead to severe damage to humans, societies and the environment during extraction, combination, use and/or end-of-life, (e.g. tantalum mercury and cadmium) where governments have introduced various regulations to limit the extraction and industrial application (Miehe et al., 2016; Miehe et al., 2015). Finally, market risks, are the last mentioned but not the last in terms of relevance. Market risks are related more often to difficulties in access to market where are established barriers regarding environmental products performance evaluation (Murillo et al., 2011). The introduction on 2010 of the French law "Le Grenelle de l'Environnement 2" in France is a good example of green market barrier (Laperche et al., 2013). Another relevant aspect of market risk is related to corporate reputation (Zeng et al., 2011) that is a valuable asset for customers, institutions, stakeholders and employees and that can be ruined if the company pursues to use products, processes or practices with a negative impact on the climate (Lash et al., 2007). This risks perception has been confirmed also by other stakeholder surveys promoted by international institutes that have a central role in development promotion such as the World Bank (2016) and that have a key role in financial services of loans grating such as Deutsche Bank (2017).

However, changing perspective, if well managed, the challenge of climate change and environmental management could represent an opportunity for companies in order to gain competitive advantages (Cadez et al., 2016). In fact, business exposure to such risks and opportunities may represent a driver for coping with environmental management (Bui et al., 2017), because, often, the identification of environmental-related risks and opportunities is considered one of the first steps for designing and implementing environmental-related strategies (Weinhofer et al., 2013). Therefore, starting from the concept that a company's risk may be another company's opportunity, it is clear that early perception of risks, in a medium-long time frame, can allow companies to develop green products and processes to get strategic market opportunities (Liu et al, 2017; Boiral, 2006). These opportunities are related mainly to: reduction of cost production, increase products differentiation through development and introduction in the market of new green products and technologies and improvement of relationships with stakeholders (Liang et al., 2017; Liao, 2016, Burritt et al., 2011). The first opportunity is related mainly to optimization in raw material supply chain and to improvement of operational ecoefficiency (Gasbarro et al., 2017). In fact, ecoefficiency promote reduction in resource consumptions (Yang et al., 2016). The second opportunity is related to the possibility of undergoes changes in consumer needs (Maniatis et al., 2016) in a market where consumers are increasingly sensitive to environmental sustainability as underline in the Flash Eurobarometer on attitudes of Europeans regarding green products and technologies (EC, 2013b). In fact, although the green market represents about 10% of the global market (Nielsen, 2017), it is in continuously growing over the last ten years (Triodos Bank, 2016). About 26% of European companies already offers green products, while another 7% are planning to do so in the next two years (EC, 2015). Also, the market of green technologies is in strong expansion with a relevant number of new patents with specific features in climate change mitigation and resource consumption reduction (Su et al., 2017; Raiser et al., 2017). The third opportunity permits to the companies of obtain better relations with regularity institutions, suppliers, customers and other strategic stakeholders (Phan et al., 2015). In the last years more often these external and internal factors have become the main drivers for companies to undertake green strategies (Gotschol et al., 2014; Min et al., 2012). Considering the International developments regarding climate change policy previously mentioned (e.g. COP 21, US out from climate agreement) the ecoefficiency is an opportunity because it allows organizations, by reducing resource use, to reduce production costs and environmental impacts (Ge et al., 2017; Feng et al., 2016). Therefore, in this global context, industries need of a robust Environmental Strategy for improving their competitiveness and proactively manage related risks and opportunities (Lopez-Gamero et al., 2016; Jorge et al., 2015). The insertion of the environmental strategy in the general strategy of organization can generate more or less structural effects (Longoni et al., 2015) that can be conducted the organization in pathways of deep modification or substitution of their products (Depping et al., 2017), process technologies (Sun et al., 2017) and of production localization in the case of multisite organizations (Validi et al., 2014). In order to manage environmental aspects and to develop environmental strategies the organizations have increased the need of environmental management tools (EMTs) (Horisch et al., 2015). These tools from one side, permit to assess actual environmental performance and find hotspots, while from the other side permit to have a pro-active perspective to assess with multi scenarios the potential environmental performances of new alternative productive solutions at product, process and organizational level. In general, the EMTs can be divided in two main class: product-oriented EMTs and organizational-oriented EMTs. The first type is represented by tools that are oriented to assess the environmental performance products and support eco design processes. The oldest of these tools, such as MIPS (Material Input per Unit of Service) (Ritthoff et al., 2002), product SFA (Substance Flow Analysis) (Antikainen et al., 2005) and Product Energy Analysis (Herendeen, 2004) are oriented to assess inventory aspects related to data resources consumptions management. The most recent tools permit instead to across inventory analysis obtaining an environmental impact assessment analysis. Life Cycle Assessment (LCA) according to ISO 14040:2006 and ISO 14044:2006 (ISO, 2006 a,b) is the most relevant EMT of this type and in general is the most diffused and practical product-oriented EMT (Reza et al., 2014). Others product-oriented EMTs based on LCA methodology were born in the recent years under the need of report life cycle assessment results addressing specific area of concern, where the area of concern is a specific environmental topic identify by the interest of society (e.g. climate change, water management) (Ridoutt et al., 2016). The most relevant examples of these EMTs are: Product Water Footprint ISO 14046:2014 (ISO, 2014), Product Carbon Footprint ISO/TS 14067:2013 (ISO, 2013) and Product Environmental Footprint (EC, 2013c). Regarding instead to organizational-oriented EMTs, Environmental Management Systems (EMS) ISO 14001:2015 (ISO, 2015a), Environmental Management Audit Scheme (EMAS) (EC, 2017), Organizational Life Cycle Assessment (OLCA) ISO/TS 14072:2014 (ISO, 2014), Environmental Organization Footprint (EC, 2013c), Strategic Environmental Assessment (SEA) and Environmental Risk Assessment (ERA) (EC, 2003) are the most relevant examples where EMS is the most diffused tool in industries (To et al., 2014) with a total of

319.324 organizations certified ISO 14001 in the world on 2015 (+8% respect to 2014) (ISO, 2015b). Each EMT faces specific organization's environmental management aspects such as managerial aspects, impact assessment aspects, data management and communication aspects. These relationship between specific EMTs and specific environmental management aspects is the basic concept on which it was created the ISO 14000 family of International Standards (ISO, 2009). When an industrial organization formulates an environmental strategy must to take into account all environmental managements aspects in order to assess which aspects are priorities for its competitiveness and which are not relevant (Wijethilake, 2017). Therefore, the coordinated use of several environmental management tools is fundamental in order to make robust the environmental strategy of the organization (Lockrey, 2015). However, industrial organizations have a controversial relationship with environmental management tools because they do not exploit all possible strategic benefits but limit their use (Rossi et al., 2016). In fact, often EMS was used mainly to ensure regulatory compliance (Johnstone et al., 2009) of LCA was used to obtain product labels for marketing (Lockrey et al., 2015). Furthermore, very often industrial organizations implement EMT in a standalone way, obtaining not a comprehensive environmental management strategy. This is mainly due to the fact that they find it difficult to understand what interactions between EMTs can exploit and what positive effects can obtain. Therefore, in order to overcome this limit there is the need of the conceptualization of EMTs integration methods (Rousseaux et al., 2017; Runhaar, 2016). In the past years some authors had propose different integration methods between EMTs. In the scientific literature, proposals have been developed for the integration of LCA and SEA such as for example in the works of: Bjorklund (2012), Loiseau et al. (2013 and Bidstrup et al. (2015). However, these kinds of approaches have proven useful for public organizations but are not oriented to industrial organizations. In fact, the main applications regard the spatial land planning topic at municipal level. The integration between LCA and ERA have been proposed for the first time by Owens (1997) with the objective to support the evaluation during the life cycle of chemicals in order to respond to the chemicals legislation according to which: a manufacturer or downstream user "shall consider all stages of the life-cycle of the substance resulting from the manufacture and identified uses" if a chemical safety assessment is required. Industrial application of this method has been proposed by Sonnemann et al. (2004) and different applications were later realized such as in water quality management (Kobayashi et al., 2015) and in chemical production (Walser et al., 2014). The most relevant EMTs integration proposed for environmental management in industrial organizations is between LCA and EMS. It was proposed for the first time by Finkbeiner et al. (1998) while subsequent proposals were made by Khan et al. (2002), Rebitzer et al. (2005) and Lewandowska (2011). Different case studies have been performed to apply this method at industrial level such as: pulp and paper sector (Gaudreault et al., 2009), waste recycling sector (Liu et al., 2012) and bio-waste sector (Manfredi et al., 2013). In addition to the integration between EMTs, many authors agree that to develop an approach that can robustly support the environmental strategy of an organization, it also serves to integrate tools that supports the implementation of EMTs. These tools could be support for example data management and decision making processes. The first type of tools is oriented improve data collection and understanding at input and output level (Kouzokias, 2016; Eun et al., 2009). In the second type are included tools oriented to identified more appropriated solutions: Multi Criteria Decision Analysis (MCDA) (Cinelli et al., 2014), multi objective mathematical models (Validi et al., 2015), other statistical and simulation tools (Ronnlund et al., 2016; Theodosiou et al., 2015) are the most important examples. Despite these attempts of EMTs in general, currently industrial organizations face criticalities in at least one of the areas on management of life cycle environmental performance listed below:

1. Environmental impacts assessment;
2. Inventory resources consumptions assessment;
3. Performance evaluation & performance tracking;
4. Ecoinnovation (Ecodesing, Ecoefficiency);
5. Strategic decision making;

6. Strategy & management.

In fact, no methodological framework for EMTs integration has been already proposed in order to face in a holistic way all previous emerged life cycle environmental management areas. Integration of different tools is needed to ensure all environmental aspects are appropriately identified, controlled and managed (Guenther et al., 2016; Buttol et al., 2012; Lozano et al., 2012). It emerged as natural consequence of using the most correct tool for each specific environmental management issue.

This introductory chapter is organized as follows:

- Section 1.1: presents a background to the research;
- Section 1.2: presents the scope of the research;
- Section 1.3: presents the research objectives;
- Section 1.4: presents the structure of the dissertation;
- Section 1.5: presents the research method and methodology.

1.1. Background to the Research

The need of the industrial organizations to address environmental sustainability issues is very increase in the last years. The Economist Intelligence Unit (EIU) warns that even if global warming is held at plus 2 degrees Celsius by 2100, private investors may lose 4.2 trillion USD on the value of their holdings from the impact of climate change (The Guardian, 2015). The importance of this topic is reflected also in the trend of scientific research activity that is considerably grown from the beginning of 2000 to today and it is more intensive in countries with developed economy (see figure 3).

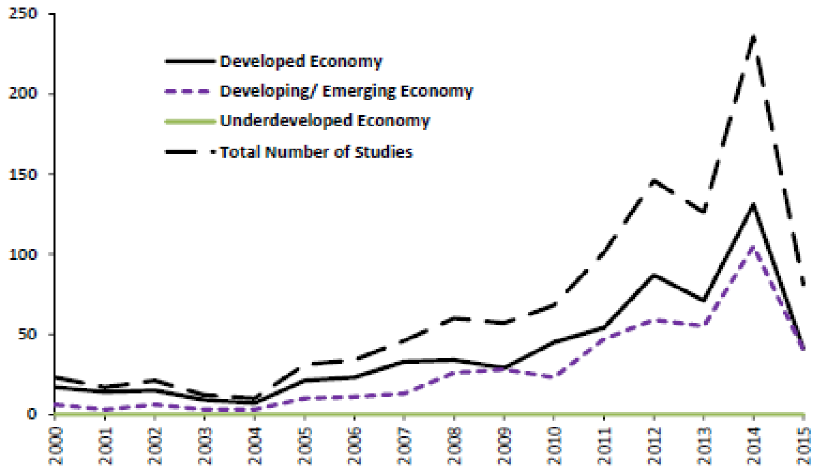


Figure 3 Trend of scientific research activity on environmental supply chain management (Rajeev et al., 2017)

Therefore, industries have the growing need to create a robust environmental strategy in order to improve their competitiveness and to manage pro-actively related business risks (Liu et al., 2017).

This is evident in a growing number of leading multi-national companies investing in environmental sustainability such as: Siemens, Cisco Systems Inc, Philips, Johnson & Johnson, Henkel, Nokia, Intesa Sanpaolo S.p.A., Schneider Electric, Total, L'Oreal, BNP Paribas, Peugeot, Coca Cola, Adidas, Sky, Eni S.p.A., LG Electronics, Novartis, Microsoft Corp, Wolters Kluwer, HP, Apple, General Mills, Unilever and BMW (Forbes, 2017). Often it is common to think companies that invest heavily in sustainability might incur higher costs and become less profitable but the returns of the 100 most worldwide sustainable companies suggest otherwise. An investment of $100 in Global 100 companies in 2005, it would have been worth $232 at the of 2016. The Global 100's cumulative return is 24 percentage points higher than the ACWI benchmark (Forbes, 2017). Many evidences support the assumption that environmental sustainability can assist firms in gaining a first-mover advantage and achieving a long-term sustained competitive advantage (Wong et al., 2012; Figge et al., 2012;). The corporate sustainability strategy according to the model proposed by Lozano et al. (2015) born to respond to internal and external factors (see figure 4).

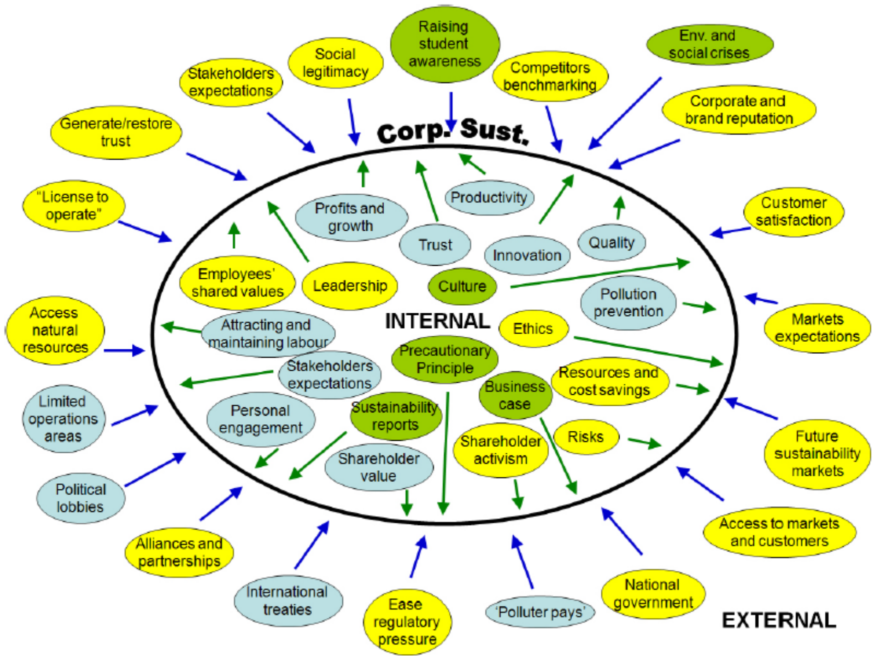


Figure 4 Corporate Sustainability driver model proposed by Lozano et al (2015). Highlighted in yellow the primary drivers and in green the secondary ones.

Internal factors are more related to the continuous improvement of the organization's competitiveness and they focus on the improvement of environmental and economic performance. Instead, external factors, many times are related to new pressures such as new market needs or change in regulatory which involve an adaptation reaction from the organization. Therefore, internal and external factors lead to the birth and continuously revision during the time of the environmental strategy of an industrial organization. In general, the environmental strategy has composed by two components: one related to ecoefficiency strategic intentions and the other one related to the ecobranding strategic intentions (Journeault et al., 2016). Relating to the ecoefficiency strategic intensions, industries face different areas of interventions, such as green product design (De Marchi et al., 2013) and green process design (manufacturing (Zhu et al., 2010) and supply chain processes (Beske et al., 2014)). Relating instead to ecobranding strategic intentions, industries face areas of interventions related to stakeholder relations (e.g. consumers (Zhao et al., 2016), regulatory institutions on environmental (Niesten et al., 2017), suppliers (Blome et al., 2014), etc.), marketing processes (Pomering, 2017) and to regulatory compliance (Henri et al., 2010). From the theoretical point in industries it is possible to identified four general approaches of environmental management strategy: reactive strategy, defensive strategy, accommodative strategy and proactive strategy.

Approach	Posture	Performance
Reactive strategy	Deny responsibility	Doing less than required (Fight all the way)
Defensive strategy	Admit responsibility but fight it	Doing the least that is required (Do only what is required)
Accommodative strategy	Accept responsibility	Doing all that is required (Be progressive)
Proactive strategy	Anticipate responsibility	Doing more than is required (Lead the industry)

Table 1 Different approaches of environmental management strategy (adapted by Clarkson, 1995)

Recent studies (Liu et al., 2017; Bui et al., 2017; Wijethilake, 2017) on industrial management are agree that the approach “Proactive environmental management strategy” is a key condition for obtain successfully competitivity gains as it favours continuous improvement (following on PDCA Deming management theory (Swamidass, 2000)). Another key aspect emerged in the last years on environmental management is the need of assume a life cycle management (LCM) perspective in order to manage the environmental impacts related to processes indirectly influenced by organization manufacturing activities (Williams et al., 2017). LCM is a business management approach that can be used by organizations to improve performance of their products and processes and thus the sustainability performance of the companies and associated value chains (UNEP/SETAC, 2009). It is based on the concept of life Cycle Thinking (LCT) focuses on to identify potential improvements of products, services and processes in the form of lower environmental impacts and reduced use of resources across all life cycle stages (EC, 2001). This begins with raw material extraction and conversion, then manufacture and distribution, through to use and/or consumption. It ends with re-use, recycling of materials, energy recovery and ultimate disposal (see figure 5).

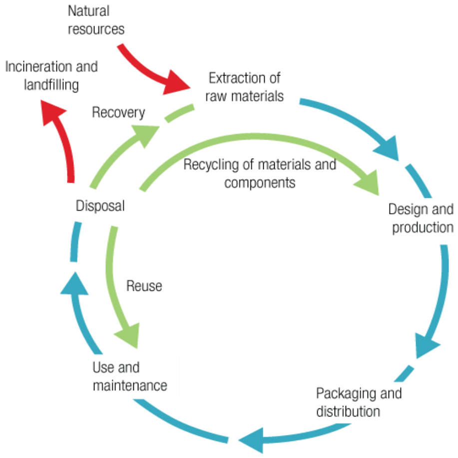


Figure 5 Life Cycle Thinking generic diagram (UNEP/SETAC, 2007)

One of the main sign in this direction is the new revision of ISO 14001:2015 (ISO, 2015) on Environmental Management Systems (EMS) that is the most important and diffused standard for environmental management at organizational level. In fact, in the new revision, has been increased the importance of controlling and influencing the way the organization’s products and services are designed, manufactured, distributed, consumed and disposed by using a life cycle perspective that can prevent environmental impacts from being unintentionally shifted elsewhere within the life cycle. Another relevant sign is represented by the birth of “Lean Green Manufacturing” concept that integrated in the business approach of “Lean manufacturing” (Womack et al., 1990; Ono, 1988) the management of environmental impacts of organization activities in a life cycle perspective (Caldera et al., 2017). In this context, these recent evolutions converge in “Sustainability Supply Chain Management (SSCM)” approach where the “Value Chain” concept proposed by Porter (1985) has been evolved integrating environmental sustainability aspects (Stindt, 2017; Rajeev et al., 2017). In fact, nowadays environmental aspects along all life cycle stages are new potential positive or negative values of the product in function of the positive or negative management of these aspects.
Therefore, to establish a robust and comprehensive environmental strategy is nowadays one of the most task for industries (Walsh et al., 2017; Jabbour et al., 2016). However, successfully adopting of environmental sustainability strategies is often a challenging task, particularly when firms are constrained by their limited resources and capabilities (Lee et al., 2008; Wu et al., 2011). Environmental sustainability has intrinsic difficulties stemming from the fact that it is a multi-perspective topic (Alroe et al., 2016; Lockrey, 2015; Geels, 2011). A qualitative representation of the main perspectives is shown in figure 6.

Figure 6 Qualitative example of the multiple perspectives of environmental sustainability (Personal elaboration, 2015)

Many industrial organizations find difficulties in facing holistically all these perspectives mainly because they do not use all the necessary environmental management tools (Rousseaux et al., 2017). In fact, many times they base all the environmental strategy only on one EMT without supporting approaches involving the combination of more EMTs (Horisch et al., 2015). However, a winning and successful environmental management strategy can be achieved only considering all the perspectives (Hallstedt et al., 2013). Different environmental management tools having different scopes that support organization to achieve improvement only on specific aspects of the environmental sustainability. Combination of different tools is needed to ensure all environmental aspects are appropriately identified, controlled and managed (Guenther et al., 2016; Pryshlakivsky et al., 2013; Buttol et al., 2012; Lozano et al., 2012). It emerged as natural consequence of using the most correct tool for each specific environmental management. Attempts to provide methods for EMTs integration have been proposed for example by Khan et al. (2002), Rebitzer et al. (2005), Le Pochat et al. (2007), Gaudreault et al. (2009), Lozano et al. (2012), Lewandowska et al. (2013), Chiarini (2014), Runhaar et al. (2016) and Rousseaux et al. (2017). In spite a large amount of EMTs, the initiatives of integration have been limited in capturing the full spectrum of sustainability and its implications for corporations, do not supporting the fully transfer to the reality of business processes of sustainability. In most cases they have been partially linked to each other, leading the company leaders and decision-makers being increasingly confused about how they could fit together or how they should be used together (Lozano et al., 2012). In fact, these methods have not systematically faced all perspectives of environmental sustainability strategy leaving critical areas in environmental management. Therefore, there is the need of new method proposals for multiple EMTs use in order to face in a holistic way all life cycle environmental management areas. This research contributes in the field of environmental sustainability management proposing a new method for EMTs combination.

1.2. Scope of the Research

Interest in sustainability grows continuously especially in large organizations and it is evidenced by over 9.400 companies in 162 countries having signed the United Nations Global Compact (UNGC, 2015). In this context, industrial organizations increasingly need to strengthen their environmental sustainability strategy as the environment management is became one of the pillars in the modern business models. A robust environmental strategy requires to manage a lot of aspects ranging from regulatory to marketing passing from aspects related to process efficiency and to product ecodesign. In order to positively manage each one of these environmental management aspects it is important to use the more appropriate environmental management tool (EMT). Therefore, it is clear that an organization must be use more than one EMT to have a comprehensive approach that it is able to make successful the environmental sustainability strategy. Methods for EMTs integrations are therefore required and are an important task of research. However, EMTs integration methods in environmental management research and practise have not already response to all the needs and issues related to environmental sustainability strategy (Rousseaux et al., 2017; Runhaar, 2016; Sala et al, 2013). In fact, no method for multiple EMTs use has been already proposed in order to face in a holistic way all criticalities identified on life cycle environmental management.

The scope of this research is the development and application at industrial level of a new method to combine environmental management tools (EMTs) to improve the life cycle environmental performance of industries. The new developed method is contextualizable in the research field of Life Cycle Management methods. The scope of this research is extended to a real test application in a multi-national industry (figure 7).

Three research phases have been identified. The first research phase has focused mainly on the identification of EMTs and the scientific gaps (criticalities) on life cycle environmental performance management considering the already published methods for multiple EMTs use. In the second phase the new method has been methodologically developed, defining features and technical aspects. In the third phase the new method has been tested at industrial level and conclusions on results obtained have been defined.

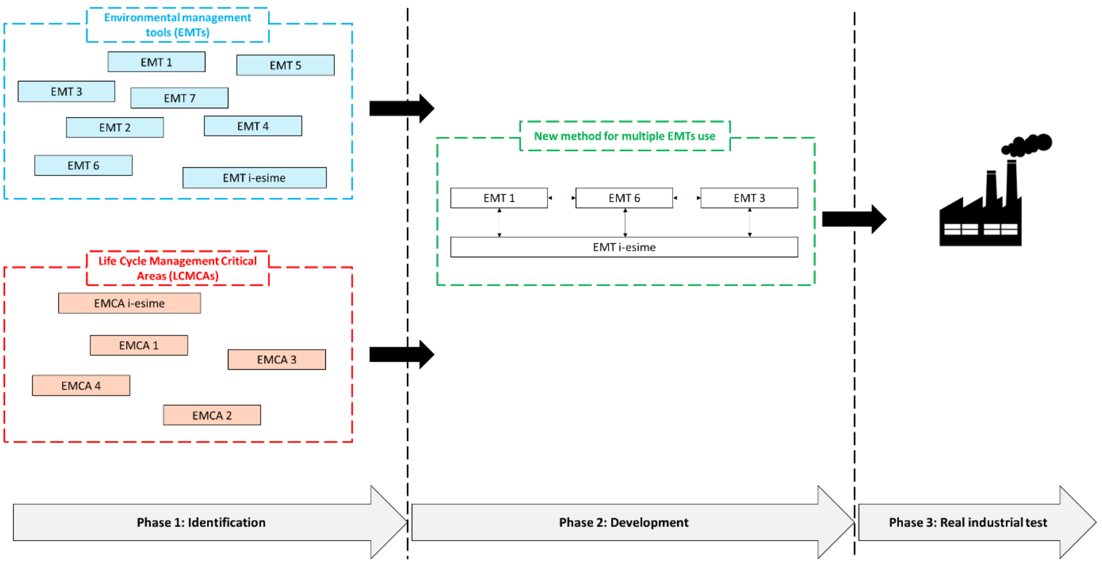


Figure 7 Scope research flow chart (Personal elaboration, 2017)

1.3. Research Objectives

In this framework took place the activity of this PhD research. The specific objectives of the research were:

1. *The develop of a new method to combine EMTs and solve identified criticalities on life cycle environmental performance management at level of 1. environmental impact assessment, 2. Inventory resources consumptions assessment, 3. performance evaluation & performance tracking, 4. ecoinnovation (Eco Design, Eco Efficiency), 5. strategic decision making and 6. strategy & management;*
2. *Test the applicability of the developed method in a real industrial case study and its effectiveness in overcome the identified criticalities on life cycle environmental performance management.*

According with the research objectives and the research phases specific research sub-objectives have been identified in order to define the research pathway, identifying the main steps as shown in the following table.

Research objectives	Scope phase	Sub-objectives (research steps)
1 Development of the new method	Phase 1: Identification	1.1 Identification of environmental management drivers (EMDs)
		1.2 Identification of environmental management barriers (EMBs)
		1.3 Identification of main available EMTs
		1.4 Identification of mechanism for the multiple EMTs use
		1.5 Identification of already published methods for multiple EMTs use
		1.6 Formulation of scientific gaps
	Phase 2: Development	2.1 Selection of EMTs
		2.2 Definition of the structure of the new method for multiple EMTs use
		2.3 Definition of the interfaces between EMTs
		2.4 Methodological development of the components of the new method
2 Test in a real case study of the new method	Phase 3: Real industrial testing	3.1 Test of the new method to face all critical areas on life cycle environmental management identified
		3.2 Comparison of the new method with already published method to identify improvements achieved.

Table 2 Research objectives defined.

1.4. Dissertation structure

This dissertation is composed by five inter-linked chapters. The following figure shows the structure of the dissertation.

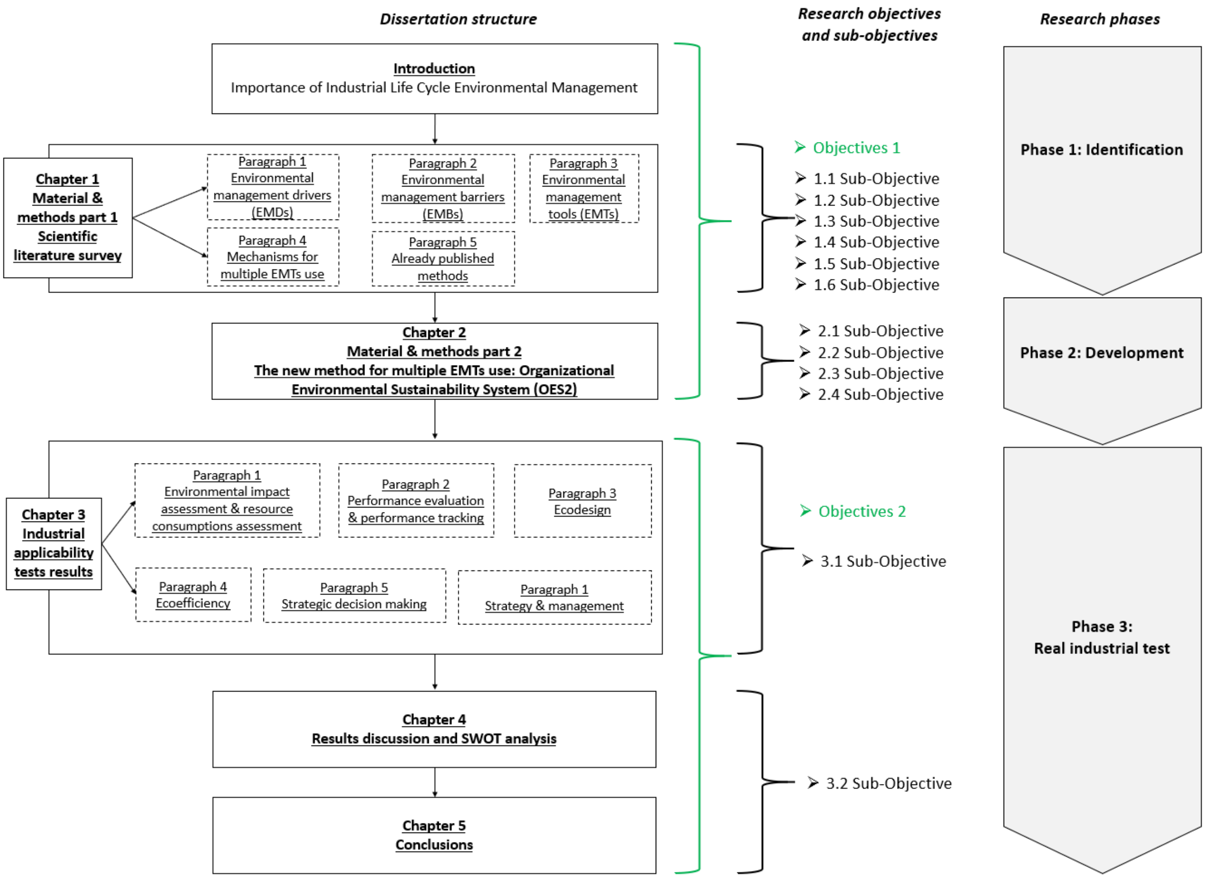


Figure 8 Dissertation structure

Introduction: introduces the issue of environmental management and the need to use methods to combine EMTs. The scope of the research, the objectives, the dissertation structure and the research methodology are described.
Chapter 1: first part of material & methods, it reports on the scientific literature review to identify limits of available methods and required characteristics to be consider for the development of the new method: Environmental Management Drivers (EMDs), the Environmental Management Barriers (EMBs), the integration/combination mechanisms, the available EMTs, and the already existing methods for multiple EMTs use.
Chapter 2: second part of material & methods, it reports on the development of the OES2 methods and the methodological development of STEMs.
Chapter 3: presents the results of the industrial application tests carried out in San Benedetto S.p.A. focusing the attention on how the OES2 method permits to solve the identified gasp on life cycle environmental management performance of the organization.
Chapter 4: presents the discussion on the results with reference to already published methods for multiple EMTs use and objectives of the research.
Chapter 5: reports on research contributions and perspectives for future researches.

1.5. Research method and methodology

In order to satisfy the objectives of this dissertation an applied, quantitative and confirmatory research was held. The chosen research method, according to research scope is a single case study. The research methodology, according to research scope and objectives, is structured in three main stages.

1. In the first phase, the method of scientific literature survey has been used in order to satisfy sub-objectives from 1.1 to 1.6, identifying the EMBs, EMDs, EMTs available, the mechanisms of integration and combination and the already published methods for multiple EMTs use, in order to identify the research scientific gaps;
2. In the second phase, have been applied different methods for the formulation of the new method for multiple EMTs use, in order to satisfy sub objectives from 2.1 to 2.4. The first methods are the single EMTs themselves, selected for the formulation of the new method for multiple EMTs use. The second method used regards the choosing of the mechanism through which the selected EMTs can interact (integration or combination mechanisms (Finkbeiner, 1998)). The third method is a set of tools used to develop the components of the new method (e.g. LCA software). In the complex the phases 1 and 2 have permitted to satisfy the first research objective.
3. In the third phase, in order to satisfy the sub-objectives 3.1 and 3.2, a method of single case study has been applied in order to test the new developed method. A SWOT analysis method has been applied in order to clarify the opportunities and threats emerged from the application of the new method developed. Finally, a comparative analysis with the already existing methods for multiple EMTs use has been performed in order to give evidences of the improvements introduced. This phase has permitted to satisfy the second research objective.

Methods used in the present dissertation and research steps are summarized in the figure 9.
Research is based on primary data collected directly from company factories studied and secondary data coming from database recognized by LCA community, statistical data published by authoritative institution and data published in peer review paper.

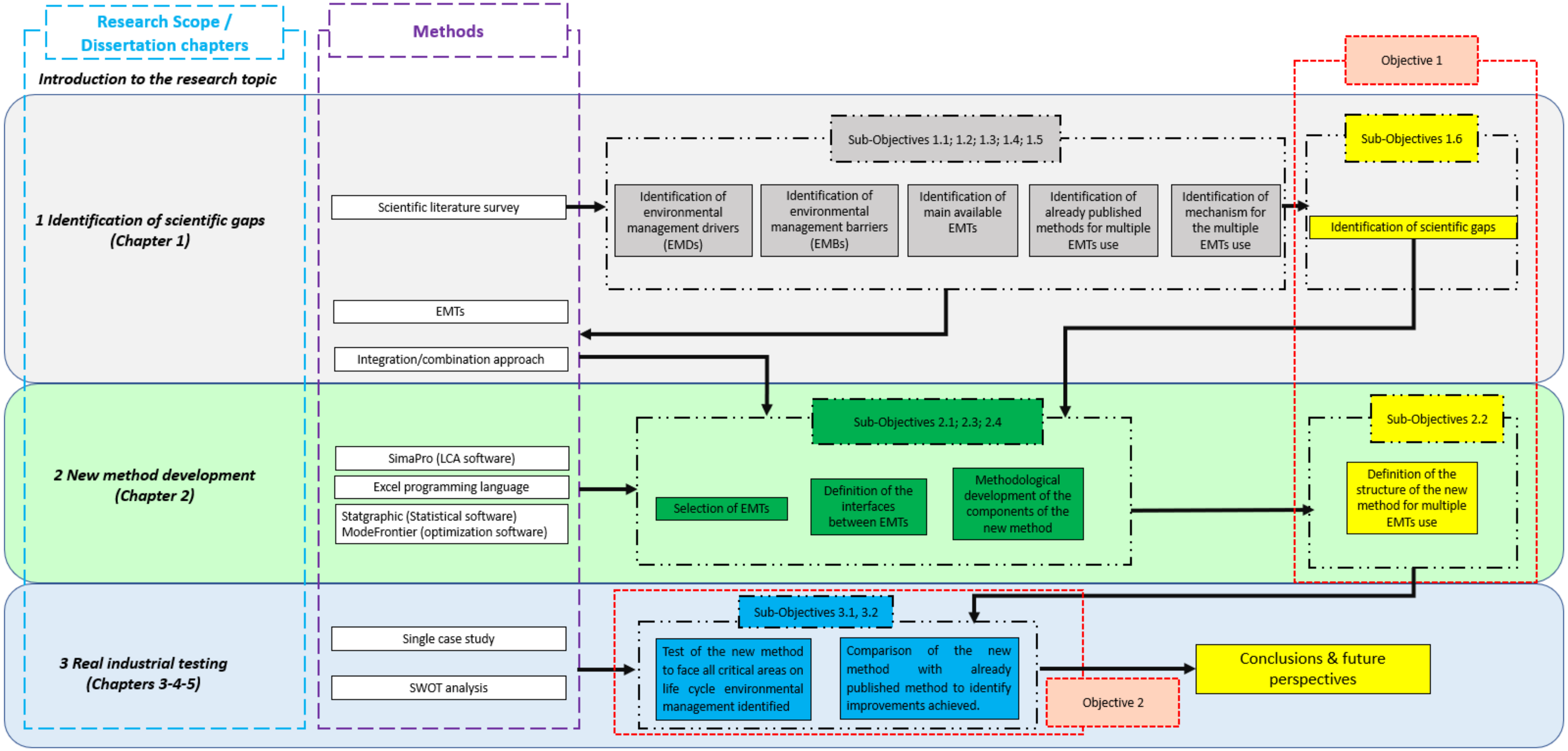


Figure 9 Research methodology framework applied

1.6. Case study company presentation: San Benedetto S.p.A.

It is April 10, 1956, when the first production site of the San Benedetto Group was born in the heart of Sile Park for the bottling of the mineral waters of Scorzè (VE) (Spring San Benedetto and Spring Guizza). The company takes its name from the spring name, known since the Venetian Republic as "Ancient Source of Health" and sought after by Venetian families for its healing qualities.

In a short time Acqua Minerale San Benedetto S.p.A. it is transformed into a small local producer present in the entire Italian territory, with strong interests outside the national borders. Today, the San Benedetto group is active in 100 countries on five continents and it is Leader Group of the Italian soft drink market. San Benedetto is a "total company", multi-specialist and multi-channel company works successfully in all segments of the non-alcoholic beverage market: from mineral waters (San Benedetto, Ancient Source of Health, Nepi Water, Cutolo Rionero Fonte Atella, Pure Rock, Guizza and Fonte Vivia) to "near water" (Aquavitamin and San Benedetto Ice Formula Zero); from soft drinks (St. Benedict and Schweppes) to tea (St. Benedict and Guizza); from baby products (San Benedetto Baby) to sport drinks (Energade); from Schweppes to drinks and juices (Oasis, Tropico, San Benedetto Succoso) to aperitifs (Ben's, Ginger Spritz and Schweppes).

In the history of San Benedetto there has always been something modern. Something about a new way of doing business based on the breadth of strategic vision, constantly looking for quality and distinctive features over the competition. It is innovation, technological and of service, of product and of process, thanks to which the San Benedetto has taken a leading role not only in terms of numbers, but also in terms of ideas and applications that can meet the real needs of consumers and of distribution. At the end of the 70's, San Benedetto introduces the "one way packaging" innovation with the transition from "glass to make" to "glass to lose", which allows San Benedetto to have a first level expansion national; in 1980 the bottle was born in PET, the first company in Italy to use it in mineral water sector, revolutionizing the market; in 1993 a completely aseptic bottling plant was produced for the production of non-carbonated drinks, guaranteeing more and more the safety of their products; in 1998 he realized the first "push & pull" cap completely aseptic and resealable, meeting the demands of an even more dynamic market and that see the "on the go" consumptions as an integral part of our daily life. All this innovative creativity is born in the Company's research and development department. A department dedicated to the production of PET containers and plastic caps (flat and push & pull) that is able to follow the entire process of containers developing and bottling process by registering patents that have allowed the Group to be at the forefront even in the PET lightening projects and projects to use of Regenerated PET (RPET).

The current corporate structure guarantees the San Benedetto Group a sizeable production capacity: six factories in Italy, two in Spain, one in Poland, one in Hungary and one joint venture in the Dominican Republic; 1,953 employees worldwide; 44 lines of bottling in Italy for a production capacity of 4.2 billion bottles per year.

The San Benedetto Mineral Water Group is the absolute leader of the Italian soft drink market.

CHAPTER ONE: MATERIAL & METHOD PART 1- SCIENTIFIC LITERATURE REVIEW

Highlights:

- **Environmental Management Drivers (EMDs)**
- **Environmental Management Barriers (EMBs)**
- **Environmental Management Tools (EMTs)**
- **Theoretical mechanisms for multiple EMTs use**
- **Already published methods for multiple EMTs use**

1. Introduction to the scientific literature review

The present chapter, starting from the description of the theoretical mechanism for built an environmental management strategy, presents a scientific literature review that explores five interrelated key aspects of environmental management:

1. Environmental Management Drivers (EMDs);
2. Environmental Management Barriers (EMBs);
3. Environmental Management Tools (EMTs);
4. Theoretical mechanisms for multiple EMTs use;
5. Already published methods for multiple EMTs use.

These five aspects are fundamental for understanding the context of the research field in order to identify the specific scientific gaps and to set the features and characteristics of the new method for multiple EMTs use, as the EMTs multiple use is born largely in order to build a comprehensive environmental management strategy. In the specific, the analysis of "Environmental Management Drivers (EMDs)" permits to catch a comprehensive assessment of the drivers that influenced the environmental management at industrial level in order to identify the most relevant management needs. The analysis of the "Environmental Management Barriers (EMBs) permits instead of to understand which are nowadays the main issues faced from industries regarding the approaches of environmental management. Go on, the analysis of "Environmental Management Tools (EMTs)" permits to identify the most relevant EMTs developed by scientific community in the last twenty years in order to find the group of EMTs that should be selected subsequently to develop the new method. The analysis of "Theoretical mechanisms" permits to identify the theoretical methodological framework to use multiple EMTs. Finally, the analysis of "Already published methods for multiple EMTs use" permits to identify the methods that already exist in order to complete the framework to identify scientific gaps. As initially declared in this chapter, these five aspects are interrelated in fact, simplifying, the first aspect sets all environmental management drivers, the second aspect sets issues relate to environmental management, the third aspect sets the EMTs available to manage EMDs and EMBs identified, the fourth aspect sets the mechanisms in order to perform the multiple use of EMTs, while the fifth aspect defines EMTs integrations already used in order identify which EMDs and EMBs have been already faced. This interrelation is representable as shown in the following figure:

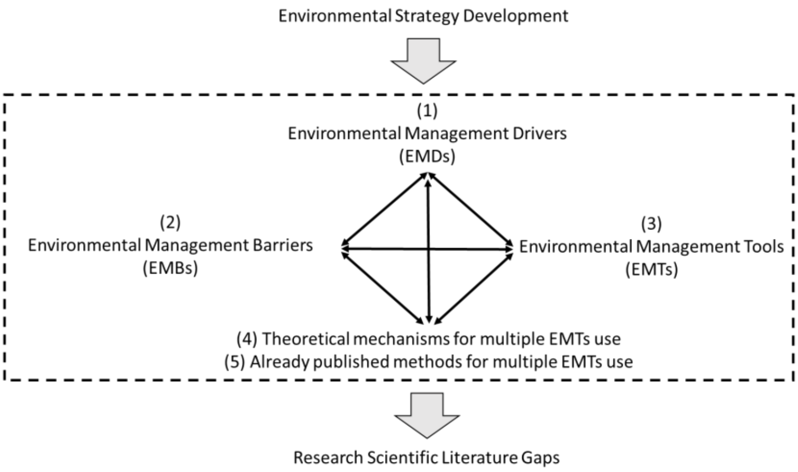


Figure 10 Key four aspects analysed during the scientific literature review.

1.1. Environmental Management Strategy Development

In recent years, organizations, especially large ones, have increase attention on environmental sustainability topic (Babiak et al., 2011), introducing radical changes in their environmental strategies that in many cases of the past resulted poorly develop (Kupers, 2011). The adoption of an environmental strategy has become an important consideration for a growing number of organizations worldwide

(Deloitte, 2012; Kiron et al., 2012; Unruh et al., 2010). The changes introducing by organizations in their environmental management strategies ranges from introducing resource-efficient technologies, sustainability reporting schemes, to modifies that regard providing sustainable products and services (Bamgbade et al., 2017; Siebenhuner et al., 2007). This trend probably will increase in the future due to concerns about climate change, greenhouse gas emissions and biodiversity impoverishment, or the consequence of more stringent regulations and increasing pressures from stakeholders (Perez-Batres et al., 2012; Delmas et al., 2008), leading the organizations to adopt compliance or legitimacy-related environmental strategies (De Marchi, 2012; Orsato, 2009).

An environmental management strategy can be defined as the set of coordinated actions established from the organization in order to manage all environmental management drivers that influence significantly the organization in order to improve in the same time the market competitivity and the environmental performances of the organization (Bui et al., 2017; Walsh et al., 2017; Geibler et al., 2016). As previously mentioned in the introduction, there are different types of environmental management strategies but the proactive environmental strategy has recently recognized as the most promotable for the organization competitivity growth (Wijethilake, 2017; Bui et al., 2017), as it allows to: efficient use of resources, increased cost advantage, reduced waste and discharge, promotion of social reputation, improved customer preferences, and generation of new innovative capabilities (Bhupendra et al., 2015, Phan et al., 2015). From a theoretical point of view Journeault et al. (2016), according to Mintzberg et al. (1985), identifies that the environmental management strategy is composed of two different components, namely the intended and realized strategy. The intended component of competitive environmental strategy refers to the integration of environmental goals and targets into the organizational strategic intentions in order to gain a competitive position that a firm hopes to build in the future (Journeault et al., 2016). The realized component could be equal to intended component if all intensions have been satisfying successfully, or it could be different from intended component more and more in function of the misalignment entity in goals and targets declared. Moreover, both the intended components can be divided in two sub-components: the ecoefficiency intentions and the ecobranding intentions (Journeault et al., 2016; De Marchi, 2012; Orsato, 2009). First, ecoefficiency intent refers to the creation of a competitive advantage by increasing production efficiency and the level of ecoinnovation of offered products and services compared to the competitors through the simultaneous reduction of environmental impacts and costs (De Marchi, 2012; Orsato, 2009). The ecobranding intent refers to the creation of competitive advantage by increasing stakeholder engagement and differentiating the offer through the introducing in the market new eco-friendly products and services. According to Journeault et al. (2016) all EMDs related to ecobranding intents are external. Instead, regarding EMDs related to ecoefficiency intents are generally internal but also some external EMDs related to regulatory compliance and changes sensibility are into the set of ecoefficiency intents. Therefore, it is possible to notice that ecoefficiency intents are related to EMDs that ranging from managerial aspects, performance improvement, environmental impacts assessment, ecoinnovation to decision making. In the case of ecobranding intents, the EMDs ranging from external communication, stakeholders engagement to market differentiation. This methodological framework is according with the schematic representation proposed by Klewitz et al. (2014) where EMDs and EMBs are elements in input to the formulation of the environmental management strategy (figure 11). In this context emerged clearly the need for the organization to have a holistic perspective during the environmental strategy formulation identifying and successfully facing all relevant EMDs and EMBs (Journeault et al., 2016; Longoni et al., 2015; Klewitz et al., 2014, Roehrich et al., 2014; Jabbour et al., 2012). In the following paragraphs have been shown the results of scientific literature review for the identification of EMDs and EMBs.

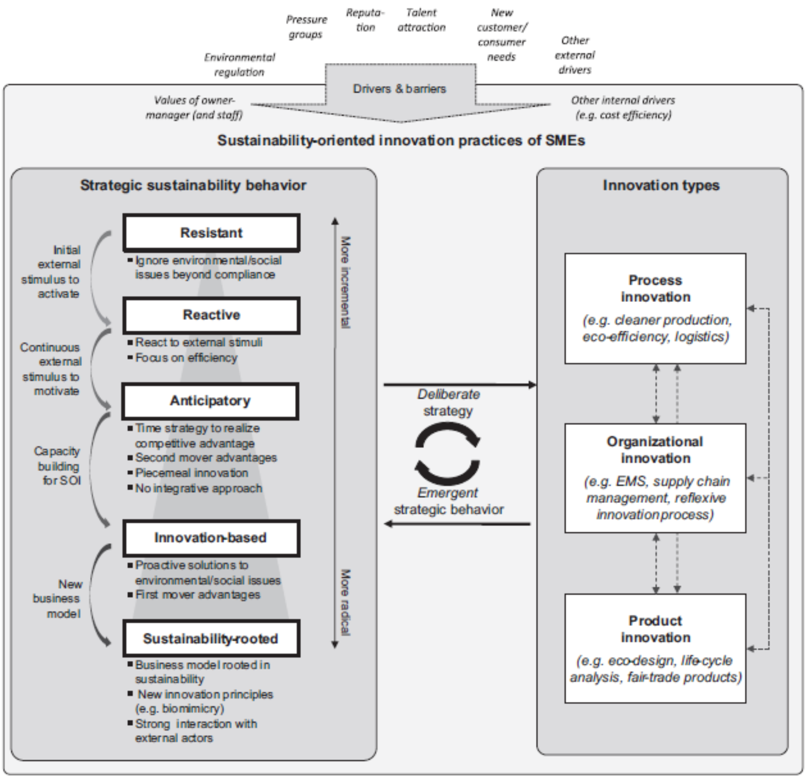


Figure 11 Integrated framework for environmental management strategy formulation (Klewitz et al., 2014).

1.2. Environmental Management Drivers (EMDs)

According to the chapter introduction a first very fundamental point to develop at industrial level an environmental management strategy is the identification of the drivers that influence environmental sustainability of organizations (Evangelista et al., 2017; Lopez-Gamero et al., 2016; Lozano et al., 2015). The Environmental Management Drivers (EMDs) can be defined as the set of factors, management perspectives, and needs that influencing the environmental management strategy and that an organization should assess and manage in order to have a comprehensive and robust approach to environmental management for its competitivity enhancement (Ferro de Guimaraes et al., 2017; Lozano et al., 2015; Granly et al., 2014). Many authors in the last twenty years have studied EMDs and their relevance in the process of environmental strategy development (Lopez-Gamero et al., 2016; Lozano et al., 2015; Klewitz et la., 2014; Agan et al., 2013; Yen et al., 2012; Zeng et al., 2011; Del Rio Gonzalez et al., 2009). EMDs range from productive operations efficiency, product eco-design, impacts assessment, management and strategy, organisational systems, procurement and marketing, and communication with its stakeholders' (Lozano, 2011). In general, two types of EMDs have been distinguished: internal and external (Montiel et al., 2010; Qi et al., 2010). In the specific:

- Internal environmental management drivers: they can be defined as internal driving forces that are resulted from company's internal motivation (enterprise itself) (Zeng et al., 2011). Many authors pointed out that internal factors overwhelmingly refer to the existence of internal preconditions and features of the company, which facilitate the company's involvement in environmental technological change;
- external environmental management drivers: they can be defined as driving forces coming from externalities (Moffat et al., 2006; Branzei et al., 2004; Delmas, 2002). Meanwhile, external factors stem from the incentives and stimulus derived from a wide range of actors and factors that exert pressures to which companies respond; external drivers thus represent interaction with other institutional, market, and social actors (Del Río González, 2009).

In this part of the literature review research stage more than 80 scientific publications have been analysed in order to identify the most relevant EMDs. The time span of publication goes from years 2000 to 2017. The following table shows the results.

Type (Internal/external)	Life Cycle Management Areas	Environmental Management Drivers (EMDs)	Strategy subcomponent	References
Internal	1. Environmental impacts assessment	Environmental Impacts Assessment – Product Level	Ecoefficiency subcomponent	Manzardo et al., 2016a; Lozano, 2015; Bidstrup et al., 2015; Klewitz et al., 2014; Tseng et al., 2009; Martin-Pena et al., 2008
		Environmental Impacts Assessment – Organizational Level	Ecoefficiency subcomponent	Six et al., 2017; Lo-Iacono-Ferreira et al., 2017; Neppach et al., 2017; Resta et al., 2016; Loss et al., 2016; Martinez- Blanco, 2016; Jungbluth et al., 2016; Manzardo et al., 2015; Martinez-Blanco et al., 2015a; Martinez-Blanco et al., 2015b; Hellweg et al., 2014
	2. Inventory resources consumptions assessment	Inventory resources consumptions assessment – Product Level	Ecoefficiency subcomponent	Jabbour et al., 2016; Jia et al., 2017; Granly et al., 2014;
		Inventory resources consumptions assessment – Organizational Level	Ecoefficiency subcomponent	Resta et al., 2016; Loss et al., 2016; Martinez- Blanco, 2016; Manzardo et al., 2015; Martinez-Blanco et al., 2015a; Martinez-Blanco et al., 2015b; Hellweg et al., 2014
	3. Performance evaluation & performance tracking	Environmental performance evaluation & performance tracking at product and organizational level	Ecoefficiency subcomponent	Ferro de Guimaraes et al., 2017; Caldera et al., 2017; Pilouk et al., 2017; Tokola et al., 2016; Journeault et al., 2016; Jabbour et al., 2016; Granly et al., 2014; Blome et al., 2014; Wu et al., 2011; Henri et al., 2010; Tseng et al., 2009; Lee et al., 2008;
		Production cost reduction or/and revenue increasing	Ecoefficiency subcomponent	Gasbarro et al., 2017; Caldera et al., 2017; Journeault et al., 2016; Jabbour et al., 2016; Lopez-Gamero et al., 2016; Galeazzo et al., 2015; Blome et al., 2014; Agan et al., 2013; Laperche et al., 2013; Lozano et al., 2013; Kesidou et al., 2012; Chen, 2010; Henri et al., 2010; Del Rio et al., 2009; Johnstone et al., 2009; Darnall et al., 2008; Ambec et al., 2008; Henriques et al., 2005;
	4. Ecoinnovation	Ecodesign	Ecoefficiency subcomponent	Walsh et al., 2017; Caldera et al., 2017; Shapira et al., 2017; Journeault et al., 2016; Kucuksayrac, 2015; Jabbour et al., 2016; Longoni et al., 2015; Cuerva et al., 2014; Horbach, 2014; Bey et al., 2013; Hallstedt et al., 2013; De Marchi et al., 2013; Laperche et al., 2013; Pigosso et al., 2013; Horbach et al., 2012; Darnall et al., 2008; Ammenberg et al., 2005; Ward et al., 2000
		Ecoefficiency	Ecoefficiency subcomponent	Abreu et al., 2017; Journeault et al., 2016; Hojnik et al., 2016; Gasbarro et al., 2016; Galeazzo et al., 2015; Longoni et al., 2015; Sproedt et al., 2015; Hallstedt et al., 2013; De Marchi, 2012; Borghesi et al., 2012; Henri et al., 2010; Porter et al., 2007;
	5. Strategic decision making	Identification of new eco-friendly solutions	Ecoefficiency subcomponent	Hallstedt et al., 2013; Henri et al., 2010;
		Investments assessment	Ecoefficiency subcomponent	Costa-Campi et al., 2017; Cainelli et al., 2015; Del Rio et al., 2013; Henri et al., 2010; Wittneben et al., 2009; Frondel et al., 2007; Boysse et al., 2003;
	6. Strategy & Management	Systematic and procedural approach for continuous improvement	Ecoefficiency subcomponent	Hojnik et al., 2016; Lozano, 2015; Granly et al., 2014; Horbach et al., 2012; Rave et al., 2011; Derimel et al., 2011; Wu et al., 2011; Henri et al., 2010; Lee et al., 2008;
		Strategy formulation with objectives and targets definition	Ecoefficiency subcomponent	Journealut et al., 2016; Benson-Armel er al., 2015; Granly et al., 2014; Guimaraes et al., 2013; Tseng et al., 2009; Henri et al., 2010;
		Top management commitment and managerial aspects	Ecoefficiency subcomponent	Buil-Fabrega et al., 2017; Hojnik et al., 2016; Roy et al., 2016; Lozano, 2015; Granly et al., 2014; Klewitz et al., 2014; Guimaraes et al., 2013; Bey

				et al., 2013; Tseng et al., 2013; Hallstedt et al., 2013; Zeng et al., 2011; Wu et al., 2011; Bos-Brouwers, 2010; Lee et al., 2008; Aragón-Correa et al., 2008;
External	7. Compliance	Regulatory compliance	Ecoefficiency subcomponent	Evangelista et al., 2017; Del Rio, 2016; Kucuksayrac, 2015; Borghesi et al., 2015; Lozano, 2015; Klewitz et al., 2014; Bey et al., 2013; Veugelers, 2012; Demirel et al., 2011; Meyer et al., 2011; Henri et al., 2010; Darnall et al., 2008; Ammenberg et al., 2005; Kolk et al., 2004; Zeng et al., 2003;
		Governmental aspects compliance (taxes and incentives)	Ecoefficiency subcomponent	Costa-Campi et al., 2017; Del Rio et al., 2016; Chassagnon et al., 2015; Veugelers, 2012; Zeng et al., 2011; Hoffman, 2005;
	8. Sensibility to relevant changes	Changes in price and availability of raw materials	Ecoefficiency subcomponent	Gasbarro et al., 2017; Masud et al., 2017; Jia et al., 2017; Lozano, 2015; Lozano et al., 2013; Yarahmadi et al., 2012; Zeng et al., 2011; Busch et al., 2007
		Physical climate changes (e.g. desertification)	Ecoefficiency subcomponent	Lei et al., 2017; Masud et al., 2017; Galbreath, 2012; Alcamo et al., 2007;
		Changes of products on market	Ecoefficiency subcomponent	Lopez-Gamero et al., 2016; Ghazilla et al., 2015; Klewitz et al., 2014; Bey et al., 2013; Johnstone et al., 2009;
		Changes of technologies on market	Ecoefficiency subcomponent	Ghazilla et al., 2015; Klewitz et al., 2014; Yen et al., 2012; Tseng et al., 2009;
		Changes in stakeholder's expectations and awareness	Ecobranding subcomponent	Evangelista et al., 2017; Gasbarro et al., 2016; Kucuksayrac, 2015; Journeault et al., 2016; Lozano, 2015; Bey et al., 2013; Laperche et al., 2013; Lozano et al., 2013; Darnall et al., 2008; Kassinis et al., 2006; Ammenberg et al., 2005; Busse et al., 2004;
	9. Market differentiation	Products differentiation	Ecobranding subcomponent	Journeault et al., 2016; Hojnik et al., 2016; Lockrey, 2015; Kucuksayrac, 2015; Del Rio et al., 2016; Chassagnon et al., 2015; Horbach et al., 2012; De Marchi 2012; Orsato, 2009; Johnstone et al., 2009; Darnall et al., 2008; Kassins et al., 2006;
	10. Communication and relationships	Corporate Brand reputation & image	Ecobranding subcomponent	Walsh et al., 2017; Yu et al., 2017; Evangelista et al., 2017; Hanninen et al., 2017; Journeault et al., 2016; Hojnik et al., 2016; Lozano, 2015; Joshi et al., 2015; Bey et al., 2013; Hallstedt et al., 2013; Laperche et al., 2013; Lozano et al., 2013; Guimaraes et al., 2013; Johnstone et al., 2009; Tseng et al., 2009; Lash et al., 2007; Kassins et al., 2006; Bansal et al., 2003;
		Labelling & reporting	Ecobranding subcomponent	Gasbarro et al., 2017; Maniatis et al., 2016; Joshi et al., 2015; Lockrey, 2015; Guimaraes et al., 2013; Tseng et al., 2009
		Competitors benchmarking and trends	Ecobranding subcomponent	Journeault et al., 2016; Hojnik et al., 2016; Kucuksayrac, 2015; Lozano, 2015; Ghazilla et al., 2015; Lozano et al., 2013; Berlin et al., 2011; Tseng et al., 2009; Walker et al., 2008; Kassins et al., 2006;
		Alliances and partnerships with other organizations	Ecobranding subcomponent	Lopez-Gamero et al., 2016; Jabbour et al., 2016; Lozano, 2015; De Marchi et al., 2013; Lozano et al., 2013; Henri et al., 2010; Seiffert, 2008;

Table 3 Environmental Management Drivers (EMDs) emerged from the scientific literature review.

For each EMD have been specified the typology (internal or external), the subcomponent of the environmental management strategy to which has linked, the specific scientific papers reviewed and the relative EMD category. In fact, the EMDs has been grouped in ten sets that represent homogeneous categories in order to simplify the understanding of which environmental management perspectives have involved (see figure below). These categories constitute the Life Cycle Management Areas. The environmental management perspectives can be seen also as the management questions that emerging when an organization faces the environmental management (Wrisberg et al., 2012).

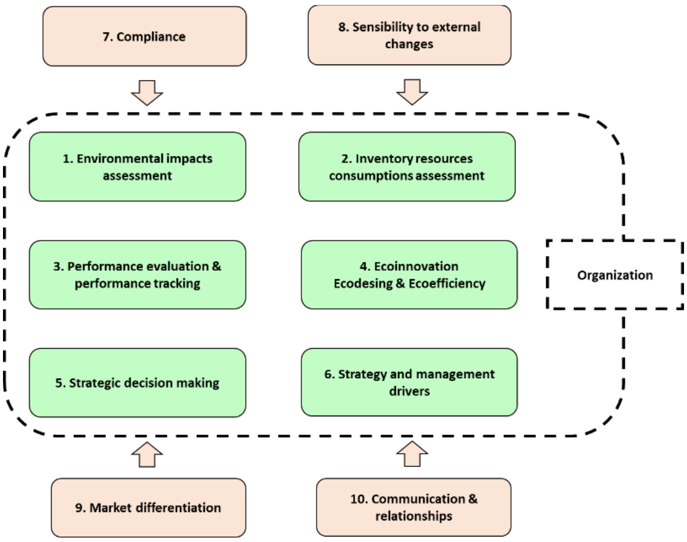


Figure 12 Internal and external Environmental Management Drivers (EMDs) categories that influence an organization (Personal elaboration, 2017).

This part of the scientific literature review has permitted to identified 25 different EMDs, 13 of them are internal EMDs the other 12 EMDs are external. 6 of EMDs life cycle management areas are internal and the other 4 are external. The description of each EMDs is reported following.

1.2.1. EMDs – Environmental impact assessment

This EMDs category, groups EMDs that regard aspects related to: environmental impacts assessment at product and organization level. The identified EMDs are following descripted:

<u>Environmental Impacts Assessment – Product Level:</u>
Organizations in order to improve and make more consistent their approaches to environmental management have the needs to assess the environmental impacts generated by their activities. Environmental impacts, following the more recent international scientific metrics, can be related to: climate change, water depletion, human toxicity, fossil depletion, land transformation and others. It is very important for the competitivity of organizations to assess the environmental impacts of their products. Furthermore, the product impact assessment is an aspect increasingly demanded by the market.

<u>Environmental Impacts Assessment – Organizational Level:</u>
It is very important to assess the environmental impacts also at organizational level in addition to the product level previously mentioned. In fact, mainly for the complex organizations (e.g. multisite organizations, organizations with large products portfolio), the assessment of environmental impacts as organizational level is need in order to manage their life cycle performance and identify the hotspots at organizational level that could be different from those that have been identified at product level.

1.2.2. EMDs – Inventory resources consumptions assessment

This EMDs category groups EMDs that regard aspects related to: resources consumptions assessment at product and organization level. The identified EMDs are following descripted:

Inventory resources consumptions assessment – Product Level:

Organizations in order to better understand their environmental performances have the need of to assess their consumptions in terms of raw materials, auxiliary materials and energy. All main mass and energy flows shall be considered. The assessment at product level is need to correctly imputed resources consumptions to a specific product in a differentiating way, identifying hotspots. Furthermore, the assessment of resource consumptions is strategical to identify opportunity for cost reduction.

Inventory resources consumptions assessment – Organizational Level:

It is very important to assess the resources consumptions also at organizational level in addition to the product level previously mentioned. In fact, it permits of obtain of a view of the whole organizational consumptions in other to identify hotspots.

1.2.3. EMDs – Performance evaluation & performance tracking

This EMDs category groups EMDs that regard aspects related to environmental and economic performance evaluation. The identified EMDs are following descripted:

Environmental performance evaluation & performance tracking at product and organizational level:

Many organizations seek ways to understand, demonstrate and improve their environmental performance. This can be achieved by effectively managing those elements of their activities, products and services that can significantly impact the environment. The environmental performance evaluation (EPE) enables organizations to measure, evaluate and communicate their environmental performance using environmental performance indicators (EPIs), based on reliable and verifiable information. The tracking of the performance is fundamental aspect to support assertions on environmental performance and to assess the trend of performance at product and organizational scale.

Production cost reduction or/and revenue increasing:

Organizations have the need of assess and successively pyritize interventions that as well as improving environmental performance, they also promote a reduction of production cost or/and a revenue increasing: The relationship between environmental performance and economic performance is a fundamental point for the financial sustainability of the environmental management activities.

1.2.4. EMDs – Ecoinnovation

This EMDs category groups EMDs that regard aspects related to: ecoinnovation though ecodesign processes and ecoinnovation through ecoefficiency processes. Defining ecoinnovation is not a simple task, as the various research studies do not agree on a common definition. The Eco-Innovation Observatory (2012) defines ecoinnovation as the “introduction of any new or significantly improved product (good or service), process, organizational change or marketing solution that reduces the use of natural resources (including materials, energy, water and land) and decreases the release of harmful substances across the whole life-cycle”. The identified EMDs are following descripted:

Ecodesign

Ecodesign is a proactive approach that through the integration of environmental aspects into product design and development seeks to prevent adverse environmental impacts before they arise. It provides a systematic opportunity to anticipate problems and their solutions along the whole product life cycle. Organizations that take proactive actions in this regard may increase their chances to benefit from this approach. The organizations generally could have different capability levels of ecodesign integration into management practice (Chrissis et al., 2003). The capability levels can be defined as follows (Pigosso et al., 2013):

- Capability level 1 e incomplete: the management practice is not applied or is applied incompletely by the company;
- Capability level 2 e ad hoc: the management practice is applied in an ad hoc way, i.e. to correct a problem or to accomplish a specific task by some individuals in the company, but not yet in a formalized and systematized way;
- Capability level 3 e formalized: the application of the management practice is formalized in documented processes and the infrastructure, responsibilities and resources to support the practice are allocated;
- Capability level 4 e controlled: the application of the management practice is formalized and controlled, i.e. its performance is measured and monitored throughout time by using performance indicators;
- Capability level 5 e improved: the performance of the application of the management practice is continuously improved based on the measurement and monitoring.

The organizations have the need of increase the capability level during the time for improve the efficacy of the results from eco-design processes.

<u>Ecoefficiency</u>

The organizations have increase the need of measure and improve the ecoefficiency of their processes and products. Ecoefficiency is an aspect of sustainability relating the environmental performance of a product/ process to its product/process functional value. Ecoefficiency shall be applied by organization to main products and processes in order to promote the improvement of environmental performance and costs reduction.

1.2.5. EMDs – Strategic decision making

This EMDs category groups EMDs that regard aspects related to strategic decision making in order to identify new eco-friendly solutions to environmental management issues faced and for assess the environmental convenience of new potential investments. The identified EMDs are following descripted:

<u>Identification of new eco-friendly solutions:</u>

Organizations may face many decision making problems during the environmental management activities. These problems may regard for example: ecodesign, ecoefficiency, process optimization, new products development, etc. Therefore, organizations have the need to find new solutions that, respecting the organizational, financial and operative constraints, permit to improve the environmental performance, or anyway, maintaining it unchanged by avoiding the worsening.

<u>Investments assessment:</u>

Organizations may face many decision making problems during the investments assessment. These problems may regard for example: new technologies acquisition, new production sites acquisition, etc. Therefore, organizations have the need to assess the environmental performance of all different investments in order to take into account also these elements to the strategic decision making process.

1.2.6. EMDs – Strategy & Management

This EMDs category groups EMDs that regard aspects related to: strategy formulation, introduction of continuous improvement concept and to managerial aspects. The identified EMDs are following descripted:

<u>Strategy formulation with objectives and targets definition:</u>
This EMDs category is related to the organization's need to establish an environmental management strategy based on goals and targets, short and medium term, achievable and monitorable. Goals and targets must be coherent with the environmental policy of the organization and with the competitive market context within which the organization operates. The strategy must be developed considering external and internal drivers and therefore both the ecoefficiency and the ecobranding intents must be considered.

<u>Systematic and procedural approach for continuous improvement:</u>
In order to systematize the approach to environmental management the organization have the need of internalize the PDCA managerial concept. The PDCA model provides an iterative process used by organizations to achieve continual improvement. It can be applied to an environmental management system and to each of its individual elements. It can be briefly described as follows.

- Plan: establish environmental objectives and processes necessary to deliver results in accordance with the organization’s environmental policy;
- Do: implement the processes as planned;
- Check: monitor and measure processes against the environmental policy, including its commitments, environmental objectives and operating criteria, and report the results;
- Act: take actions to continually improve.

A key element for introduce this concept in organization is the introduction of specific technical documentation (e.g. procedures, manual, etc.)

<u>Top management commitment and managerial aspects:</u>
Top management shall demonstrate leadership and commitment with respect to the environmental management. It is a very fundamental point for the proper functioning of environmental management activities. Top management shall:

- taking accountability for the effectiveness of the environmental management;
- ensuring that the environmental policy and environmental objectives/targets are established and are compatible with the organization’s environmental management strategy;
- ensuring the integration of the environmental management activities into the organization’s business processes;
- ensuring that the resources needed for the environmental management are available (e.g. human, financial, technical);
- communicating the importance of effective environmental management;
- ensuring that the organization achieves the intended outcomes regarding environmental management;
- directing and supporting persons to contribute to the effectiveness of the environmental management;
- promoting continual improvement.

1.2.7. EMDs – Compliance

This EMDs category groups EMDs that regard compliance aspects related to: environmental regulation, governmental aspects and fundraising. The identified EMDs are following descripted:

<u>Regulatory compliance:</u>
The compliance with environmental regulatory is a very important need of the organization as it represents a fundamental operative requirement. The environmental regulatory may be very complex and it often changes over time. Therefore, the compliance is rather demanding.

<u>Governmental aspects compliance (taxes and incentives):</u>
Organizations have the need of ensure the compliance of specific governmental requirements regards environmental management in order to be able to access to incentives or tax breaks. Other cases may be related to governmental programs (e.g. Italian green public procurement) or to laws that create market barriers (e.g. French Grenelle law).

<u>Fundraising:</u>
Organizations often have the need of respect new compliance requirements in order to access to funding for projects and to bank loans (e.g. Deutsche Bank).

1.2.8. EMDs – Sensibility to relevant changes

This EMDs category groups EMDs that regard capability of to be sensible to changes on: raw materials price and availability, physical climate change, products on market, technologies on market and stakeholder's expectations and awareness. The identified EMDs are following descripted:

<u>Changes in price and availability of raw materials:</u>
Organizations have the need of to identify promptly changes in price and raw materials availability in order to assess if the business competitivity is potentially in danger, and then apply strategic respond actions (e.g. raw material substitution, stock acquisition of raw materials, financial protection of the raw material contracts (e.g. use of financial derivatives)).

<u>Physical climate changes (e.g. desertification):</u>
Organizations have the need of to identify promptly changes in climate conditions in order to assess if the business competitivity is potentially in danger, and then apply strategic respond actions. In this case the perception is a long term and it is important for business sensible to atmospheric events (e.g., storms), climate conditions (e.g. temperature, humidity) or to water availability.

<u>Changes of products on market:</u>
Organizations have the need of to identify changes in the characteristics of the competitor products available in the same market segment. It is fundamental in order to assess if the products offered by some organizations have the need of an upgrading to include the new characteristics introduced by other organizations in their products.

<u>Changes of technologies on market:</u>
Organizations have the need of to identify changes in the performance of new technologies available on the market. It is fundamental in order to assess if the new technology may improve the environmental and economic performance of specific process of the organization.

<u>Changes in stakeholder's expectations and awareness:</u>
Organizations have the need of to identify changes in stakeholder's expectations and awareness. It is fundamental in order to assess if the products/services have need of an upgrading or if there is the need of new products development in order to satisfy the new stakeholder's expectations in terms of environmental performance.

1.2.9. EMDs – Market differentiation

This EMDs category groups EMDs that regard market differentiation of products. The identified EMDs are following descripted:

Products differentiation:

Organizations have the need to develop new products for differentiating their offers and product portfolio, inserting eco-friendly products. It is an important point to increase the competitivity of the organization in order to find new green market segments.

1.2.10. EMDs – Communication and relationships

This is the last EMDs category and it groups EMDs that regard communication and relationships aspects. The identified EMDs are following descripted:

Corporate Brand reputation:

Organizations have the need of manage and improve the image of the Brand regarding environmental topics following the stakeholders' awareness. External communications initiatives may be supportive in order to externalize the organization's initiatives on environmental management.

Labelling:

Organizations have the need of to use labels in order to promote their eco-friendly products. The labels may be very supportive to communicate to stakeholders the environmental performance of products.

Competitors benchmarking:

Organizations have the need of to assess the environmental management strategy of the competitors and the external communication processes utilized by them. The benchmarking with competitors may be qualitive and quantitative. The qualitative benchmarking is based on the comparison of the eco-friendly initiatives. The quantitative benchmarking is based on the comparison of specific environmental performances (e.g. PEF, EPD).

Alliances and partnerships with other organizations:

Organizations have the need of to establish alliances and partnerships with other organization in order to achieve different possible competitive advantages such as: external communication of initiatives realized in partnership may be more efficacy with stakeholders, the partnership may be the base for improving commercial agreements, cost of eco-friendly initiatives may be divided on the members of the partnership and not by one organization.

1.3. Environmental Management Barriers (EMBs)

Environment is a strategic frontier in which organizations can act proactively and develop competitive advantages. However, many organizations though try to adopt environmental management strategies, do not achieve gaining competitive advantages because there are barriers that limit the management efficacy (Echegaray, 2014; Milanez, 2009; Shi et al., 2008; Aragon-Correa et al., 2008; Stone, 2006). The Environmental Management Barriers (EMBs) can be defined as the set of unmanaged EMDs, limits in EMDs addressing, and other factors that inhibit the environmental management strategy not allowing the achievement of competitive advantages (Shi et al., 2008). Specifically, the three types of EMBs can as following defined:

- EMBs - unmanaged EMDs: this type of barriers is related to EMDs completely not consider and manage by the organization;
- EMBs - limits in EMDs managing: this type of barriers is related to issues that the organization faces during EMDs management;
- EMBs – other factors: this type of barriers is related to other factors that can be intrinsic characteristics of EMDs or other types of issues.

EMBs constitute therefore the criticalities that often an organization faces during the environmental management. Many authors in the last twenty years have studied EMBs and their relevance in the inhibition of the environmental strategy development process (Lopez-Gamero et al., 2016; Lozano et al., 2015; Klewitz et la., 2014; Agan et al., 2013; Yen et al., 2012; Zeng et al., 2011; Del Rio et al., 2009). Also, the EMBs can be distinguished in internal and external, and congruently with the approach used for EMDs identification, the same sets have been used to group EMBs.

In this part of the literature review research stage more than 60 scientific publications have been analysed in order to identify the most relevant EMBs. The time span of publication goes from years 2002 to 2017. The following table shows the results.

Type (Internal/external)	Life Cycle Management Critical Areas	Environmental Management Barriers (EMBs)	Type of EMBs	References
Internal	1. Environmental impact assessment	Lack of Environmental Impact– Product Level	EMBs - limits in EMDs managing	Zvezdov et al., 2016; Meinrenken et al., 2012; Ghazilla et al., 2015; Bidstrup et al., 2015; Finkbeiner et al., 2014; Bey et al., 2013; Stechenesse et al., 2012; Bretz et al., 1996;
		Lack of Environmental Impact – Organizational Level	EMBs - unmanaged EMDs	UNEP, 2015; Resta et al., 2016; Loss et al., 2016; Manzardo et al., 2015; Alroe et al., 2016; Martinez-Blanco et al., 2015; Hellweg et al., 2014; Bey et al., 2013; WRI, 2013; Clift et al., 2000
		Correlation between product and organizational scale not considered	EMBs - unmanaged EMDs	Zvezdov et al., 2016; UNEP, 2015; Resta et al., 2016; Loss et al., 2016; Manzardo et al., 2015; Alroe et al., 2016; Martinez-Blanco et al., 2015; Meinrenken et al., 2012; Stechemesser et al., 2012.
		Lack of Comprehensive impact assessment (Multi-indicators)	EMBs - unmanaged EMDs	Williams et al., 2017; Caldera et al., 2017; Stindt, 2017; Alroe et al., 2016; Moreno et al., 2015; WRI, 2013;
		Lack of Life Cycle Management approach	EMBs - limits in EMDs managing	Sonneman et al., 2015; Nilsson-Linden et al., 2014; Moreno et al., 2015; Finkbeiner et al., 2013b; UNEP, 2009;
		Issues in hotspots identification and on burdens shifting	EMBs – other factors	Manzardo & Loss et al., 2017; Martinez-Blanco et al., 2016; Finkbeiner et al., 2014; Draucker et al., 2013; Hellweg et al., 2014; Pelletier et al., 2013; Downie et al., 2011.
		Impact assessment based on inventory indicators	EMBs - limits in EMDs managing	Alroe et al., 2016; Moreno et al., 2015; Lewandowska et al., 2014; Liu et al., 2012; Zobel et al., 2004; Zobel et al., 2002;
		Technical difficulties in large impact assessment data management	EMBs – other factors	Badiezadeh et al., 2017; Zvezdov et al., 2016; Alroe et al., 2016; Lewandowska et al., 2011; Burrit et al., 2011
	2. Inventory resources consumptions assessment	Technical difficulties in large inventory data management	EMBs – other factors	Ferro de Guimaraes et al., 2017; Badiezadeh et al., 2017; Zvezdov et al., 2016; Riexinger et al., 2016; Kouziokas et al., 2016; Dorn et al., 2016; Ghazilla et al., 2015; Witezak et al., 2014; Sarkis et al., 2013; Bennett et al., 2013; Magnan et al., 2013; Lewandowska et al., 2011; Henri et al., 2010; Finkbeiner, 2009; Tseng et al., 2009; Isenmann et al., 2008; Bretz et al., 1996.
	3. Performance evaluation & performance tracking	Lack of OPIs for environmental performance evaluation related to life cycle management at product and organizational level	EMBs - limits in EMDs managing	Pilouk et al., 2017; Hellono et al., 2017; Journeault et al., 2016; Bey et al., 2013; Henri et al., 2010;
		Difficulties in performance tracking and OPIs trends analysis	EMBs – other factors	Riexinger et al., 2016; Dorn et al., 2016; Magnan et al., 2013; Henri et al., 2010;
	4. Ecoinnovation	Difficulties in implementation of practical ecodesign processes and new eco-friendly alternative solutions comparison	EMBs - limits in EMDs managing	Resta et al., 2016; Luglietti et al., 2016; Kucuksayrac, 2015; Martinez-Blanco et al., 2015; Ghazilla et al., 2015; Lewandowska et al., 2014; Pigosso et al., 2013; Arzoumanidis et al. 2013; Bey et al., 2013; Buttol et al. 2012; Le Pochat et al., 2007; Boks, 2006; Johansson, 2006; Luttropp et al., 2006;
		Lack of indicators for ecoefficiency assessment	EMBs - unmanaged EMDs	Journeault et al., 2016; Sproedt et al., 2015; Validi et al., 2015; Bey et al., 2013; Jacquemin et al., 2012; Henri et al., 2010;

	5. Strategic decision making	Lack of use of Decision making Tools (MCDA, optimization, statistical techniques, etc.)	EMBs – other factors	Yue et al., 2014; Bey et al., 2013; Liu et al., 2012; Jacquemin et al., 2012; Pieragostini et al., 2012; Ljubas et al., 2011; Marazza et al., 2010; De Benedetto et al., 2009; Chen et al., 2009;
		Difficulties in the assessment of environmental performance of investments	EMBs – other factors	Granly et al., 2014; Fleiter et al., 2012; Murillo-Luna et al., 2011
	6. Strategy & Management	Unbalanced environmental management strategies	EMBs - limits in EMDs managing	Journeault et al., 2016; Lewandowska et al., 2014; Bey et al., 2013; Pigosso et al., 2013; WRI, 2013; De Marchi, 2012; Mourillo-Luna et al., 2011;
		Divergence between intended and realized environmental management strategy	EMBs - limits in EMDs managing	Journeault et al., 2016; Engert et al., 2016; WRI, 2013
		Lack of Top management commitment	EMBs - limits in EMDs managing	Ghazilla et al., 2015; Granly et al., 2014; Guimaraes et al., 2013; Mollahoseini et al., 2012; Mourillo-Luna et al., 2011; Massoud et al., 2010; Bos-Brouwers, 2010; Tseng et al., 2009; Aragón-Correa et al., 2008;
		Lack of Systematic and procedural approach for continuous improvement	EMBs - limits in EMDs managing	Resta et al., 2016; Ghazilla et al., 2015; Lisi et al., 2015; Pigosso et al., 2013; Gond et al., 2012;
		Lack of employees' skills & undefined responsibilities	EMBs - limits in EMDs managing	Hermann et al., 2017; Campi et al., 2017; Evangelista et al., 2017; Jabbour et al., 2016; Kucuksayrac, 2015; Ghazilla et al., 2015; Bey et al., 2013; Lozano et al., 2013; Demirel et al., 2011; Murillo-Luna et al., 2011; Massoud et al., 2010, Chan et al., 2008; Lee et al., 2008;
External	7. Compliance	Low ability to perceive changes in regulation & Unclear regulation	EMBs - limits in EMDs managing	Elijido, 2017; Hermann et al., 2017; Shen et al., 2017; Bhupendra et al., 2015; Zhang et al., 2013; Murillo-Luna et al., 2011; Luken et al., 2008;
		Lack of economic advantages (e.g. taxes reduction, incentives)	EMBs - limits in EMDs managing	Hermann et al., 2017; Kucuksayrac, 2015; Buttol et al., 2012; Mourillo-Luna et al., 2011; Massoud et al., 2010
	8. Sensibility to relevant changes	Low ability to perceive changes in resources availability and price	EMBs - limits in EMDs managing	Hermann et al., 2017; Miehe et al., 2016; WRI, 2013; Mourillo et al., 2011;
		Low ability to perceive changes of products on market	EMBs - limits in EMDs managing	Bhupendra et al., 2015; Ghazilla et al., 2015; Zhang et al., 2013; Luken et al., 2008;
		Low ability to perceive changes of technologies on market	EMBs - limits in EMDs managing	Ghazilla et al., 2015; Lozano et al., 2013; Murillo-Luna et al., 2011
	9. Market differentiation	Difficulty in highlighting the differences in terms of environmental performance of their products respects those of competitors	EMBs - limits in EMDs managing	Laso et al., 2017; Cordella et al., 2016; Lockrey, 2015; EC, 2013b
	10. Communication and relationships	Low stakeholders engagement	EMBs - limits in EMDs managing	Lozano et al., 2013; Guimaraes et al., 2013; Mourillo-Luna et al., 2011; Massoud et al., 2010; Molina-Murillo et al., 2009; Tseng et al., 2009
		Lack of alliances and partnerships with other organizations	EMBs - limits in EMDs managing	Bey et al., 2013; Seiffert, 2008;
Other important evidence	11. EMTs implementation	EMTs selection and EMTs high variety	EMBs – other factors	Rousseaux et al., 2017; Kucuksayrac, 2015; Rossi et al., 2016; Alroe et al., 2016; Ghazilla et al., 2015; Bey et l., 2013; Lozano et al., 2013; Mourillo-Luna et al., 2011; Tseng et al., 2009
		High implementation costs	EMBs – other factors	Ghazilla et al., 2015; Murillo-Luna et al., 2011; Massoud et al., 2010

Table 4 Environmental Management Barriers (EMBs) emerged from the scientific literature review.

This part of the scientific literature review has permitted to identified 29 different EMBs, 19 of them are internal EMBs the other 8 EMBs are external while the remaining 2 EMBs are related to the EMTs implementation. 6 of life cycle management critical areas are internal and the other 4 are external. Furthermore, in the case of EMBs there is an additional critical area respect the ten used for EMDs. The eleventh life cycle management critical area is related to issues emerged during the implementation of the environmental management tools. This aspect is very important because strengthens the importance of this thesis research regarding the need of EMTs selection. The description of each EMBs is reported following.

1.3.1. EMBs – Environmental impact assessment

This EMBs category groups EMBs that regard issues in environmental impact assessment. The identified EMBs are following descripted.

Lack of Environmental Impact Assessment – Product Level:

Although the number of organizations that had implemented product LCA is increased the industrial application is yet limited. Furthermore, organizations that has applied LCA has selected one or few products without investigates the major part of its product portfolio. There is the need of develop tools for the assessment of large products portfolio.

Lack of Environmental Impact Assessment – Organizational Level:

Only few organizations assess environmental impacts at organizational level and very few organizations have applied LCA methodology at organizational level (The case study of this thesis is the first published application of OLCA). In this context organizations do not know their life cycle environmental impacts and hotspot along the value chains. Furthermore, the contradiction between the organizational environmental performance and the product environmental performance could exist and could be a risk for the organization in terms of reputation.

Correlation between product and organizational scale not considered:

The correlation between the organizational environmental performance and the products environmental performance is currently unmeasured from organizations and it is a strong limit into correlate the efforts that organization promotes at product and process scale to the potential improvement of the life cycle environmental performance at organizational scale.

Lack of Comprehensive impact assessment (Multi-indicators):

Many organizations monitor only one environmental impact category (e.g. climate change). It is fundamental to establish approaches in the organizations able to assess and monitor all the environmental impact categories considered relevant from scientific community. It is important to underline that also if the organization monitor many impact categories (for internal environmental strategy purposes), it may choose of based its external communication strategy only on one impact category (e.g. climate change).

Lack of Life Cycle Management approach:

Often the organization in the environmental management activities and initiatives do not use a life cycle management approach, focusing only on directly controlled processes (e.g. core processes). However, it is common know that an organization generates environmental impacts especially in the upstream processes (e.g. raw material extraction) and in the downstream processes (e.g. transports, usage phase, end of life). Considering the LCM concept is fundamental requirement to achieve the environmental sustainability also considering other concepts such as: circular economic, ecodesign, etc.

<u>Environmental burdens shifting issues:</u>
Often the organizations keep choices that apparently improve the environmental performance but realty move the environmental issues under another point of view. These issues as well know with the scientific term of "burdens shifting". In the literature two types of burden shifting have been recognized:

1. Burdens shifting type one: the choice generates that a part of the environmental impacts are shift from a life cycle stage to another life cycle stage without a reduction of the whole impact;
2. Burdens shifting type two: the choice generates a reduction of the environmental impacts on one specific impact category (e.g. climate change) but an increase of impacts on other impact categories (e.g. water depletion, human toxicity, etc.)

<u>Impact assessment based on inventory indicators:</u>
Many organizations base impropriety the environmental performance assessment only on the assessment of inventory indicators (e.g. resources consumptions). However, the environmental impacts categories represent environmental issues of concern to which life cycle inventory analysis results may be assigned though the characterization processes. Therefore, choices apparently equal from the inventory analysis perspective may be very different from the impact assessment analysis perspective.

<u>Technical difficulties in large impact assessment data management:</u>
The environmental impacts assessment at organizational level and for many products generate a very large amount of results that must be interpreted. This interpretation phase normally requires many time and implies high cost. Solutions to reduce effort related to this activity are required.

1.3.2. EMBs – Inventory resources consumptions assessment

This EMBs category groups EMBs that regard issues in inventory analysis. The identified EMBs are following descripted.

<u>Technical difficulties in large inventory data management:</u>
The inventory analysis with data collection activities at organizational level and for many products normally requires many time and implies high cost. Solutions to reduce effort related to this activity are required.

1.3.3. EMBs – Performance evaluation & performance tracking

This EMBs category groups EMBs that regard issues on environmental performance evaluations. The identified EMBs are following descripted.

<u>Lack of OPIs for environmental performance evaluation related to life cycle management at product and organizational level:</u>
The key to a successful environmental management is the proper identification and evaluation of environmental aspects and their potential impacts because the most significant environmental aspects play a crucial role in the formulation of effective environmental policy, in terms of the definition of objectives and targets, therein providing the basis for the entire EMS (Põder 2006). Organizations use rarely sets of KPI in order to evaluate and monitor environmental performance of processes, products, and whole organizations. This aspect does not permit to the organizations to have a simply and fast continues assessment of their environmental performance.

<u>Difficulties in performance tracking and OPIs trends analysis</u>
Many organizations had assessed the environmental performance of products at least one time. However, often many organizations do not continue to reassess the performance of these products

subsequently. This aspect does not permit to manage the life cycle environmental performance of products. The same considerations can be made for the organizational scale. Furthermore, the organizations loss the possibility to promote market strategies based on environmental performance and to establish ecodesign processes for the continuous improvement of life cycle performance of them and of their products.

1.3.4. EMBs – Ecoinnovation

This EMBs category groups EMBs that regard issues on ecoinnovation especially regarding: ecodesing and ecoefficiency activities. The identified EMBs are following descripted.
Difficulties in implementation of practical ecodesign processes and alternative solutions comparison

<u>Difficulties in implementation of practical ecodesign processes new eco-friendly alternative solutions comparison:</u>
Organizations that have start ecodesing activities face the issue of link ecodesing activates to other business activates. Ecodesing activates result often isolated and it is a critical point to transform ecodesing intentions into real ecodesigned specifications for products development. A systematic application of ecodesing is required. The core gaps regarding ecodesign implementation and management are:

- Lack of systematization of existing ecodesign practices in detriment to managerial models;
- Lack of integration between ecodesign and the broad context of product development, management and corporate strategy;
- Lack of a roadmap to support companies on continuous improvement of ecodesign implementation, which can continually drive actions toward higher implementation levels;
- Difficulties faced by companies in defining and prioritizing the ecodesign practices to be employed and in moving from pilot projects to anchoring eco-design into business.

Furthermore, many times, organizations face a large number of innovation projects and the analysis of alternatives with ecodesign perspective often required a lot of time and resources. Therefore, organizations have the need of operative tools that permit the fast alternatives comparison and the identification of the best environmental solution.

<u>Lack of indicators for ecoefficiency assessment:</u>
Organizations rarely assess and monitor ecoefficiency of processes and products. This aspect does not permit to the organizations to have a simply and fast continues assessment of their ecoefficiency in order to reduce resources consumptions and economic costs.

1.3.5. EMBs – Strategic decision making

This EMBs category groups EMBs that regard issues on strategic decision making: identification of optimize solutions, investment assessment. The identified EMBs are following descripted.

<u>Lack of use of Decision making Tools (MCDA, optimization, statistical techniques, etc.):</u>
Most of times, the environmental management activities generate multi objective problems or decision making problems. In fact, for example often in a ecodesign processes there is the objective of environmental performance improvement but there are other objectives such as cost reduction, or improvement of some performance characteristic of a product. In other cases, there will be a number of options and possibilities for improvements and it may not always be obvious, which of them represents the optimum solution. Secondly, there may exist more than one optimal solution for improving the system’s performance, in which case the issue becomes that of choosing the best compromise option from a number of optimum solutions. Therefore, there is the need that organization integrate into

decision making process on environmental management, specific tools for decision making such as MCDA, mathematical optimization approaches, statistical techniques, etc.

Difficulties in the assessment of environmental performance of investments:
Organizations have the need of to assess how new potential investments may influencing environmental performance of products, processes or whole organizations. In fact, choosing eco-friendly investments may be an important asset for improve environmental performances through new technologies acquisition and financial support of new eco-friendly products development.

1.3.6. EMBs – Strategy & Management

This EMBs category groups EMBs that regard issues in strategy formulation and on managerial aspects. The identified EMBs are following descripted.

Unbalanced environmental management strategies:
Although from a theoretical point of view an environmental management strategy is composed by the ecoefficiency component and the ecobranding component, many times organizations develop strategies expanding only the ecobranding component, limiting the developed of the ecoefficiency component. In the extreme case, when no ecoefficiency intents are established, the strategy could become “Green washing”. In a balance environmental management strategy, both two parts are developed, the ecobranding component is built on the results generated by ecoefficiency component and when ecobranding goals have been set the ecoefficiency component works to obtain them.

Divergence between intended and realized environmental management strategy:
The competitive environmental strategy is composed of two different components, namely the intended and realized strategy. The intended component of competitive environmental strategy refers to the integration of environmental ambitions into the organizational strategic intentions in order to gain a competitive position that a firm hopes to build in the future. The realized component refers to the intentions expressed in the intended component effectively realize by the organization. Many organization intents to achieve goals and targets regarding environmental management and performance but do not catch to achieve the major part of them, creating a divergence between the intended component and the realized component and losing the major part of potential competitive advantages.

Lack of Top management commitment:
The top management commitment is an essential aspect to ensure the achieving of improvements of environment performance of an organization and of its products. In fact, companies achieve much greater success if they are characterized a strong commitment from top management. However, the top commitment is often low.

Lack of Systematic and procedural approach for continues improvement:
Many times, organizations face the environmental management without internalize the PDCA managerial concept. It follows that the environmental management activities are not cyclic and do not favour the continues improvement. In fact, in these cases the environmental management activities result spot and unlinked to the business activities of the organization. This aspect in very critical for the efficacy of the environmental management strategies and the competitivity results.

Lack of employees’ skills & undefined responsibilities:
The environmental management is a very complex subject and therefore require that employees have specific skills. The general low employees’ skills on environmental management often limits the development of practical actions in the organization. In other case, also if there are employees with

correct skills, without a defined organization of the responsibilities, the environmental management activities go on with difficulties.

1.3.7. EMBs – Compliance

This EMBs category groups EMBs that regard issues on compliance mainly at regulatory level. The identified EMBs are following descripted.

<u>Low ability to perceive changes in regulation & Unclear regulation:</u>
Many organizations although have the need of is continuously updated on changes in environmental regulation, do not control this aspect and undergo different kind of operative issues such as production stops, heavy fines, etc.

<u>Lack of economic advantages (e.g. taxes reduction, incentives):</u>
Many organizations see as barrier to environmental management the lack of economic advantages from taxes reduction or access to incentives. This aspect is very variable at international level from country to country.

1.3.8. EMBs – Sensibility to relevant changes

This EMBs category groups EMBs that regard the low sensibility to relevant external changes of: price and resource availability, products in the same market segment and new technologies. The identified EMBs are following descripted.

<u>Low ability to perceive changes in resources availability and price:</u>
Many organizations although have the need of is continuously updated on price and resources availabilities, do not control this aspect and undergo different kind of operative issues such as increasing production cost, production limited by low resource availability, etc.

<u>Low ability to perceive changes of products on market:</u>
The eco-friendly characteristics of the products on the market may change rapidly especially in market segments rich of producers. Many organization do not respond promptly to these changes losing competitivity.

<u>Low ability to perceive changes of technologies on market:</u>
Many organization do not monitor continuously the opportunities offered by the innovation produced by new production technologies available on the market in order to improve their environmental performance and their market competitivity.

1.3.9. EMBs – Market differentiation

<u>Difficulty in highlighting the differences in terms of environmental performance of their products respects those of competitors:</u>
The organizations, although develop new green products, encounter issue that the actual communication tools often do not permit to communicate effectively environmental performance to consumers. Furthermore, communication tools developed for benchmarking (e.g. EPD) show limits, do not guaranteeing robust performance comparison and discouraging consequently the consumer confidence.

1.3.10. EMBs – Communication and relationships

This EMBs category groups EMBs that regard external communications and relationships. The identified EMBs are following descripted.

Low stakeholders engagement:
Organizations often do not activate communication processes for stakeholders engagement regarding environmental performance and commitment. These communication processes may be: external reporting, product labelling, participation in scientific conferences, publication of literature, etc.

Lack of alliances and partnerships with other organizations:
Organizations often face the environmental management without not share the experience with other organizations. This approach does not able the organizations to achieve potential competitive advantages such as: activities cost sharing, sharing of data (e.g. inventory primary data), commercial relationships improvement, etc.
An organization may search partners along its supply chain or in different market segments with similar experiences in environmental management.

1.3.11. EMBs – EMTs implementation

The last EMBs category groups EMBs that emerged during the EMTs implementation. This category is considered separately and has been identified in order to underline the importance of the issue related to EMTs selection. The identified EMBs are following descripted.

EMTs selection:
A large amount of EMTs exists and organizations have difficulties in EMTs selection limiting their application at industrial level. In fact, it is important underline that the so great variety of EMTs is one of the most important reason for the low implementation and integration of EMTs at industrial level. Organizations have need of EMTs selection guide in order to overcome this important EMB. Respect to this necessity, the present PhD research give an important contribution identifying a new method for multiple EMTs use that defines also which are the EMTs to select, proposing roles and ways to use different EMTs. This aspect is very important because strengthens the importance of this thesis research regarding the need of EMTs selection

High implementation costs:
The implementation of EMTs generates cost for organizations that in some case is high due to certification cost, the access to external expertise (e.g. academic resources, professional consultants, etc.) and software purchasing. This aspect often is problematic mostly when the organization focus the attention mainly on the objective to achieve certifications without focus on the objective of to improve its performance that often can generates economic savings which cover extensively the implementation costs.

1.4. Environmental Management Tools (EMTs)

In the present paragraph has presented the third part of the scientific literature review. This part focuses on the environmental management tools that have been developed from scientific community and that are in the last decades used by organizations in order to face and manage the environmental management drivers (EMDs) and overcome environmental management barriers (EMBs) encountered.

1.4.1. EMTs developed by scientific community

In recent decades, the environmental sustainability concept has acquired growing importance, and a large number of Environmental Management Tools (EMTs) have been developed to promote the implementation of its principles inside industrial companies in order to improve competitiveness (Zhang et al., 2017; Pigosso et al., 2015). In fact, following the increase awareness of the international community on environmental sustainability topic, a growing number of organizations are adopting different EMTs in order to assess, monitor and reduce the environmental impacts generated from their activities while other organizations are facing the need for EMTs selection (Rossi et al., 2016). An Environmental Management Tool is defined as tool to support and improve environmental management at organization, process and product level. Therefore, the EMTs are tools born in the environmental management scientific field to solve specifically environmental management issues (e.g. LCA, EMS). In order to better understand the definition of EMT two key definition are required: the definition of environmental management and the definition of management tool. Regarding environmental management, starting from Jolly (1978) arriving to Barrow (2006) there are many definitions, most having evolved over time and through feedback. In the present research, the environmental management is defined as a "decision-making process which regulates the impact of human activities on the environment in such a manner that the capacity of the environment to sustain human development will not be impaired, through a sustainable exploitation of natural and artificial resources and mitigation of environmental impacts generated from human activities (elaborated from Barrow, 2006)". Therefore, environmental management is contextualizable as an approach that seeks to steer the development process to take advantage of opportunities, try to avoid hazards, mitigate impacts on eco system, and prepare organizations for unavoidable difficulties by improving adaptability and resilience (Barrow, 2006). In fact, the survival of an organisation today depends directly on its capacity to be efficient and competitive. Growing transformations in the world impose changes in industrial management paradigms and environmental management can be seen as one of these changes, which brings in itself a series of opportunities and risks. As a management tool, the definition proposed by Moisdon (1997) can be considered: "a formalization of organised activity, (…) any system of reasoning that formally links a certain number of variables within an organisation, designed to provide information for the different acts of management, which can be grouped under the terms of the trilogy: plan, decide, control". EMTs have changed much over the last 50 years. From an individualist perspective of production site preventive measures, companies have moved on to embrace life cycle management (LCM) approaches. Following 30 years of development, there is today a wide amount of EMTs (Rousseaux et al. 2017; Lozano et al., 2012; Unger et al., 2008; Baumann et al., 2002). In fact, in 2002, more than 150 tools were identified by Baumann et al. (2002) and thirteen years later Pigosso et al. (2015) has listed 350 of them, the difference between these two numbers is simply an indirect measure of the velocity of development and diffusion of EMTs. However, EMTs are not equally diffused and applied. Therefore, this part of the literature analysis has been performed in order to identify the main important voluntary EMTs. The first analysis step is the classification of EMTs. In the past years different proposal for a EMTs taxonomy have been done in order to classify the large amount of EMTs (Rousseaux et al., 2017; Rossi et al., 2016). The taxonomy classification proposed in this research is based on a multi-level approach recently proposed by Rousseaux et al. (2017) and on considerations emerged by Rossi et al. (2016), Brones et al. (2015) and Hernandez et al. (2011). The taxonomy classification levels are:

- Level 1 – Object of analysis: define if the EMT is applicable at organization level, process level or product level (Rossi et al., 2016; Reyes et al, 2007);
- Level 2 – Normative level: define if the EMT is a normative or not normative tool (Rousseaux et al., 2017). Where normative tools include texts of standards (for instance, if a company wants a certification or applicable rules, it will use normative tools to reach its wish or strategy); non-normative tools encompass all other type of texts or methods that can be needed for improvement environmental management;
- Level 3 – Use-oriented level: define the environmental management perspective for which is used the tool (Brones et al., 2015; Lonzano et al., 2012; Hernandex-Pardo et al., 2011, Berkel et al., 1997). The level is composed by five categories:
    - Environmental Assessment Analytical tools - Inventory level: tools oriented to quantitative analysis of input and output mass and energy flows regarding a product or organization system;
    - Environmental Assessment Analytical tools - Impacts level: tools oriented to quantitative analysis of environmental impacts characterized in different environmental impact categories due to input and output mass and energy flows regarding a product or organization system. The inventory level is included in these tools.
    - Performance Evaluation and Improvement tools: tools oriented to facilitate management decisions regarding an organization's environmental performance. Ecodesign and ecoefficiency tool fall into this category being improvement tools;
    - Managerial tools: tools oriented to build an environmental strategy based on continuous improvement. Typically, they are procedural tools that permit to establish goals and objectives conforming the strategy and to allocate financial and human resources.
    - Communications tools: tools oriented to support process of internal and external communication. They vary from product labelling to external reports.

The distinction between environmental assessment tool and environmental improvement tools is based on Janin (2000) considerations. It is important that although as proposed by Rousseaux et al. (2017), at the first level EMTs are distinguishable in regulatory and non-regulatory tools, the present research focus only on voluntary EMTs and therefore excluded the regulatory tools. In the following table are listed the main EMTs emerged from the scientific literature review. EMTs have been characterized following the taxonomy scheme previously descripted.

			Level 1	**Level 2**		**Level 3**				
N°	**Tools**	**Relevant references**	**Object of analysis**	**Normative Tools**	**Non Normative Tools**	**Environmental Assessment Analytical Tools: Inventory level**	**Environmental Assessment Analytical Tools: Impacts level**	**Performance Evaluation and Improvement Tools**	**Managerial Tools**	**Communication Tools**
1	Environmental management control system (EMCS)	Guenther et al., 2016			√	Limited, often oriented to core process's flows		Limited to inventory performance evaluation	√	√
2	Global Reporting Initiative (GRI)	GSSB, 2016	Organization		√	Limited, not in a life cycle perspective		Limited to inventory performance evaluation		√
3	Environmental management system (EMS)	ISO, 2015	Organization	√		Limited, often oriented to core process's flows		Limited to inventory performance evaluation	√	√
4	Environmental Failure Mode and Affects Analysis	Roszak et al., 2015	Product & process		√				Limited to ecodesign choices	
5	Water Footprint (WF)	ISO, 2014	Organization & product & process	√		Limited to water consumptions and water quality	Limited to impacts on water resource			
6	Organizational Life Cycle Assessment (OLCA)	ISO, 2014	Organization	√		√	√			
7	Carbon Footprint – Product (CFP)	ISO, 2013	Product & process	√		Limited to GHG emissions	Limited to impacts on climate change			
8	Environmental performance evaluation (EPE)	ISO, 2013	Organization & process	√				√		
9	GHG Protocol - Product and supply chain standards	WRI, 2013	Product & process		√	Limited to GHG emissions	Limited to impacts on climate change			
10	GHG Protocol - Organization Accounting and Reporting Standards	WRI, 2013	Organization		√	Limited to GHG emissions	Limited to impacts on climate change			
11	Organization Environmental Footprint (OEF)	EC, 2013	Organization	√		√	√			√

			Level 1	Level 2		Level 3				
N°	**Tools**	**Relevant references**	**Object of analysis**	**Normative Tools**	**Non Normative Tools**	**Environmental Assessment Analytical Tools: Inventory level**	**Environmental Assessment Analytical Tools: Impacts level**	**Performance Evaluation and Improvement Tools**	**Managerial Tools**	**Communication Tools**
12	Product Environmental Footprint (PEF)	EC, 2013	Product & process	√		√	Liaison with LCA			√
13	Ecoefficiency Assessment (EEA)	ISO, 2012	Product & process	√				√		√
14	Ecosystem Services (ES)	Busch et al., 2012	Product & process		√	√			√	
15	Water Footprint Network	Hoekstra et al., 2011	Product & process		√	Limited to water consumptions and water quality	Limited to impacts on water resource			
16	EMAS Registration	EU, 2017	Organization	√		Limited, often oriented to core process's flows			√	√
17	Ecodesign Integration Method (EDIMS)	Le Pochat et al., 2007			√	Liaison with LCA	Liaison with LCA		Limited to ecodesign choices	
18	Method for Sustainable Development (MSPD)	Byggeth et al., 2007			√				Limited to ecodesign choices	
19	Life Cycle Assessment (LCA)	ISO, 2006	Product & process	√		√	√			
20	Environmental Declaration & claims Type I, II, III	ISO, 2001; 2016; 2006	Product	√						√
21	Cost-Benefit Analysis (CBA)	Pearce, 2006	Organization & product & process		√	√				
22	ABC - Analysis	Byggeth et al., 2006	Product & process		√				Limited to ecodesign choices	
23	Typological Environmental Analysis	Le Pochat et al., 2005	Product & process		√	Liaison with LCA	Liaison with LCA			
24	Strategic Environmental Assessment (SEA)	Dalal-Clayto, et al., 2005	Process	√		Limited, not in a life cycle perspective			√	

			Level 1	**Level 2**		**Level 3**				
N°	**Tools**	**Relevant references**	**Object of analysis**	**Normative Tools**	**Non Normative Tools**	**Environmental Assessment Analytical Tools: Inventory level**	**Environmental Assessment Analytical Tools: Impacts level**	**Performance Evaluation and Improvement Tools**	**Managerial Tools**	**Communication Tools**
25	Carbon Footprint – Organization	ISO, 2004	Organization	√		Limited to GHG emissions	Limited to climate change			
26	Material Flow Accounting (MFA)	Brunner et al., 2004	Product & process		√	√				
27	Substance Flow Analysis (SFA)	Sokka et al., 2004	Product & process		√	√				
28	Environmental Risk Assessment (ERA)	EC, 2003	Organization	√					Limited to risk management	
29	Life Cycle Engineering (LCE)	Jeswiet, 2003	Product & process		√	Liaison with LCA	Liaison with LCA		√	
30	Multicriterial Analysis for Sustainable Industrial Technologies (MASIT)	Benoit et al., 2003	Product & process		√	Liaison with LCA	Liaison with LCA			
31	Environmental Design Strategy Matrix (EEDSM)	Lagerstedt, 2003	Product & process		√				Limited to ecodesign choices	
32	Design for environment Ecodesign	ISO, 2002	Product & process	√				√	Limited to ecodesign choices	
33	Environmental Management Accounting (EMA)	Burritt et al., 2002	Organization		√	√	Liaison with LCA			
34	Input – output analysis (I/O)	Suh et al., 2002	Product & process		√	√				
35	Material Intensity Per unit of Service (MIPS)	Ritthoff et al., 2002)	Product & process		√	√				
36	Environmental Auditing (EASO) – ISO 14015	ISO, 2001	Organization	√					√	
37	Total material requirement (TMR)	Bringezu et al., 2001	Product & process		√	√				
38	Environmental Effect Analysis	Lindahl, 2000	Product & process		√	√				

			Level 1	Level 2		Level 3				
N°	**Tools**	**Relevant references**	**Object of analysis**	**Normative Tools**	**Non Normative Tools**	**Environmental Assessment Analytical Tools: Inventory level**	**Environmental Assessment Analytical Tools: Impacts level**	**Performance Evaluation and Improvement Tools**	**Managerial Tools**	**Communication Tools**
39	Environmental Impact Assessment (EIA)	Petts, 1999	Process		√	Limited, not in a life cycle perspective				
40	Embodied Energy Analysis (EEA)	Treloar, 1999	Product & process		√	Limited to energy flows				
41	Technology Assessment (TA)	Braun, 1998	Process					√		
42	Material cycle, Energy use and Toxic emissions (MET)	Brezet et al., 1997	Product & process		√	√				
43	Material, Energy, Chemical & Others (MECO)	Wenzel et al., 1997	Product & process		√	√				
44	Ecological Footprint (EF)	Wackernaget al., 1996	Organization		√	√				√
45	Ecological modelling (EcoM)	Jorgensen et al., 1996	Process		√	Limited to ecological aspects	Limited to ecological aspects			
46	MET- matrix	Brezet et al., 1995	Product & process		√	√				
47	Environmentally Responsible Product Assessment (ERPA)	Graedel et al., 1995	Product & process		√	√				
48	Resource Management (RM)	Liedtke et al., 1994	Product & process		√	√			√	

Table 5 List and taxonomy characterization of the main environmental management tools applied in the scientific literature.

About fifty EMTs have been identified and although they are the most applied, a lot of other EMTs exists. Often new EMTs are derived as evolution of other previous EMTs or from the integration of EMTs. The previous list focus on EMTs consolidated in the scientific literature.

Despite the many existing EMTs, their use in companies is still limited (Rossi et al., 2016; Bey et al., 2013; Zhang et al., 2013). In fact, it is important that the so great variety of EMTs is one of the most important reason for the low implementation and integration of EMTs at industrial level (Rossi et al., 2016). This aspect has been also identified in the previous paragraph during the EMBs identification. Furthermore, being know that for a comprehensive environmental management more than one EMT has necessary (Sala et al., 2013), it is important to note that many EMTs present often overlapping areas in terms of evaluation and being developed as standalone without a specific reference to an integrability framework many issues during integration processes could emerged. In this context, the great number of available EMTs associated with a lack of procedures for supporting the assessment, selection and integration of tools, low knowledge about them, and lack of specialized or trained staff (Rousseaux et al., 2017) are some the reasons why it is important to rationalize EMTs.

Under the push of the growing number of EMTs, companies are today facing a new challenge: how can they select appropriate EMTs for organize suitable environmental activities to improve sustainability and market competitivity? In this direction, at International level the organization that have the scope of to define and develop the environmental management tools in order to support sustainable development is the International Organization for Standardization (ISO). ISO established on 1947, is an independent non-governmental international organization with a membership of 163 national standards bodies. Through its members, it brings together experts to share knowledge and develop voluntary, consensus-based, market relevant International Standards that support innovation and provide solutions to global challenges. ISO standards are the tools through which ISO promotes the developed of industrial and public organization in all relevant competitive topics. Until today about 21.657 standards have been developed. ISO standards have mainly four key characteristics:

- ISO standards respond to a need in the market: ISO does not decide when to develop a new standard, but responds to a request from industry or other stakeholders such as consumer groups.
- ISO standards are based on global expert opinion: ISO standards are developed by groups of experts from all over the world, that are part of larger groups called technical committees. These experts negotiate all aspects of the standard, including its scope, key definitions and content.
- ISO standards are developed through a multi-stakeholder process: The technical committees are made up of experts from the relevant industry, but also from consumer associations, academia, NGOs and government.
- ISO standards are based on a consensus: Developing ISO standards is a consensus-based approach and comments from all stakeholders are considered.

In total, there are about 242 technical committees and the one that focus on Environmental Management is ISO/TC 207. ISO/TC 207 can be seen as the absolute reference point regarding the development of tools for environmental management at industrial level. In fact, it guides at international level the development of environmental management tools since 1993s and enjoys of a strong international endorsement. ISO/TC 207 has the scope of the standardization in the field of environmental management systems and tools in support of sustainable development. It is important to note that feedbacks from organizations show that a standardized tool is more credible (Rousseaux et al., 2017). In the following table is shown through topics and tools the vision regarding environmental management promoted by ISO/TC 207.

Topics	Sub topics	Main relevant ISO standards	Scope
ISO/TC 207/SC 1 **Environmental management systems** **Scope:** Standardization in the field of environmental management systems to support the achievement of sustainability	ISO/TC 207/SC 1/WG 7 Monetary valuation of environmental impacts	ISO/CD 14008 Monetary valuation of environmental impacts and related environmental aspects -- Principles, requirements and guidelines (Under development)	Not yet define, standard under development
	ISO/TC 207/SC 1/WG 8 Guidelines on determining environmental costs and benefits	ISO/AWI 14007 Environmental management -- Determining environmental costs and benefits – Guidance	Not yet define, standard under development
	ISO/TC 207/SC 1/WG 9 ISO 14005 Revision	ISO 14005:2010 Environmental management systems -- Guidelines for the phased implementation of an environmental management system, including the use of environmental performance evaluation	ISO 14005:2010 provides guidance for all organizations, but particularly small- and medium-sized enterprises, on the phased development, implementation, maintenance and improvement of an environmental management system.
	ISO/TC 207/SC 1/WG 10 ISO 14006 revision	ISO 14006:2011 Environmental management systems -- Guidelines for incorporating ecodesign	ISO 14006:2011 provides guidelines to assist organizations in establishing, documenting, implementing, maintaining and continually improving their management of ecodesign as part of an environmental management system (EMS).
	ISO/TC 207/SC 1/WG 11 Applying ISO 14001 framework to environmental aspects by topic areas	ISO 14001:2015 Environmental management systems -- Requirements with guidance for use	ISO 14001:2015 specifies the requirements for an environmental management system that an organization can use to enhance its environmental performance. ISO 14001:2015 is intended for use by an organization seeking to manage its environmental responsibilities in a systematic manner that contributes to the environmental pillar of sustainability.
ISO/TC 207/SC 2 **Environmental auditing and related environmental investigations** **Scope:** Standardization in the field of environmental auditing and related environmental investigations	ISO/TC 207/SC 2/WG 6 Verification of environmental and sustainable reports	ISO 14015:2001 Environmental management — Environmental assessment of sites and organizations (EASO)	Provides guidance on how to conduct an EASO through a systematic process of identifying environmental aspects and environmental issues and determining, if appropriate, their business consequences.
		ISO/AWI 14016 Environmental management -- Guidelines on verification and validation of the environmental component of sustainability reports	Not yet define, standard under development
ISO/TC 207/SC 3 **Environmental labelling** **Scope:** Standardization in the field of environmental labelling, including first-party practices (self-declaration/claims), and guiding principles for third-party certification programs (private and government	ISO/TC 207/SC 3/WG 5 Development of product category rules	ISO/TS 14027:2017 Environmental labels and declarations -- Development of product category rules	ISO/TS 14027:2017 provides principles, requirements and guidelines for developing, reviewing, registering and updating PCR within a Type III environmental declaration or footprint communication programme based on life cycle assessment (LCA) according to ISO 14040 and ISO 14044 as well as ISO 14025, ISO 14046 and ISO/TS 14067.
	ISO/TC 207/SC 3/WG 6 Communication of footprint information	ISO/DIS 14026 Environmental labels and declarations -- Principles, requirements and guidelines for communication of footprint information	Not yet define, standard under development

Topics	Sub topics	Main relevant ISO standards	Scope
	ISO/TC 207/SC 3/WG 7 ISO 14024 Amendment – Type 1 environmental labelling	ISO 14024:2001 Environmental labels and declarations -- Type I environmental labelling -- Principles and procedure	Establishes the principles and procedures for developing Type 1 environmental labelling programs, including the selection of product categories, product environmental criteria and product function characteristics; and for assessing and demonstrating compliance. This International Standard also establishes the certification procedures for awarding the label
		ISO 14021:2016 Environmental labels and declarations -- Self-declared environmental claims (Type II environmental labelling)	ISO 14021:2016 specifies requirements for self-declared environmental claims, including statements, symbols and graphics, regarding products. It further describes selected terms commonly used in environmental claims and gives qualifications for their use.
		ISO 14025:2006 Environmental labels and declarations -- Type III environmental declarations -- Principles and procedures	ISO 14025:2006 establishes the principles and specifies the procedures for developing Type III environmental declaration programmes and Type III environmental declarations.
ISO/TC 207/SC 4 **Environmental performance evaluation** **Scope:** Standardization in the field of environmental performance evaluation in support of sustainability	ISO/TC 207/SC 4/WG 4 Quantitative environmental information	ISO 14031:2013 Environmental management -- Environmental performance evaluation -- Guidelines	ISO 14031:2013 gives guidance on the design and use of environmental performance evaluation (EPE) within an organization. It is applicable to all organizations, regardless of type, size, location and complexity.
		ISO/TS 14033:2012 Environmental management -- Quantitative environmental information -- Guidelines and examples	ISO/TS 14033:2012 supports the application of standards and reports on environmental management. It provides guidelines on how to acquire quantitative environmental information and data and implement methodology. It gives guidelines to organizations on general principles, policy, strategy and activities necessary to obtain quantitative environmental information for internal and/or external purposes.
	ISO/TC 207/SC 4/WG 5 Environmental Technology Verification	ISO 14034:2016 Specifies principles, procedures and requirements for environmental technology verification (ETV).	The objective of environmental technology verification (ETV) is to provide credible, reliable and independent verification of the performance of environmental technologies. An environmental technology is a technology that either results in an environmental added value or measures parameters that indicate an environmental impact.
	ISO/TC 207/SC 4/WG 6 ISO 14063 revision Environmental communication	ISO 14063:2006 Environmental management -- Environmental communication -- Guidelines and examples.	ISO 14063:2006 gives guidance to an organization on general principles, policy, strategy and activities relating to both internal and external environmental communication. It utilizes proven and well-established approaches for communication, adapted to the specific conditions that exist in environmental communication.
ISO/TC 207/SC 5 **Life cycle assessment**	ISO/TC 207/SC 5/WG 8 Water footprint	ISO 14046:2014 Environmental management -- Water footprint -- Principles, requirements and guidelines	ISO 14046:2014 provides principles, requirements and guidelines for conducting and reporting a water footprint assessment as a stand-alone assessment, or as part of a more comprehensive environmental assessment.

Topics	Sub topics	Main relevant ISO standards	Scope
Scope: Standardization in the field of life cycle assessment and related environmental management tools for products and organizations. It includes life cycle based resource efficiency and ecoefficiency assessment, and encompasses consideration of a life cycle perspective in the assessment of impacts from the extraction of raw materials to the final disposal of waste.	ISO/TC 207/SC 5/WG 11 Life cycle assessment -- Requirements and guidelines	ISO 14040:2006 Environmental management -- Life cycle assessment -- Principles and framework	ISO 14040:2006 describes the principles and framework for life cycle assessment (LCA) including: definition of the goal and scope of the LCA, the life cycle inventory analysis (LCI) phase, the life cycle impact assessment (LCIA) phase, the life cycle interpretation phase, reporting and critical review of the LCA, limitations of the LCA, the relationship between the LCA phases, and conditions for use of value choices and optional elements.
		ISO 14044:2006 Environmental management -- Life cycle assessment -- Requirements and guidelines	ISO 14044:2006 specifies requirements and provides guidelines for life cycle assessment (LCA) including: definition of the goal and scope of the LCA, the life cycle inventory analysis (LCI) phase, the life cycle impact assessment (LCIA) phase, the life cycle interpretation phase, reporting and critical review of the LCA, limitations of the LCA, relationship between the LCA phases, and conditions for use of value choices and optional elements.
		ISO 14045:2012 Environmental management -- Ecoefficiency assessment of product systems -- Principles, requirements and guideline	ISO 14045:2012 describes the principles, requirements and guidelines for ecoefficiency assessment for product systems including: goal and scope definition of the ecoefficiency assessment; the environmental assessment; the product-system-value assessment; the quantification of ecoefficiency; interpretation; reporting; critical review of the ecoefficiency assessment.
		ISO/TS 14072:2014 Environmental management -- Life cycle assessment -- Requirements and guidelines for organizational life cycle assessment	ISO/TS 14072:2014 provides additional requirements and guidelines for an effective application of ISO 14040 and ISO 14044 to organizations.
ISO/TC 207/SC 7 **Greenhouse gas management and related activities** **Scope:** Standardization related to the management of greenhouse gas emissions and removals and related activities. Excludes National GHG inventory guidelines that are responsibility of the Intergovernmental Panel on Climate Change	ISO/TC 207/SC 7/WG 4 Quantification and reporting of greenhouse gas emissions and removals at organizational level	ISO 14064-1:2006 Greenhouse gases -- Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals	ISO 14064-1:2006 specifies principles and requirements at the organization level for quantification and reporting of greenhouse gas (GHG) emissions and removals. It includes requirements for the design, development, management, reporting and verification of an organization's GHG inventory.
	ISO/TC 207/SC 7/WG 5 Quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements for projects	ISO 14064-2:2006 Greenhouse gases -- Part 2: Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements	It includes requirements for planning a GHG project, identifying and selecting GHG sources, sinks and reservoirs relevant to the project and baseline scenario, monitoring, quantifying, documenting and reporting GHG project performance and managing data quality.
	ISO/TC 207/SC 7/WG 6 Validation and verification of greenhouse gas assertions and bodies for use in accreditation or other forms of recognition	ISO 14064-3:2006 Greenhouse gases -- Part 3: Specification with guidance for the validation and verification of greenhouse gas assertions	ISO 14064-3:2006 specifies requirements for selecting GHG validators/verifiers, establishing the level of assurance, objectives, criteria and scope, determining the validation/verification approach, assessing GHG data, information, information systems and controls, evaluating GHG assertions and preparing validation/verification statements.

Topics	Sub topics	Main relevant ISO standards	Scope
	ISO/TC 207/SC 7/WG 8 Carbon footprint of products — Requirements and guidelines for quantification	ISO/TS 14067:2013 Greenhouse gases -- Carbon footprint of products -- Requirements and guidelines for quantification and communication	ISO/TS 14067:2013 specifies principles, requirements and guidelines for the quantification and communication of the carbon footprint of a product (CFP), based on International Standards on life cycle assessment (ISO 14040 and ISO 14044) for quantification and on environmental labels and declarations (ISO 14020, ISO 14024 and ISO 14025) for communication.
	ISO/TC 207/SC 7/WG 9 High Level Framework on Adaptation	ISO/DIS 14080 Greenhouse gas management and related activities -- Framework and principles for methodologies on climate actions	Not yet define, standard under development
		ISO/WD 14090 Greenhouse gases -- Framework for adaptation to climate change	Not yet define, standard under development
	ISO/TC 207/SC 7/WG 10 Climate finance	ISO/AWI 14091 Climate Change Adaptation -- A guidance to Vulnerability Assessment	Not yet define, standard under development
	ISO/TC 207/SC 7/WG 11 Vulnerability assessment	ISO/NP 14097 Framework and principles for assessing and reporting investments and financing activities related to climate change	Not yet define, standard under development
ISO/TC 207/WG 8 **Material flow cost accounting – General principles and framework**	Not applicable	ISO 14051:2011 Environmental management -- Material flow cost accounting -- General framework	ISO 14051:2011 provides a general framework for material flow cost accounting (MFCA). Under MFCA, the flows and stocks of materials within an organization are traced and quantified in physical units (e.g. mass, volume) and the costs associated with those material flows are also evaluated.
		ISO 14052:2017 Environmental management -- Material flow cost accounting -- Guidance for practical implementation in a supply chain	ISO 14052:2017 provides guidance for the practical implementation of material flow cost accounting (MFCA) in a supply chain. MFCA fundamentally traces the flows and stocks of materials within an organization, quantifies these material flows in physical units (e.g. mass, volume) and evaluates the costs associated with material flows and energy uses.
ISO/TC 207/WG 9 **Land degradation and desertification**	Not applicable	ISO/DIS 14055-1 Guidelines for establishing good practice for combating land degradation and desertification - Part 1: Guidelines and general framework	Not yet define, standard under development
ISO/TC 207/WG 10 **Environmentally conscious design**	Not applicable	ISO/TR 14062:2002 Environmental management -- Integrating environmental aspects into product design and development	ISO/TR 14062:2002 describes concepts and current practices relating to the integration of environmental aspects into product design and development.

Table 6 Scientific environmental management topics faced by ISO/TC 207 and relative tools developed.

Only a part of these standards are environmental management tools (EMTs) to assess and manage environmental aspects inasmuch some of these standards are born to support and improve the implementation of EMTs by providing guidance, examples and technical explanations. In fact, for example ISO 14005 provides guidelines for including environmental performance evaluation conforms to ISO 14031, in a EMS conforms to ISO14001. Another example is ISO 14006 that provides guidelines for including Eco Design conforms to ISO 14062, in a EMS conforms to ISO14001. Therefore, it is possible to distinguish in the following table the 15 different EMTs developed by ISO/TC 207.

Tool category	Standard/EMT
Managerial tools	1) ISO 14001/Environmental Management System (EMS); 2) ISO14015:2001/Environmental assessment of sites and organizations (EASO).
Communication tools	3) ISO14021/Environmental labels and declarations -- Type I (Label type I); 4) ISO14024/Environmental labels and declarations -- Type II (Label type II); 5) ISO14025/Environmental labels and declarations -- Type III (Label type III).
Performance evaluation & improvement tools	6) ISO14031/Environmental Performance Evaluation (EPE); 7) ISO14034/Environmental Technology verification (ETV); 8) ISO14045/Eco Efficiency (EcoE) 9) ISO 14062/Eco Design (EcoD)
Environmental impact assessment & inventory assessment tools	10) ISO14040 & ISO14044/ Life Cycle Assessment (LCA) 11) ISO14046/Water Footprint (WF) 12) ISO/TS 14072/Organizational LCA (OLCA) 13) ISO 14064;/Organizational Carbon Footprint (OCF) 14) ISO/TS 14067/Product Carbon Footprint (PCF) 15) ISO 14051/ Material flow cost accounting (MFCA)

Table 7 EMTs developed by ISO/TC 207.

From this point for all the other part of this PhD research thesis will considered as EMTs only the ISO tools listed in the previously table.

1.4.2. Correlation between EMTs, EMDs and EMBs

The EMTs developed by ISO/TC 2017 have different capabilities to respond to environmental management drivers (EMDs) and to support the overcoming of encountered environmental management barriers (EMBs). In order to assess for each EMTs these capabilities, the correlation analysis have been performed in the two following tables. Both tables have been separated in two parts for better visibility of the reported results. Emerged clearly, that nothing EMTs respond to all EMDs and noting EMTs support the overcoming of all EMBs. In fact, each EMTs have capabilities in specific areas such as: strategy & management, environmental impacts assessment, etc. Therefore, in order to achieve a comprehensive environmental management strategy, the multiple EMTs use is required (Rousseaux et al., 2017; Runhaar, 2016; Sala et al., 2013). The identification of the specific areas where each EMTs can to respond to need EMDs and where they can be supportive in overcoming EMBs is a very important point in order to favour a correct EMTs selection for the creation of the new method of multiple EMTs use.

Life Cycle Management Areas	Environmental Management Drivers (EMDs)	1) ISO 14001- EMS	2) ISO 14015: - EASO	3) ISO 14021 – Label Type I	4) ISO 14024 – Label Type II	5) ISO 14025 – Label Type III	6) ISO 14031 - EPE	7) ISO 14034 - ETV
1. Environmental impacts assessment	Environmental Impacts Assessment - Product Level							
	Environmental Impacts Assessment – Organizational Level							
2. Inventory resources consumptions assessment	Inventory resources consumptions assessment – Product Level		√					
	Inventory resources consumptions assessment – Organizational Level	Partial, no full life cycle perspective					√	
3. Performance evaluation & performance tracking	Environmental performance evaluation & performance tracking at product and organizational level	Partial, generally only for main core processes					√	
	Production cost reduction or/and revenue increasing							
4. Ecoinnovation	Ecodesign	Liaison. It can sustain eco design processes, providing specific procedures						
	Ecoefficiency							
5. Strategic decision making	Identification of new eco-friendly solutions							Limited to new technologies
	Investments assessment							
6. Strategy & Management	Systematic and procedural approach for continuous improvement	√	√				√	
	Strategy formulation with objectives and targets definition	√	√				√	
	Top management commitment and managerial aspects	√	√				√	
7. Compliance	Regulatory compliance	√	√					
	Governmental aspects compliance (taxes and incentives)	√						
8. Sensibility to relevant changes	Changes in price and availability of raw materials	√	√					
	Physical climate changes (e.g. desertification)	√	√					
	Changes of products on market	√						
	Changes of technologies on market	√						

	Changes in stakeholder's expectations and awareness	√	√					
9. Market differentiation	Products differentiation			√	√	√		√
10. Communication and relationships	Corporate Brand reputation & image	Internal (compulsory) and external communication (optional)		√	√	√		
	Labelling & reporting			Environmental label	Self declared environmental assertions (e.g Ecolabel, Blauer angel)	Environmental declaration (e.g. EPD)		
	Competitors benchmarking and trends					√		
	Alliances and partnerships with other organizations	√						

Table 8 Correlations between EMTs with EMDs (Part 1)

Life Cycle Management Areas	Environmental Management Drivers (EMDs)	8) ISO 14045 – EcoE	9) ISO 14062 – EcoD	10) ISO 14040 & 14044 - LCA	11) ISO/TS 14072 - OLCA	12) ISO 14046 - WF	13) ISO/TS 14067 - PCF	14) ISO 14064 - OCF	15) ISO 14051 - MFCA
1. Environmental impacts assessment	Environmental Impacts Assessment – Product Level			√		Limited to impacts on water resource	Limited to impacts on climate change		
	Environmental Impacts Assessment – Organizational Level				√	Limited to impacts on water resource		Limited to impacts on climate change	
2. Inventory resources consumptions assessment	Inventory resources consumptions assessment – Product Level			√		Limited to water consumptions and water quality	Limited to GHG emissions		√
	Inventory resources consumptions assessment – Organizational Level				√	Limited to water consumptions and water quality		Limited to GHG emissions	√
3. Performance evaluation & performance tracking	Environmental performance evaluation & performance tracking at product and organizational level								
	Production cost reduction or/and revenue increasing			√	√	Limited	Limited		√

4. Ecoinnovation	Ecodesign		√	Liaison. LCA is supportive tool for environmental impacts assessment during eco-design assessment		See LCA but limited to water resources	See LCA but limited to GHG emissions	
	Ecoefficiency	√		Liaison. LCA is supportive tool for environmental impacts assessment during ecoefficiency assessment		See LCA but limited to water resources	See LCA but limited to GHG emissions	
5. Strategic decision making	Identification of new eco-friendly solutions		√					
	Investments assessment		√					
6. Strategy & Management	Systematic and procedural approach for continuous improvement							
	Strategy formulation with objectives and targets definition							
	Top management commitment and managerial aspects							
7. Compliance	Regulatory compliance							
	Governmental aspects compliance (taxes and incentives)							
8. Sensibility to relevant changes	Changes in price and availability of raw materials			Is a supportive tool for resource availability screening	Is a supportive tool for resource availability screening			√
	Physical climate changes (e.g. desertification)							
	Changes of products on market							
	Changes of technologies on market							
	Changes in stakeholder's expectations and awareness							
9. Market differentiation	Products differentiation		√	√		√	√	
	Multisite production differentiation		√		√	√		

10. Communication and relationships	Corporate Brand reputation & image		√	√	√	√		
	Labelling & reporting		√	√	√	√		
	Competitors benchmarking and trends		√		√	√		√
	Alliances and partnerships with other organizations							

Table 9 Correlations between EMTs with EMDs (Part 2)

Life Cycle Management Critical Areas	**Environmental Management Barriers (EMBs)**	**1) ISO 14001-EMS**	**2) ISO 14015: -EASO**	**3) ISO 14021 – Label Type I**	**4) ISO 14024 – Label Type II**	**5) ISO 14025 – Label Type III**	**6) ISO 14031 - EPE**	**7) ISO 14034 - ETV**
1. Environmental impacts assessment	Lack of Environmental Impact Assessment – Product Level	Supporting, systematizes the assessment approach						
	Lack of Environmental Impact Assessment – Organizational Level	Supporting, systematizes the assessment approach						
	Correlation between product and organizational scale not considered							
	Lack of Comprehensive impact assessment (Multi-indicators)							
	Lack of Life Cycle Management approach	Supporting, facilitates the introduction of LCM concept management						
	Issues on hotspots identification and on burdens shifting							
	Impact assessment based on inventory indicators							
	Technical difficulties in large impact assessment data management							
2. Inventory resources consumptions assessment	Technical difficulties in large inventory data management							

3. Performance evaluation & performance tracking	Lack of OPIs for environmental performance evaluation related to life cycle management at product and organizational level						√
	Difficulties in performance tracking and OPIs trends analysis						√
4. Ecoinnovation	Difficulties in implementation of practical ecodesign processes and new eco-friendly alternative solutions comparison	Supporting, systematizes the assessment approach					
	Lack of indicators for ecoefficiency assessment						
5. Strategic decision making	Lack of use of Decision making Tools (MCDA, optimization, statistical techniques, etc.)						
	Difficulties in the assessment of environmental performance of investments						
6. Strategy & Management	Unbalanced environmental management strategies	Partially, contributes in strategy elaboration and management		Partially, contributes to ecobranding strategy component	Partially, contributes to ecobranding strategy component	Partially, contributes to ecobranding strategy component	
	Divergence between intended and realized environmental management strategy	Partially, contributes in strategy elaboration and management					Partially, contributes to performance tracking
	Lack of Top management commitment	√	√				√
	Lack of Systematic and procedural approach for continuous improvement	√	√				√
	Lack of employees' skills & undefined responsibilities	√					
7. Compliance	Low ability to perceive changes in regulation & Unclear regulation	√	√				

	Lack of economic advantages (e.g. taxes reduction, incentives)	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
8. Sensibility to relevant changes	Low ability to perceive changes in resources availability and price	√						
	Low ability to perceive changes of products on market	√						
	Low ability to perceive changes of technologies on market	√						
9. Market differentiation	Difficulty in highlighting the differences in terms of environmental performance of their products respects those of competitors					Partially, issues in consumers engagement		Limited to new technologies
10. Communication and relationships	Low stakeholders engagement	√	√	√	√	√		
	Lack of alliances and partnerships with other organizations	√						
11. EMTs implementation	EMTs selection	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
	High implementation costs	√						

Table 10 Correlations between EMTs with EMBs (Part 1)

N.A.= Not applicable because the aspect is independent from specific EMT.

Life Cycle Management Critical Areas	**Environmental Management Barriers (EMBs)**	**8) ISO 14045 – EcoE**	**9) ISO 14062 – EcoD**	**10) ISO 14040 & 14044 - LCA**	**11) ISO/TS 14072 - OLCA**	**12) ISO 14046 - WF**	**13) ISO/TS 14067 - PCF**	**14) ISO 14064 - OCF**	**15) ISO 14051 - MFCA**
1. Environmental impacts assessment	Lack of environmental Impact Assessment – Product Level			√		Limited to impacts on water resource	Limited to impacts on climate change		
	Lack of Environmental Impact Assessment – Organizational Level				√	Limited to impacts on water resource		Limited to impacts on climate change	
	Correlation between product and organizational scale not considered								
	Lack of Comprehensive impact assessment (Multi-indicators)			√	√				

	Lack of Life Cycle Management approach		Partially, supportive at product level	Partially, limited to products understudy	√	Partially, limited to water resource	Partially, limited to products understudy and climate change
	Issues on hotspots identification and on burdens shifting		Partially, supportive at product level	Partially, limited to products understudy	√		
	Impact assessment based on inventory indicators			√	√	√	√
	Technical difficulties in large impact assessment data management						
2. Inventory resources consumptions assessment	Technical difficulties in large inventory data management						
3. Performance evaluation & performance tracking	Lack of OPIs for environmental performance evaluation related to life cycle management at product and organizational level	√					
	Difficulties in performance tracking and OPIs trends analysis						
4. Ecoinnovation	Difficulties in implementation of practical ecodesign processes and new eco-friendly alternative solutions comparison						
	Lack of indicators for ecoefficiency assessment	√					
5. Strategic decision making	Lack of use of Decision making Tools (MCDA, optimization, statistical techniques, etc.)						
	Difficulties in the assessment of environmental performance of investments		Partially, it is related to eco design EMBs				
6. Strategy & Management	Unbalanced environmental management strategies	Partially, contributes to ecoefficiency strategy component	Partially, contributes to ecoefficiency strategy component				

	Divergence between intended and realized environmental management strategy		Partially, contributes to forecast of environmental performance	Partially, contributes to performance tracking	Partially, contributes to performance tracking				
	Lack of Top management commitment								
	Lack of Systematic and procedural approach for continuous improvement								
	Lack of employees' skills & undefined responsibilities								
7. Compliance	Low ability to perceive changes in regulation & Unclear regulation								
	Lack of economic advantages (e.g. taxes reduction, incentives)	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
8. Sensibility to relevant changes	Low ability to perceive changes in resources availability and price			Is a supportive tool for resource availability screening	Is a supportive tool for resource availability screening				
	Low ability to perceive changes of products on market								
	Low ability to perceive changes of technologies on market								
9. Market differentiation	Difficulty in highlighting the differences in terms of environmental performance of their products respects those of competitors			√		√	√		
10. Communication and relationships	Low stakeholders engagement			√	√	√	√		
	Lack of alliances and partnerships with other organizations								
11. EMTs implementation	EMTs selection	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
	High implementation costs			√	√	√	√	√	√

Table 11 Correlations between EMTs with EMBs (Part 2)

N.A.= Not applicable because the aspect is independent from specific EMT.

1.5. Theoretical mechanisms for multiple EMTs use

Nowadays, more than in the past, the importance of a comprehensive choice and a complementary approach towards EMTs has grown, as different tools aim to answer different questions and industrial organizations need to solve environmental management issues from all relevant perspective in order to optimize their environmental performance and to build a robust environmental management strategy (Fet et al., 2013). The term "questions" has used with reference to the different perspectives of environmental management. In the specific, there are two major reasons for multiple EMTs use. One reason is to avoid problem shifting, since no single concept or tool is able to address all relevant questions and depict all kinds of problem shifting. Another, related reason is to compensate for a tool weakness in a given decision situation. According to these two reasons, in the previous paragraphs have been identifying: the environmental management drivers (EMDs), the environmental management barriers (EMBs) and the EMTs developed by scientific community. When the methodological issue of multiple EMTs use is faced there are two principal conceptual ways (Finkbeiner, 1998):

- Integration of EMTs, using one tool but expanding the scope so that the main features of the other tool are included;
- Combination of EMTs, using both tools in a systematic, coherent way depending on the individual situation at the organisation respectively the main environmental management problems.

In order to integrate or combined EMTs successfully there are many technical and suitability criteria that must be analysed. These criterial range from goal & scope, spatial characteristics to the environmental interventions and impact types considered. These criteria are important for the EMTs selection but mainly for the application of the practical adjustments that are required when EMTs are integrated or combined.

The goal of this paragraph is give a detailed panoramic on theoretical mechanisms useful for EMTs multiple use, also detailing: technical and suitability criteria to be consider.

1.5.1. Criteria to consider for multiple EMTs use

Before to enter in the deep description of integration and combination methods for multiple EMTs use, it is very important to analyse the main aspects that characterize each EMT and that influence the possibility of multiple use of them. These aspects can be distinguished in two groups: technical characteristics and suitability characteristics. They are listed and descripted following (Fet et al., 2013; Wrisberg et al., 2012; Finkbeiner, 1998):

Technical criteria:

a) Type of tool: What kind of EMTs is?
b) Goal & scope: Which environmental management drivers (EMDs) faced?
c) Analysis object: What is the object analysed from the EMT?
d) Methodological stages: Which methodological stages are involved?
e) System boundaries: Which life cycle processes are included in the analysis?
f) Reference unit;
g) Allocation;
h) Data and parameters. Which types of data are required? What is the data intensity?
i) Operation conditions: How are processes mechanisms modelled?
j) Spatial characteristics: What is the spatial scale and what is the level of spatial specification?
k) Temporal characteristics: EMT has used static conditions or dynamic conditions?
l) Environmental impacts assessment: The EMT is able to perform the impact assessment?
m) Position in cause-effect chain: Where in the cause-effect chain is the focus of the EMT?

n) Comprehensive or specific: The EMT in the impact assessment considers many impact categories or focuses only on some?

Suitability criteria:

a) Software availability and needing: Is software available? Is a software a key aspect tool application?
b) Data availability and needing: Is data available? Is required the access to international database?
c) Human resource requirements: Expert knowledge required for understanding methodology, outcome and use of method.
d) Handing of uncertainties: How are uncertainties being addressed?

All technical and suitability characteristics have been descripted following and analysed at level of the specific EMTs in the tables 12 and 13.

1.5.1.1. Technical criteria

a) Type of tool:
   EMTs may be of different types. In general, as descripted in the paragraph 1.4, it is possible to distinguish: Managerial EMTs, Environmental Impacts Assessment EMTs, Environmental Inventory Assessment EMTs, Performance Evaluation and Improvement EMTs, Managerial EMTs and Communication EMTs. It is important to underline that the appurtenance of a EMT to one specific of these categories do not signify that the EMT could not have some features of another category. Therefore, the appurtenance to a specific category is based on the analysis of the major part of EMT's features.
b) Goal & scope:
   The first characteristic that should be assessed is the EMTs goal and scope. In the goal and scope is defined the areas of environmental management drivers (EMDs) to which the EMT is able to respond. What is the question to which the EMT would answer? Therefore, it is important, in function of the EMDs areas listed in the paragraph 1.2., to identify if the EMT is a managerial tool or and environmental impact assessment tool, or etc. Most likely a combination of EMTs will be appropriate between EMTs with different goal and scope in order to manage different EMDs areas minimizing overlapping between EMTs (Wrisberg et al., 2012).
c) Analysis object:
   Often different EMTs could have different object of analysis. This characteristic defined specifically if the object of analysis is a product system, a whole organization, specific processes or substances emitted in environmental sub-compartments. Therefore, it is possible to distinguish generally product oriented EMTs by organizational oriented EMTs.
d) Methodological stages:
   In the case of every EMT the use is based on the application of different methodological steps. The definition of the methodological stages is fundamental for the identification of the possible interfaces through which link different EMTs in combination mechanism for multiple use EMTs. The methodological stage may be seen as a clearly delimited stage that specify technical requirements and guide step by step the correct application of the EMT. For example, LCA is based on four methodological stages that are: Goal & scope definition, Life Cycle Inventory Analysis, Life Cycle Impact Assessment and Interpretation. The EMS is based on four methodological stages that in this case are: Planning, Support and Operation, Performance Evaluation, Improvement.
e) System boundaries:
   The different choice of system boundaries is of high practical relevance and it can influence grater the results of the analysis (Finkbeiner, 1998). System boundaries is in general influenced by two aspects: intrinsic characteristic of the EMT and from individual choices conducted in

the application stage from the practitioner. Some EMTs (e.g. LCA), being based on a life cycle perspective, include all processes anyway. Instead, other EMTs (e.g. EMS) focus only on a part of the life cycle processes and therefore are sensitive to changes in processes localization. In fact, when a process is externalized, with the first type of EMTs the results do not change, because all processes which are necessary to fulfil the technical function of the studied object are included. Instead with the second type of EMTs the results often could change because are EMTs are sensitive to the actual location of a process. However, from a general viewpoint of sound environmental management it is clear that the potential environmental impact of an identical process is independent from its location.

f) Reference unit:
Often in EMTs the input/output flows of material and energy, and relative environmental impacts, are normalised to a reference unit. In the case of some EMTs (e.g. EMS) the reference unit is normally a certain period of time (e.g. one financial year). Instead, in the case of other EMTs (e.g. LCA) the reference unit is the so-called functional unit or, in comparison, the functional equivalence of the alternatives.

g) Allocation;
Another methodological aspect which shows a distinct difference between EMTs is the allocation problem. The allocation question, i.e. the partitioning of environmental burdens in multi-input- or multi-output-processes, is one of the major methodological problems inherent in the type of question answered by EMTs that focus on products or on a part of the organization (e.g. LCA), which is not encountered or avoided in EMTs that consider the whole organization (e.g. EMS). In fact, in the case of this second type of EMTs this problem does not occur, because multi-input- and multi-output-processes are considered as a whole.

h) Data and parameters.
Data collection activities very often requires many time and implies high cost as underline during EMBs analysis. Different EMTs imply different data collection loads and these loads are inasmuch proportional to processes included in the system boundaries. Some EMTs (e.g. EMS) have a documental structure that can favourite the data collection (e.g. procedures, data logs, etc.). Certainly, from a practical and economical point of view it is desirable that exist only one data source and therefore it is important to identify the EMTs able to collect all data required for the application of all EMTs applied by the organization. In the case of some EMTs (e.g. LCA) the data which are relevant, are flows which cross the border between technosphere and ecosphere. They are called elementary flows respectively product flows. As a consequence of the life cycle concept the elementary flows consist of resources on the input-side and emissions on the output-side only. All intermediate products are followed back to their origin, i.e. the intermediate flows are completely within the technosphere and therefore inputs and outputs of processes but not of the final LCI. In other EMTs (e.g. EMS) only the flows which enter and leave an organisation are relevant. Therefore, there is the need of assess the total data required for the application of all EMTs selected and identify one EMT totally responsible of the data collection stage. In the case of some EMTs (e.g. LCA) many data are obtained by the use of database especially for model life cycle processes without control by the organization (e.g. upstream processes and downstream processes).

i) Operation conditions:
Another difference in the parameters studied are operative conditions and stocks. In some EMTs (e.g. LCA) all processes are assumed to operate at a steady-state-level and at regular operation conditions. Only the allocated net inputs and outputs are used to calculate the LCI. In other EMTs (e.g. EMS) also non-regular-operative conditions and stocks of materials are considered (Wrisberg et al., 2012).

j) Spatial characteristics:

The spatial characteristics shows basically two groups of EMTs: non-site specific EMTs which are operating on a global or regional scale, and site specific tools operating on local scale. In fact, some EMTs (e.g. EMS) assess environmental impacts, reflecting local/regional conditions influenced by the organization. Other EMTs (e.g. LCA) assess environmental impacts, many times without considering local conditions because the environmental impacts methods are based on average characterization factors (non-site specific) and on database that consider average inventory data. Some exceptions exist, in fact, for example in the case of impacts generated by water resource consumptions, some modern impact assessment methods (e.g. AWARE (Boulay et al., 2017)) are based on local/regional characterization factors. Furthermore, database development (e.g. Ecoinvent database) continuously introduce local/regional processes (e.g. electricity country mix). However, although are made these efforts, evident differences on spatial characteristics between EMTs exist (Wrisberg et al., 2012).

k) Temporal characteristics:
A comparison of the temporal characteristics of the EMTs shows that almost all EMTs are static. Sometimes EMTs may be used into dynamic modelling of time paths.

l) Environmental impacts assessment:
Some EMTs (e.g.) base the environmental performance evaluation on inventory indicators related to such as: material and energy consumptions, emissions in environmental sub compartments and other inventory aspects. Other EMTs (e.g. LCA) operates the environmental performance evaluation inserting in addition to the inventory analysis an impact assessment analysis. While the inventory analysis involves the compilation and quantification of inputs and outputs for the processes included in system boundaries by the specific EMT, the impact assessment analysis assigns inventory analysis results to impact categories; for each impact category, a life cycle impact category indicator is selected and the category indicator result (indicator result) is calculated; the collection of indicator results or the profile provides information on the environmental issues associated with the inputs and outputs of the product system. This aspect is fundamental because, the inventory analysis is not sufficient to understand and evaluate the magnitude and significance of the potential environmental impacts.

m) Position in cause-effect chain:
A clear distinction between the EMTs can be made on the basis of their position in cause-effect chain (or environmental mechanism). It is possible to distinguish three different cases (Wrisberg et al., 2012):

- EMTs that perform only the environmental interventions analysis. In this analysis EMTs consider the effects of processes included in the system boundaries only in terms of material/energy extractions, emissions and land use.
- EMTs that perform the midpoint analysis. In this case the environmental intervention analysis is included. In this analysis EMTs consider the effects of processes included in the system boundaries in terms of environmental impacts on categories such as climate change, human toxicity, water depletion, water quality degradation, etc.
- EMTs that perform the endpoint analysis. In this case the environmental intervention analysis is included while the midpoint analysis may be included in function of the specific environmental impact assessment method used for the analysis. In this analysis EMTs consider the effects of processes included in the system boundaries in terms of environmental damages on safeguard areas such as human health, ecosystem quality and resource depletion.

n) Comprehensive or specific:
EMTs that perform the environmental impact assessment, only a part of them (e.g. LCA) use a comprehensive approach including all relevant environmental intervention areas such as: climate change, human toxicity, water depletion, water quality degradation, etc. Other EMTs

that perform the environmental impact assessment (e.g. Carbon Footprint, Water Footprint), focus only on specific environmental intervention areas (e.g. climate change in the first case, water depletion and water quality degradation in the second case). Finally, sometimes EMTs may oriented to other intervention areas not associated directly with environmental aspects such as costs, as in the case of (MFCA) Material Flow Cost Accounting).

1.5.1.2. Suitability criteria

a) Software availability and needing:
   The application of EMTs may be require the use of software available on the market. In many cases the software permits of simplified the application of a specific EMT. For example, in the case of LCA there are many software available and the use of a software is fundamental. Instead, in the case of EMS although some software exists, a software for the tool application is not strongly need.
b) Database availability and needing:
   The application of EMTs may be required the use of database available on the market. For example, in the case of LCA there are many databases available and the use of a database is fundamental.
c) Human resource requirements
   The application of EMTs may generates different requirements related to practitioner's skills and number of human resources. For example, in the application of LCA many times is required high competence by practitioners, but one human resource is enough. Instead, in the case of the application of an EMS, the skills required are less complex, but many times are required many human resources especially at initial when the environmental management system is established.
d) Handing of uncertainties:
   EMTs may have features in order to address uncertainties being addressed. The systems to address uncertainties may be different such as: analytical uncertainty analysis, sensitivity analysis, verification procedures, audits, etc. In fact, for example in the case of LCA the uncertainties are addressed with analytical uncertainty analysis, sensitivity analysis and audits.

Aspects	1) ISO 14001- EMS	2) ISO 14015: - EASO	3) ISO 14021 – Label Type I	4) ISO 14024 – Label Type II	5) ISO 14025 – Label Type III	6) ISO 14031 - EPE	7) ISO 14034 - ETV
Type of tool	Managerial	Managerial	Communication	Communication	Communication	Performance Evaluation & Improvement	Performance Evaluation & Improvement
Goal & Scope	See tables 8 and 10 where a detailed correlation between the capabilities of these EMTs of to face EMDs and EMBs have been presented						
Analysis object	Organization	Organization	Product	Product	Products	Organization or specific process of the organization	Product (as technologies)
Methodological stages	4 stages: 1) Planning 2) Support & operation 3) Performance evaluation 4) Improvement	5 stages: 1) Planning 2) Assessment 3) Validation 4) Evaluation 5) Reporting	-	-	-	4 stages: 1) Planning EPE 2) Managing data 3) Reviewing EPE 4) Improving EPE	5 stages 1) Application 2) Pre-verification 3) Verification 4) Reporting 5) Post-verification
System boundaries	Mainly processes included in organizational boundaries. Stressed the importance of life cycle perspective	Processes included in organizational boundaries	-	-	-	Organizational boundaries.	Processes including in the life cycle of the technology
Reference unit	Often financial year	Often financial year	N.A.*1	N.A.*1	N.A.*1	Often financial year. Depend from indicator formulation	Functional unit used for the study
Allocation	No	No	N.A.*1	N.A.*1	N.A.*1	Potentially yes	Potentially yes
Data and parameters	On site primary data	On site primary data	-	-	-	One site primary data	Primary data and databases
Operation conditions	Steady state and not steady state	Steady state and not steady state	N.A.*1	N.A.*1	N.A.*1	Steady state	Steady state
Spatial characteristics	Site specific	Site specific	N.A.*1	N.A.*1	N.A.*1	Site specific	N.A.*1
Temporal characteristics	Static	Static	N.A.*1	N.A.*1	N.A.*1	Static	Static
Environmental impacts assessment	Inventory level	Inventory level	N.A.*1	N.A.*1	N.A.*1	Inventory level	Impact assessment level and inventory level
Position in cause-effect chain	Environmental interventions analysis	Environmental interventions analysis	N.A.*1	N.A.*1	N.A.*1	Environmental interventions analysis	Midpoint analysis & Endpoint analysis
Comprehensive or specific impact assessment	N.A.*1	N.A.*1	N.A.*1	N.A.*1	N.A.*1	N.A.*1	Comprehensive

Software availability and needing	Some software exists but without international recognition / No	No / No	N.A.[*1]	N.A.[*1]	N.A.[*1]	No / Yes it would be useful	Yes for LCA assessment / Yes
Database availability and needing	No / No	No / No	N.A.[*1]	N.A.[*1]	N.A.[*1]	No / Yes it would be useful	Yes for LCA assessment / Yes
Human resource requirements	Yes, high workload	Yew, low workload	Yes, very low workload	Yes, very low workload	Yes, very low workload	Yes, high workload	Yes, medium workload
Handing of uncertainties	No	No	N.A.[*1]	N.A.[*1]	N.A.[*1]	No	Yes with sensitivity and uncertainty analysis

Table 12 Correlations between EMTs with EMBs (Part 1)

Aspects	8) ISO 14045 – EcoE	9) ISO/TR 14062 – EcoD	10) ISO 14040 & 14044 - LCA	11) ISO/TS 14072 - OLCA	12) ISO 14046 - WF	13) ISO/TS 14067 - PCF	14) ISO 14064 - OCF	15) ISO 14051 - MFCA
Type of tool	Performance Evaluation & Improvement	Performance Evaluation & Improvement	Environmental Impacts Assessment	Environmental Impacts Assessment	Environmental Impacts Assessment	Environmental Impacts Assessment	Environmental Impacts Assessment	Environmental Impacts Assessment
Goal & Scope	See tables 9 and 11 where a detailed correlation between the capabilities of these EMTs of to face EMDs and EMBs have been presented							
Analysis object	Product and process	Product	Product	Organization	Product & organization	Product	Organization	Product
Methodological stages	5 stages: 1) Goal & scope definition 2) Environmental assessment 3) Value assessment 4) Quantification of ecoefficiency 5) Interpretation	6 stages: 1) Planning 2) Conceptual design 3) Detailed design 4) testing/prototype 5) Production, market lunch 6) Product review	4 stages: 1) Goal & scope definition 2) Inventory analysis 3) Impact assessment 4) Interpretation	4 stages: 1) Goal & scope definition 2) Inventory analysis 3) Impact assessment 4) Interpretation	4 stages: 1) Goal & scope definition 2) Inventory analysis 3) Impact assessment 4) Interpretation	4 stages: 1) Goal & scope definition 2) Inventory analysis 3) Impact assessment 4) Interpretation	4 stages: 1) Goal & scope definition 2) GHG inventory 3) Reporting 4) Reduction activities	4 stages: 1) Planning 2) I/A analysis, physical and monetary quantification 3) Interpretation and communication 4) Improvement
System boundaries	Life cycle processes related to product or process system	Life cycle processes related to product or process system	Life cycle processes related to product or process system	Life cycle processes related to organization	Life cycle processes related to product, process or organizational system	Life cycle processes related to product or process system	Organizational process that generate direct emissions or indirect emissions from energy consumption	Organizational processes related to product or process system
Reference unit	Functional unit and value function used for the study	Functional unit used for the study	Functional unit used for the study	Reporting unit used for the study	Functional unit used for the study	Functional unit used for the study	Functional unit used for the study	Functional unit used for the study

Allocation	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Data and parameters	Primary data and database	Primary data and database	Primary data and database	Primary data and database	Primary data and database	Primary data and database	Primary data and database	Primary data
Operation conditions	Steady state	Steady state	Steady state	Steady state	Steady state	Steady state	Steady state	Steady state
Spatial characteristics	Site specific	Not for all assessment site specific	Not for all assessment site specific	Not for all assessment site specific	Not for all assessment site specific	Not for all assessment site specific	Not for all assessment site specific	Not for all assessment site specific
Temporal characteristics	Static	Static	Static	Static	Static	Static	Static	Static
Environmental impacts assessment	Impact assessment level	Impact assessment level	Impact assessment level	Impact assessment level	Impact assessment level	Impact assessment level	Impact assessment level	Inventory level
Position in cause-effect chain	Midpont analysis & Endpoint analysis	Midpont analysis & Endpoint analysis	Midpont analysis & Endpoint analysis	Midpont analysis & Endpoint analysis	Midpont analysis & Endpoint analysis	Midpont analysis & Endpoint analysis	Midpont analysis & Endpoint analysis	Environmental interventions analysis
Comprehensive or specific impact assessment	Normally specific	Comprehensive	Comprehensive	Comprehensive	Comprehensive	Comprehensive	Comprehensive	Normally specific
Software availability and needing	Yes for LCA assessment / Yes	Yes for LCA assessment / Yes	Yes / Yes	Yes / Yes	Yes / Yes	Yes / Yes	Yes / Yes	Some software exists but without international recognition / Yes
Database availability and needing	Yes for LCA assessment / Yes	Yes for LCA assessment / Yes	Yes / Yes	Yes / Yes	Yes / Yes	Yes / Yes	Yes / Yes	No / No
Human resource requirements	Yes, high workload	Yes, high workload	Yes, high workload	Yes, very high workload	Yes, medium workload	Yes, medium workload	Yes, medium workload	Yes, medium workload
Handing of uncertainties	Yes with sensitivity and uncertainty analysis	Yes with sensitivity and uncertainty analysis	Yes with sensitivity and uncertainty analysis	Yes with sensitivity and uncertainty analysis	Yes with sensitivity and uncertainty analysis	Yes with sensitivity and uncertainty analysis	Yes with sensitivity and uncertainty analysis	No

Table 13 Correlations between EMTs with EMBs (Part 2)

N.A.= Not applicable because the aspect is not provided EMT.

1.5.2. Integration mechanism

The integration mechanism is the first theoretical way for the EMTs multiple use. In the integration mechanism, considering for example the case of two EMTs integration, one of the two EMTs is chosen and its scope is expanding in order to include the main features of the other EMT. This mechanism is shown in the following figure.

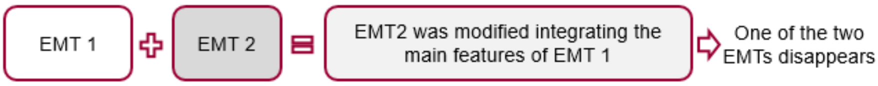


Figure 13 Representation of the integration mechanism in the case of two EMTs (Personal elaboration, 2016).

As it is possible to notice, in the case of mechanism, one of the two EMTs disappears. For the integration of the EMTs two approaches can be conceived:

- Approach one: the EMT 1 (e.g. LCA) is integrated into the EMT 2 (e.g. EMS);
- Approach two: the EMT2 (e.g. EMS) is integrated into the EMT1 (e.g. LCA).

Although at the first impact can appear similar these two approaches, equally realizable, they are instead very different. In fact, it is fundamental to choose the EMT between the two that is more adaptable to absorb the features of the other EMT. In fact, EMTs are conceived to be quite flexible and can be adapted in a way that allows one to come up to the requirements of a certain decision situation. For instance, there is no particular problem in LCA to add new environmental items in the impact assessment. In the case of more than two EMTs, the base mechanism is the same and therefore one of the EMTs adsorbs all relevant features of the others EMTs while the other EMTs disappears. It is evidence that during the integration processes, when the features of the integrated EMTs were selected for the integration, some other features of EMTs integrated were lost. It is important to notice that when an organization decide to integrate EMTs, its constricts to applied in the same time the whole integrated EMT resulted by the integration mechanism. This fact implies managerial and practical effects related to:

- Skills: practitioners must have skills and competence for all EMTs integrated;
- Software: when in many times on the market are available software for the application of single EMTs, no software is available for the application of a new "super-EMT" resulted by the integration process;
- Organization resources: the organization must be available at the start al required human and financial resources.

1.5.3. Combination mechanism

The combination mechanism is the second theoretical way for the EMTs multiple use. In the combination mechanism, considering for example the case of two EMTs integration, the implementations of the two EMT remain separate and are established interactions rules to coordinate the combined EMTs use. This mechanism is shown in the following figure.

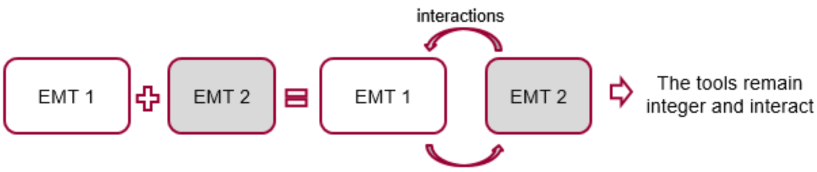


Figure 14 Representation of the combination mechanism in the case of two EMTs (Personal elaboration, 2016).

In fact, the combination of two EMTs provides the use of both tools in a systematic, coherent way depending on the individual situation at the organisation respectively the main environmental management problems. In the case of this mechanism all EMTs remain integer and all the features of all EMTs are conserved. When more than two EMTs are combined the base mechanism is the same and only new interaction rules should be added. It is important to notice that when an organization decide to combine EMTs, its can decides to primarily apply one EMT and as a second step complements it in a problem oriented way with the other EMTs. The decision which tool should primarily be applied depends on the individual situation of the company and the main environmental problems of the company. Therefore, this decision has to be made company by company. On the contrary respect the integration mechanism, the skills of practitioners can be developed step by step in function of the specific EMT implemented. Alto the organization resource in terms of human and financial resources can be available step by step and not all at the start. While in the case of software, each EMT combined can undergoes specific software available on the market. In general, it is evident that the combination of EMTs could increase the environmental and economic efficiency of application respect to the case of the single standalone use of the EMTs by promoting their synergisms and compensating their weaknesses. Following this concept, the weaknesses of individual tools can be compensated by linking them to other tools which have specific strengths in a particular field. For the combination of the EMTs three approaches can be distinguished (Baumann et al., 1999):

- Overlapping EMTs approach: where the type of system definition for the tools is identical;
- Consecutive steps EMTs using approach: which are steps to provide answers to different questions after each other; in this situation, the result from the use of one tool is an input to the use of a second tool;
- Parallel EMTs using approach: to highlight different aspects of the same question, or to answer (slightly) different questions; this may also imply a competitive use of analytical tools.

1.5.3.1. Overlapping EMTs approach

Overlapping EMTs may either be partly overlapping or inclusive as indicated in figure 15. EMTs are overlapping when the type of system definition and the modes of analysis are the same. The overlap may be total or partial depending on whether the same interventions are considered. It is obvious that the combination of fully overlapping EMTs is superfluous. But the combined use of partly overlapping EMTs may make sense.

Figure 15 Two ways of using overlapping EMTs during a combination process (Wrisberg, 2012).

1.5.3.2. Consecutive steps EMTs using approach

There is a need for the use of more EMTs in consecutive steps in a number of decision making situations. This is typically the case when an initial (screening) analysis indicates the need for a more detailed analysis with respect to more detail in the technical processes, the spatial or temporal characteristics or the environmental interventions considered. For instance, an initial non-site specific analysis may show the need for a site-specific analysis. In this case we refer to the linear use of tools in consecutive steps where the object of analysis remains the same, see following figure.

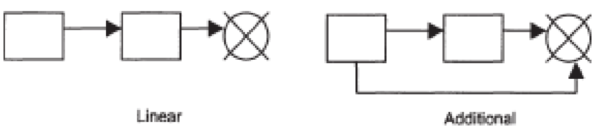


Figure 16 Two ways of using EMTs in consecutive steps during a combination process (Wrisberg, 2012).

Other decisions require both a broad analysis of the question as well as an analysis of specific aspects; then there are different objects of analysis. We refer to this as the additional use of EMTs in consecutive steps, because the decision will be supported by both types of analysis, see figure 16. The system definitions are different and the tools are complimentary.

1.5.3.3. Parallel EMTs using approach

The use of EMTs in parallel concerns the additional use of EMTs to support a decision. EMTs may be used here in addition to each other when they address the same object of analysis but analyse different dimensions, such as product and organization. Another possibility is that one decision can be the subject of a number of related but different questions, each of which is addressed with a different tool. We refer to the latter situation as that the tools are competing, as indicated in the following figure.

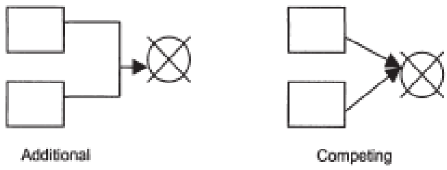


Figure 17 Two ways of using EMTs in parallel during a combination process (Wrisberg, 2012).

1.6. Already published methods for multiple EMTs use

The paragraph 1.4 shows how EMTs are able to respond to different environmental management perspective in terms of capacity to face and respond to EMDs and EMBs. In this context, the multiple EMTs use is a promising solution that permits to avoid problem shifting, since no single concept or tool is able to address all relevant questions and depict all kinds of problem shifting, and to compensate for a tool weakness in a given decision situation. The results of this part of the literature review are structured underlining two key information areas:

- Identify already published methods for multiple EMTs use and their methodological aspects;
- Capabilities of identify methods for multiple EMTs use to face EMDs and EMBs.

1.6.1. Methodological aspects from scientific literature on multiple EMTs use

In this paragraph have been analysed the scientific literature review regarding the multiple EMTs use focusing on the most relevant methodological aspects such as:

- Mechanism chosen for multiple EMTs use. What mechanisms have been chosen, combination or integration?
- EMTs selected. Which EMTs have been selected?
- Methods proposed. The author proposes a method for the multiple EMTs use?
- Interfaces proposed. The interfaces are the links established between the different methodological stages of different EMT selected. The author proposes interfaces to link different EMTs?
- Case studies application. The method has been applied in real case studies?
- Relevancies, opportunities & threats. The author gives remarks in terms of relevancies of multiple EMTs use and in terms of opportunities & threats deriving from multiple EMTs use.
- Integration of other tools. The author proposes the inclusion in the method for multiple EMTs use also of other tools?

In total 36 scientific paper have been analysed. The time span of publication goes from 1999 to 2017.

Reference	Combination or Integration	EMTs selected	Method name	Methods proposed	Interfaces proposed	Case studies application	Opportunities & threats	Integration of other tools
Mazzi et al., 2017	Combination	LCA + EMS	-	√	√	√	√	
Jonkute et al., 2016	Combination	LCA + EMS + EcoDesign + Communication & Labels	SURESCOM	√			√	GRI
Nakano, 2015	Combination	LCA + EMS + EcoDesign	-			√	√	
Lewandowska et al., 2014	Combination	LCA + EMS + EcoDesign	-				√	
Salomone et al., 2013	Combination	LCA + EMS + EcoDesign + Communication & Labels	POEMS	√			√	
Joachimiak-Lechman, 2013	Combination	LCA + EMS	-				√	
Swanstrom et al., 2013	Combination	LCA + EMS + EPE	-	√			√	
Lewandowska et al., 2013a,b	Combination	LCA + EMS	-			√	√	
Manfredi et al., 2013	Combination	LCA + EMS	-			√	√	
Kostevsek et al., 2013	Combination	LCA + EMS				√	√	
Lewandowska et al., 2011a,b	Combination	LCA + EMS	-	√	√	√	√	
Liu et al., 2012	Integration	LCA + EMS	-	√	√		√	MCDA
Gaudreault et al., 2009	Integration	LCA + EMS	-	√	√	√	√	
Eun et al., 2009	Combination	LCA + EMS + MFCA + EcoDesing	SMIS	√	√	√	√	
Buxmann et al., 2009	Combination	LCA + EMS	-			√	√	
Perotto et al., 2008	Combination	EMS + EPE						
Masoni et al., 2007	Combination	LCA + EMS + EcoDesign + Communication & Labels	POEMS	√		√		
Hermann et al., 2007	Integration	LCA + EPE	COMPLIMENT	√	√	√	√	MCDA
Gernuks et al., 2007	Combination	LCA + EMS	-	√	√	√		
Lundberg et al., 2007	Integration	LCA + EMS	-			√	√	
Donnelly et al., 2006	Combination	LCA + EMS + EcoDesign	PBEMS	√	√			
Ardente et al., 2006	Combination	LCA + EMS + EcoDesign + Communication & Labels	POEMS	√	√	√	√	
Ammenberg et al., 2005	Combination	EMS + EcoDesign	POEMS				√	
Rebitzer et al., 2005	Combination	LCA + EMS	-			√		Data management tools
Zackrisson, 2005	Combination	LCA + EMS	-				√	
Siegenthaler et al., 2005	Combination	LCA + EMS	-				√	
Zutshi et al., 2004	Integration	LCA + EMS	-				√	
Zobel et al., 2002	Integration	LCA + EMS	-	√	√		√	
Khan et al., 2002	Integration	LCA + EMS	EEMS	√	√		√	
Bakker et al., 2002	Combination	EMS + EcoDesign	-			√	√	
Ross et al., 2002	Combination	LCA + EMS				√	√	
Ayres et al., 2002	Integration	LCA + EMS	-				√	
Berkel et al., 1999	Combination	LCA + EMS + EcoDesign	P-EMS	√		√		
Stewart et al., 1999	Combination	LCA + EMS	-			√	√	
Finkbeiner et al., 1999	Combination	LCA + EMS	-			√		
Finkbeiner et al., 1998	Combination	LCA + EMS		√	√		√	

Table 14 Scientific experiences on method for multiple EMTs use already published in scientific literature

In order to simplify the EMTs nomenclature reported in the previous table, the following correspondence have been used between the terms used and the ISO EMTs:

- LCA = ISO 14040 & ISO 14044;
- EMS = ISO 14001;
- EcoDesign = ISO/TR 14062;
- EcoEfficiency = ISO 14045;
- EPE = ISO 14031;
- Communication & Labels = ISO 14021 & ISO 14024 & ISO 14025.

This simplified nomenclature will be used often in the following chapters.

Following are summarized the most relevant methodological aspects emerged for single point of analysis.

1.6.1.1. Mechanism chosen for multiple EMTs use

From the literature review emerges that on 36 papers only 8 papers refer to integration mechanism for multiple EMTs use therefore in about 75% of cases the combination mechanism has been chosen. In a cost/benefit-perspective this combination approach seems most effective and favourable (Wrisberg, 2012; Scholl, 1999; Stewart et al., 1999; Finkbeiner, 1998). The main reason could be researched in the fact of the combination approach permits of to concentrate on individual solutions. In fact, it permits to the organization to decides to primarily apply one EMT and as a second step complements it in a problem oriented way with the other EMTs. In fact, the organizations that have already implemented an EMTs (e.g. EMS) can complete the chosen tool by applying the other one (e.g. LCA) and orienting it according to their own needs and problems. (Mazzi et al., 2017). On the contrary, with an integration approach the implementation of many EMTs in the same time require most significant efforts, the expenditures expected for a strictly integrative approach often are a too large barrier for practical relevance. Finally, the combination mechanism can lead to a more comprehensive view of the impacts associated with the environmental aspects of organization.

Remarks:

- ***the combination mechanism is preferable***

1.6.1.2. EMTs selected

From the literature review emerges that Life Cycle Assessment (LCA) and the Environmental Management System (EMS) are two fundamental EMTs that are practically always selected for the development of methods for multiple EMTs use. Starting from year 2005, the inclusion of the EMT EcoDesing growth consistency. The implementation of ISO 14031 (Environmental Performance Evaluation) and ISO EMTs for Communication & Labels are quite seldom. No cases of use of Organizational Life Cycle Assessment (OLCA) have been yet published. The use also of other tools is very poorly in the development of methods for multiple EMTs use in only three cases emerged the use of other tools for decision making (e.g. MCDA) and for data management.

Remarks:

- ***LCA and EMS are two EMTs always selected;***
- ***EcoDesing tool is strongly recommended;***
- ***EMTs for EPE and Communication & Labels are quite seldom applied;***
- ***OLCA and EcoEfficiency has never been inserted in a method for multiple EMTs use;***

- ***The implementation of other tools is very poorly (e.g. tools for data management and decision making).***

1.6.1.3. Methods proposed

In the last twenty years only about eleven methods for multiple EMTs use have been proposed. In the major times only two EMTs have been used for the develop of the methods for multiple EMTs use. Sometimes the EMTs used have been three and rarely four. One of the method most deeply studied from experts is the POEMS method (Product oriented Environmental Management System). Starting from Berkel et al. (1999) this model has been developed arriving to the most recent published proposal by Salomone et al. (2013). The most relevant scientific contribution has been done from scientific work of Masoni et al. (2007). This method is based on the combination of four EMTs: LCA, EMS, EcoDesign and Communication & Labels. Lewandowska et al. (2011a) gives important information regarding methodological and practical modifies that should be implemented in order to combine LCA and EMS.

Remarks:

- ***There are still poorly experiences on the adoption of methods for multiple EMTs use;***
- ***The POEMS method for multiple EMTs use is the most studied in the scientific literature and the most structured.***

1.6.1.4. Interfaces proposed

The interfaces between EMTs are a fundamental aspect to define the interaction rules between EMTs. In the scientific literature, the following interfaces have been analysed:

a) Interfaces between LCA and EMS;
b) Interfaces between LCA and EcoDesign;
c) Interfaces between EMS and EcoDesign;
d) Interfaces between EMS and EPE.

The most relevant interfaces are between LCA and EMS inasmuch are the two EMTs most used in the development of methods for multiple EMTs use. In the following figure are shown the interfaces normally established between LCA and EMS. In the first case, the stage of EMS “Support & Operation” is linked with the stage of LCA “Inventory analysis”, inasmuch the in the EMS’s stage are internalized the activity for data collection required from the LCA inventory analysis. In the case of the second interface, the stage of LCA “Impact assessment” is linked with the stage of LCA “Performance evaluation” inasmuch the EMS’s stage internalized environmental impact assessment results useful to improve the performance evaluation.

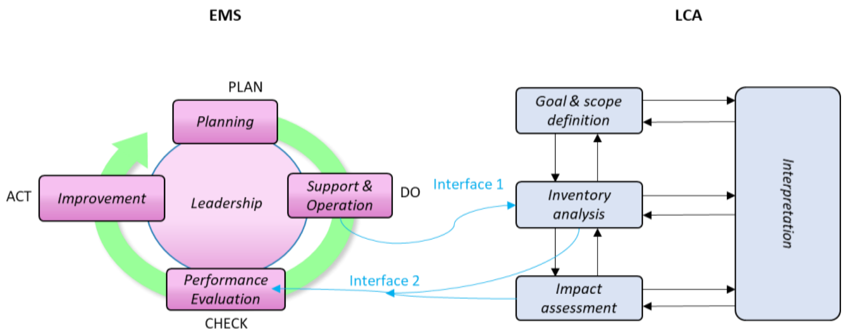


Figure 18 Interfaces between LCA and EMS normally established in the literature review (Personal elaboration, 2015).

Regarding the Interfaces between LCA and EcoDesign according to ISO guideline 14006:2002 the LCA is used as a tool for assess the environmental performance of design alternatives. In the following figure are shown the two interfaces normally established between LCA and Ecodesign.

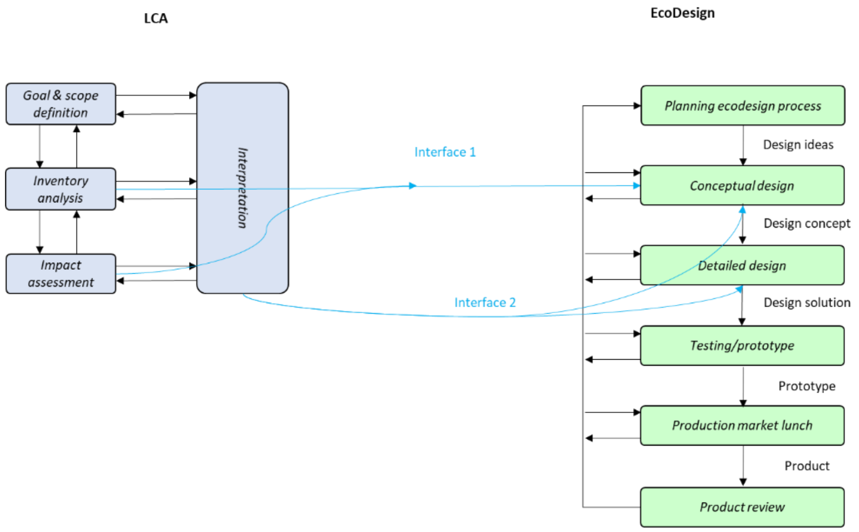


Figure 19 Interfaces between LCA and EcoDesign normally established in the literature review (Personal elaboration, 2015).

In the case of the first interface, LCA provides results generated by inventory analysis and by impact assessment analysis. The results relevant for ecodesign projects are make available in order to be used to simulate ecodesign alternatives during the conceptual design stage. In the case of second interface, the information acquired by LCA interpretation stage are used to identify design concept, to refine the design solutions or to solve any hotspots identified in order to finalize the design solutions.

Regarding the Interfaces between EMS and EcoDesign according to ISO guideline 14006:2002, EMS and ecodesign interacts with four interfaces. In the case of first interface, the EMS's stage "Planning" gives goals and targets regards the eco-design strategy component in order to achieve trough the ecodesign process the set environmental performance. In the case of second interface, the EMS identifies the data required for the assessment of ecodesign project while in the case of the third interface the EMS collects and makes available data necessary for the assessment. Finally, in the case of forth interface, the ecodesign process gives results in terms of environmental performance improvement to EMS's stage "Improvement". However, the use of ecodesign for elaboration of strategical scenarios in input to the process of goals and strategy setting is often missing. The forecast of effects of ecodesign processes in terms of environmental performance improvement is a very important point, especially at organizational level, to set targets and goals achievable.

The last relevant interface that can be found in the scientific literature is between the EMS and the EPE tool. In this case, the EPE tool is used to improve the choice and utilization of the environmental performance indicators (EnPi) that are used during the EMS's stage "Performance Evaluation".

Remarks:

- ***Interfaces LCA – EMS. Established between EMS's stage "Support & operation" and LCA's stage "Inventory analysis"; between LCA's stage "Impact assessment" and EMS's stage "Performance evaluation".***
- ***Interfaces LCA – EcoDesign. LCA is used in the EcoDesign process for the assessment of environmental performance of design alternatives under study.***
- ***Interfaces EMS – EcoDesign. EMS sets goals and targets for the EcoDesign process. The ecodesign process gives to EMS results in terms of environmental performance improvement.***
- ***Interfaces EMS – EPE. The EPE tool is used to improve the EMS's stage "Performance Evaluation".***

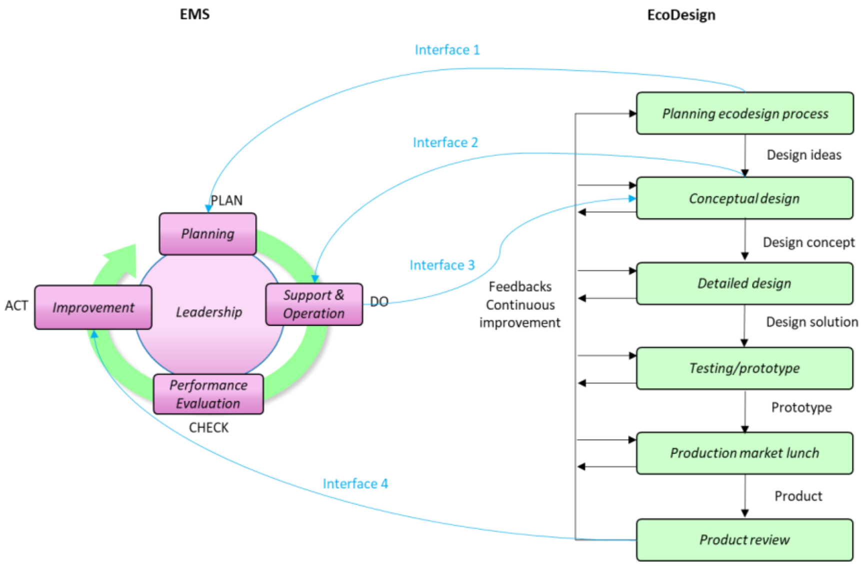


Figure 20 Interfaces between EMS and EcoDesign normally established in the literature review (Personal elaboration, 2017).

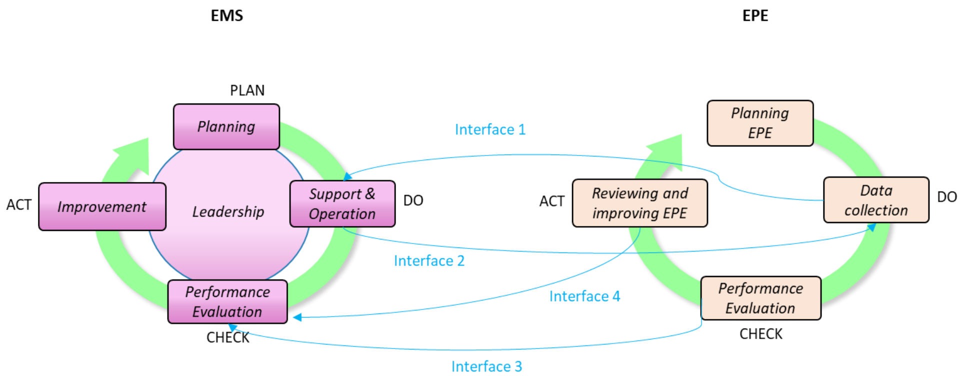


Figure 21 Interfaces between EMS and EPE normally established in the literature review (Personal elaboration, 2017).

1.6.1.5. Case studies application

About the 50% of the analysed scientific publication present also the application of method for multiple EMTs use. The main industrial sectors analysed are the pulp paper production and the chemicals production. Other sectors where have been applied methods for multiple EMTs use are: automotive, furniture production, household appliances production, metallurgical sector, transports sector and wine production. Some authors as Lewandowsa et al. (2011a,b) have conducted case studies on a large groups of companies of different industrial sectors considering 36 organizations. In other cases, authors such as Lewandowska et al. (2013a,b) and Finkbeiner (1999) have conducted surveys interviewing respectively 85 and 270 industrial organizations.

Remarks:

- ***Methods for multiple EMTs use have been not already applied in the sector of beverage.***

1.6.1.6. Relevancies, opportunities & threats

Many authors have debated the relevance of the development of methods for multiple EMTs use at industrial level. Some methodological considerations are very diffused and regard that:

a) Different EMTs can be used in a complementary way based on the perspective of the comprehensive approach (Finkbeiner et al., 1998);

b) The methods for multiple EMTs use may be developed with a company-oriented approach based on environmental management problems faced by the company (Mazzi et al., 2017);
c) The ideal prospect, for multiple EMTs use is to combine different EMTs in order to select for each environmental management aspects the EMTs that permit to best capture and manage each aspect (Lewandowska et al., 2011). The aspects are related to EMDs and EMBs. In fact, EMTs with different scopes give different outcomes and it is very important to make a careful choice of EMTs according to the faced EMDs and EMBs.
d) For the development of a new method for multiple EMTs use are required: 1) a set of EMTs selected; 2) a scheme of the method in order to organize EMTs selected 3) a description of the interfaces between the EMTs in order to establish clearly the interaction rules.

In addition, a deep investigation of opportunities and threats have been conducted by different authors. The most important opportunities can be summarized in:

- **Support the shifting to a life cycle management approach:** The inclusion of the life cycle EMTs (e.g. LCA) allows to transcend the boundaries of the company and to cover, using a common quantitative analysis, both the direct and indirect environmental aspects;
- **Prioritization of objectives and targets:** The combination of different EMTs such as LCA and EMS improve the prioritization of environmental management objectives and targets at product and organization level;
- **Comprehensive approach:** The multiple EMTs use permits of achieve a comprehensive environmental management approach. In fact, for example LCA is able to assess environmental impacts but is not able to assess the legal requirements compliance while for this second aspect the EMS is the most indicated EMT.
- **Continues improvement principle:** the combination of the EMS, that is based on the continuous improvement principle, with other EMTs (e.g. LCA) permits to transfer this principle to the other EMTs applications.
- **Assess both quantitative and qualitative environmental management aspects**: Some EMTs (e.g. LCA) are able to assess quantitative environmental aspects (e.g. environmental impacts on climate change in terms of GHG emissions), while other EMTs (e.g. EMS) are able to assess also qualitative environmental aspects (e.g. managerial indicators). The combination of these EMTs permits of to manage quantitative and qualitative environmental management aspects Lewandowska et al. (2011).
- **Introduce of scientific standardized impact assessment elements:** The combination of impact assessment EMTs (e.g. LCA) with managerial EMTs (e.g. EMS) improve the performance evaluation, increasing its robustness and objectivity, thanks to the inclusion in the assessment of international scientific elements such as impact categories. In fact, the use of environmental impact assessment EMTs (e.g. LCA) in combination with an environmental management system permits to upgrade the inventory analysis, achieving the impact assessment analysis improving the decision-making framework. For example, regarding the water management of a production site, the potential environmental impacts assessed only through the analysis on water flows can be very different when are assessed including the water scarcity characterization factor developing in the LCA methodological framework.
- **Improving eco design processes:** The combination of LCA and EMS makes it possible to realise eco-design processes in a repeatable, measurable (quantitative) way, based on normalised methods and with the access to calculation supporting databases and software packages. Therefore, it means that it is possible to use simplified eco-design tools, which seems particularly important in case of SMEs, particularly because for SMEs the implementation of an EMS alone is often a challenge (Fresner 2004; Hillary 2004).

- **Increase the spatialized detail of the environmental management approach:** The use of EMTs (e.g. EMS) try to overcome the problem of spatialized LCI often faced in LCA. In fact, the EMS supports the collection of spatialized data inasmuch it is a site specific EMT.
- **Improving data management and data quality assessment:** the use of EMS in combination with different EMTs (e.g. LCA) gives important benefits of improving the efficacy in terms of time and human resource for data collection activities.
- **Increase reproducibility and support to performance tracking:** the combination of managerial EMTs (e.g. EMS) and other EMTs (e.g. LCA for environmental impact assessment) support and improve the performance tracking of life cycle environmental performance systematizing the approach.
- **Improving of environmental improving plans:** the use of impact assessment, eco design, ecoefficiency EMTs, in combination with managerial EMTs (e.g. EMS) permit of improve the robustness and achievability of the environmental improving plans, assisting the investment decisions (Gaudreault et al., 2009).
- **Reducing burdens shifting issues:** the multiple EMTs use supports the reduction and often the prevention of burdens shifting issues, making more robustness the decision making framework.
- **Multi scale approach:** the multiple EMTs use may support the achieve of a multiscale approach to the environmental management merging product oriented analysis with organizational oriented analysis.

The most important threats can be summarized in:

- **Complexity growth:** often the methods for multiple EMTs use can introduced an increasing of general complexity during the procedure application. It is very important to pay close attention to mitigate complexity making the more possible intuitive the new method.
- **Data requirement growth:** the multiple EMTs use increase the requirement of data.
- **Employees' skills requirement growth:** the multiple EMTs use increase the requirement of employees' skills on EMTs and their application.
- **Cost growth**: the multiple EMTs use increase the general cost deriving from EMTs application (e.g. certification, consultants, use of specific software and database, etc.).

1.6.2. Capabilities of methods for multiple EMTs use to face EMDs and EMBs

The methods for multiple EMTs use analysed through the scientific literature review in the previous paragraph in terms of technical characteristics, are now analysed in terms of capabilities of to face EMDs and EMBs. The results are obtained merging the considerations done on EMDs (paragraph 1.2), on EMBs (paragraph 1.3) and on the capabilities of single EMT (paragraph 1.4). Therefore, the capabilities of a method for multiple EMTs use are the sum of the capabilities to face EMDs and EMBs of single EMTs included in the method with ad additional perspective. In this way, in order to simplify the results presentation, the methods have been grouped on the base of the EMTs included, with the following categories:

- LCA + EMS;
- LCA + EMS + EcoDesign;
- LCA + EMS + EcoDesign + Communication & Labels;
- EMS + EPE;
- EMS + EcoDesign.

In the following tables have been shown the results:

Life Cycle Management Areas	Environmental Management Drivers (EMDs)	1) LCA + EMS	2) LCA + EMS + EcoDesign	3) LCA + EMS + EcoDesign + Communication & Labels	4) EMS + EPE	5) EMS + EecoDesign
1. Environmental impacts assessment	Environmental Impacts Assessment – Product Level	√		√		
	Environmental Impacts Assessment – Organizational Level					
2. Inventory resources consumptions assessment	Inventory resources consumptions assessment – Product Level	√		√		
	Inventory resources consumptions assessment – Organizational Level					
3. Performance evaluation & performance tracking	Environmental performance evaluation & performance tracking at product and organizational level				√	
	Production cost reduction or/and revenue increasing		√	√		
4. Ecoinnovation	Ecodesign		√	√		√
	Ecoefficiency					
5. Strategic decision making	Identification of new eco-friendly solutions		√	√		
	Investments assessment		√	√		
6. Strategy & Management	Systematic and procedural approach for continuous improvement	√	√	√	√	√
	Strategy formulation with objectives and targets definition	√	√	√	√	√
	Top management commitment and managerial aspects	√	√	√	√	√
7. Compliance	Regulatory compliance	√	√	√	√	√
	Governmental aspects compliance (taxes and incentives)	√	√	√	√	√
8. Sensibility to relevant changes	Changes in price and availability of raw materials		√	√		
	Physical climate changes (e.g. desertification)		√	√		
	Changes of products on market		√	√		
	Changes of technologies on market		√	√		
	Changes in stakeholder's expectations and awareness		√	√		
9. Market differentiation	Products differentiation		√	√		
10. Communication and relationships	Corporate Brand reputation & image			√		
	Labelling & reporting			√		
	Competitors benchmarking and trends			√		
	Alliances and partnerships with other organizations		√	√		

Table 15 Correlations between main methods for multiple EMTs use with EMDs.

Life Cycle Management Critical Areas	Environmental Management Barriers (EMBs)	1) LCA + EMS	2) LCA + EMS + EcoDesign	3) LCA + EMS + EcoDesign + Communication & Labels	4) EMS + EPE	5) EMS + EecoDesign
1. Environmental impacts assessment	Lack of Environmental Impact Assessment – Product Level	√	√	√		
	Lack of Environmental Impact Assessment – Organizational Level					
	Lack of Comprehensive impact assessment (Multi-indicators)	√	√	√		
	Correlation between product and organizational scale not considered					
	Lack of Life Cycle Management approach	Partially	Partially	Partially		
	Issues in hotspots identification and on burdens shifting	Partially	Partially	Partially		
	Impact assessment based on inventory indicators	√	√	√		
	Technical difficulties in large impact assessment data management					
2. Inventory resources consumptions assessment	Technical difficulties in large inventory data management					
3. Performance evaluation & performance tracking	Lack of OPIs for environmental performance evaluation related to life cycle management at product and organizational level				√	
	Difficulties in performance tracking and OPIs trends analysis					
4. Ecoinnovation	Difficulties in implementation of practical ecodesign processes and new eco-friendly alternative solutions comparison					
	Lack of indicators for ecoefficiency assessment					
5. Strategic decision making	Lack of use of Decision making Tools (MCDA, optimization, statistical techniques, etc.)					
	Difficulties in the assessment of environmental performance of investments		Partially	Partially		
6. Strategy & Management	Unbalanced environmental management strategies			Partially		
	Divergence between intended and realized environmental management strategy			Partially		
	Lack of Top management commitment	√	√	√	√	√
	Lack of Systematic and procedural approach for continuous improvement	√	√	√	√	√
	Lack of employees' skills & undefined responsibilities	√	√	√	√	√
7. Compliance	Low ability to perceive changes in regulation & Unclear regulation	√	√	√	√	√
	Lack of economic advantages (e.g. taxes reduction, incentives)	N.A.	N.A.	N.A.	N.A.	N.A.
8. Sensibility to relevant changes	Low ability to perceive changes in resources availability and price	√	√	√	√	√
	Low ability to perceive changes of products on market	√	√	√	√	√
	Low ability to perceive changes of technologies on market		√	√		
9. Market differentiation	Difficulty in highlighting the differences in terms of environmental performance of their products respects those of competitors			Partially		
10. Communication and relationships	Low stakeholders engagement	√	√	√	√	√
	Lack of alliances and partnerships with other organizations	√	√	√	√	√
11. EMTs implementation	EMTs selection	√	√	√	√	√
	High implementation costs					

Table 16 Correlations between main methods for multiple EMTs use with EMBs.

N.A.= Not applicable because the aspect is independent from specific method for multiple EMTs use

1.7. Other relevant evolutions emerged from the literature review

The present literature review has permitted to analyse the Environmental Management Drivers (EMDs), the Environmental Management Barriers (EMBs), the Environmental Management Tools (EMTs) developed especially by ISO, the mechanisms to develop methods for multiple EMTs use and scientific experiences on methods for multiple EMTs use. In addition to these fundamentals aspects, some final considerations must be done regarding important methodological evolutions that have been happen under the push of international scientific initiatives carry out by ISO and other organizations such as SETAC, UNEP and JRC. These evolutions have been happened during the PhD programme and have been taken into account in order to internalize them in the new method developed. Therefore, this makes the new model up to date with the latest evolutions in environmental management. In the present paragraph are summarized the main aspects regarding the three main evolutions on environmental management:

- Importance growth of multiscale assessment;
- Revision of ISO14001;
- Lunching of ISO/TS 14072 to introduce the OLCA;

About this first aspect, in the last years important changes have been happened in terms of environmental management perspective of the EMTs. In order to assess these changes, a qualitative diagram has been proposed in the figure 22. In this diagram three important aspects have been assessed:

- The importance of life cycle perspective (axis z). This aspect measures in a qualitative way how the life cycle perspective principle is stressed by the EMT;
- Product-orientation (axis y). This aspect measures how the EMT is oriented to the management of environmental aspects related to products;
- Organizational-orientation (axis x). This aspect measures how the EMT is oriented to the management of environmental aspects related to organizations.

It is possible to recognize a starting state where:

- LCA was developed for the application only to products with max importance of life cycle perspective, max orientation to products and absence of orientation to organizations;
- EMS was developed for application to organizations with low importance of life cycle perspective, max orientation to organizations and absence of orientation to products.

International scientific initiatives have modified this starting state promoting an environmental management with a multi scale approach giving importance at the same time to both scales, the product scale and the organization scale (Martinez-Blanco et al., 2016). The main international scientific initiatives have been:

- The development of ISO/TS 14072 (ISO, 2014) that starting from traditional standards for LCA (ISO 14040/44:2006) extends the applicability of LCA methodology from products to organizations;
- The revision of ISO 14001 (ISO, 2015) that starting from the previous standard version (ISO, 2004) introduces important changes, increasing the role of the product eco design processes as a leverage for improve the environmental performance of the organizations;
- The born of ISO 14046 (ISO, 2014) the standard on Water Footprint. It is the first standard that at the same time gives requirements for the calculation of water footprint of products and organizations;
- The UNEP-SETAC flagship project on Life Cycle Management (LCM) (UNEP-SETAC, 2009) that in the last years had a key role in the diffusion and consolidation of the life cycle perspective principle at organizational level. This project has favourite the transfer of this principle born for products to organization and can be seen as one of the precursors of the extension of LCA methodology from products to organizations.

- The UNEP-SETAC flagship project on Organizational Life Cycle Management (O-LCA) (UNEP-SETAC, 2015) that according with the previous point and at the same time of ISO process for the development of ISO/TS 14072, has supported the extension of LCA methodology from products to organizations.
- Finally, but not less important, the initiative of the European Commission with the JRC of to develop the Organizational Environmental Footprint (OEF) (EC, 2013).

It is important to underline, especially in the case of ISO standards developments, that these scientific initiatives follow practical and real needs of the organizations on the market in terms of improving environmental performance to increase competitiveness. The diagram shows. In qualitative way, how different scientific initiatives in the field of environmental management have increase the importance of a multi scale approach that considers at the same time the environmental performance of the organization and its products. Therefore, a comprehensive approach to environmental management require the use simultaneity of EMTs oriented to products and EMTs oriented to organizations. This trend is according to the positive relation between EMTs product oriented and EMTs organizational oriented that had been hypothesized by Ayres et al. (2002) in continuous increasing in the future.

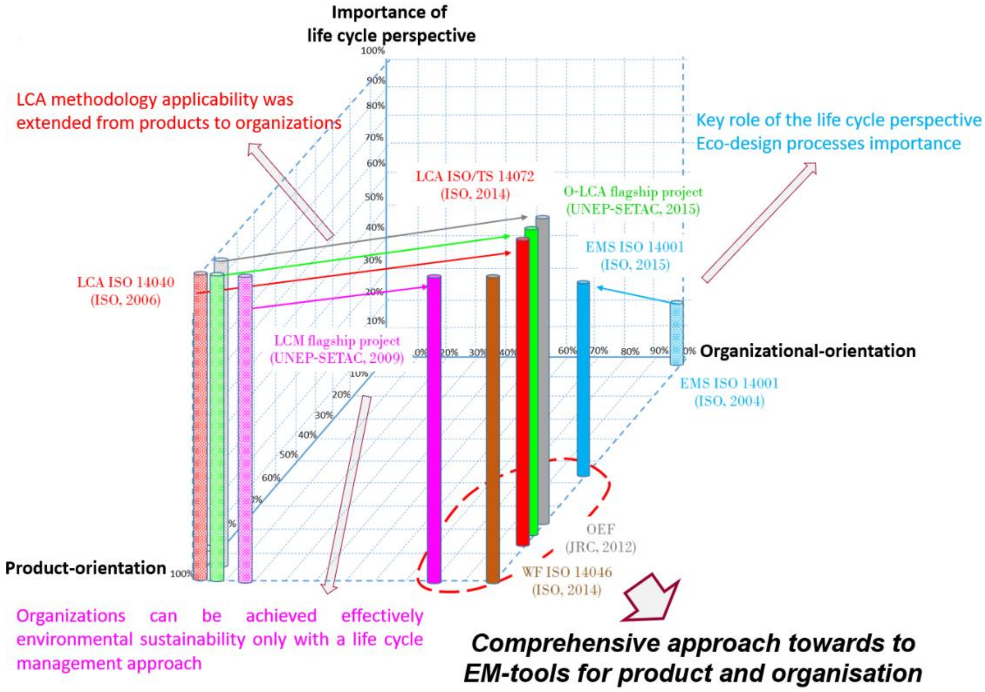


Figure 22 Qualitative representation of importance growth of multi scale approach (Personal elaboration, 2015).

In this context, another very important evolution has been the born of Organizational LCA (OLCA) according to ISO/TS 14072 that has extended the goal & scope of LCA from products to organizations. New aspects have been introduced and one of the most important is related to the study of product portfolio of organization. This aspect confirms the importance of multiscale assessment. Organizations using OLCA can identify global environmental impacts and eventual hotspots along their value chains. OLCA is considered to be one of the most important emerging application of life cycle approach (Hellweg et al., 2014) and therefore it is a key element to be considered in the developed of the new method for multiple EMTs use.

Finally, the last one relevant evolution has been the new revision of ISO14001:2015 that has introduced many novelties. The most relevant is the introduction of many direct and indirect references to LCT. One of the key changes is organisations adapting a wider perspective to see how their environmental impact stretch across the whole supply chain. Another key recommendation is to use eco-design for identifying and assessing the environmental aspects in relation to products. The whole life cycle of the products should be analysed, which will result in the inclusion of indirect environmental aspects that are beyond the direct control of the organisation (Lewandowska et al., 2014).

1.8. Formulation of scientific literature gaps in the research field

This last paragraph formalizes the scientific gaps emerged from the literature review. These gaps will guide in the next chapter the development of the new method for multiple EMTs use. The gaps formulation has been realized considering the EMBs completely or partially unsolved by the already available methods for multiple EMTs.

Life Cycle Management Critical Areas	Identified scientific gaps
1. Environmental impacts assessment	Lack of Environmental Impact Assessment – Product Level
	Lack of Environmental Impact Assessment – Organizational Level
	Correlation between product and organizational scale not considered
	Lack of comprehensive impact assessment (Multi-indicators)
	Lack of Life Cycle Management approach
	Issues on hotspots identification and on burdens shifting
	Impact assessment based on inventory indicators
	Technical difficulties in large impact assessment data management
2. Inventory resources consumptions assessment	Technical difficulties in large inventory data management
3. Performance evaluation & performance tracking	Lack of OPIs for environmental performance evaluation related to life cycle management at product and organizational level
	Difficulties in performance tracking and OPIs trends analysis
4. Ecoinnovation	Difficulties in implementation of practical ecodesign processes and new eco-friendly alternative solutions comparison
	Lack of indicators for ecoefficiency assessment
5. Strategic decision making	Lack of use of Decision making Tools (MCDA, optimization, statistical techniques, etc.)
	Difficulties in the assessment of environmental performance of investments
6. Strategy & Management	Unbalanced environmental management strategies
	Divergence between intended and realized environmental management strategy
7. Market differentiation	Difficulty in highlighting the differences in terms of environmental performance of their products respects those of competitors

Table 17 Scientific gaps identified during the literature review regarding methods for multiple EMTs use.

The gaps previously identified in terms of EMBs completely or partially unsolved, can be seen also in terms of specific limits of methods for multiple EMTs use already published, as follow:

- No method for multiple EMTs use already published perform LCA for many products, limiting the application of LCA to products of the organization;
- No method for multiple EMTs use already published applied OLCA;
- No method for multiple EMTs use already published consider the correlation between organizational scale and product scale;
- No method for multiple EMTs use already published use tools for large inventory data management and for large impact assessment data management
- No method for multiple EMTs use already published use tools to support operatively performance evaluation and performance tracking
- No method for multiple EMTs use already published use tools to support operatively ecodesign during the comparison of alternatives environmental performance;
- No method for multiple EMTs use already published consider the ecoefficiency
- No method for multiple EMTs use already published use tools for decision making based on statistical and mathematical approaches
- No method for multiple EMTs use already published support the process of environmental strategy definition in order to avoid issues related to unbalancing between ecoefficiency strategy component and ecobranding strategy component, and issues related to divergence between intended and realized strategy.
- The methods for multiple EMTs use already published are not able to overcome the difficulty related to highlighting the differences in terms of environmental performance between the products of an organization and those of competitors.

CHAPTER TWO: MATERIAL & METHODS PART 2 - THE NEW METHOD FOR MULTIPLE EMTs USE: ORGANIZATIONAL ENVIRONMENTAL SUSTAINABILITY SYSTEM (OES2)

Highlights:

- **EMTs selected**
- **Interfaces between EMTs established**
- **The new method for multiple EMTs use: OES2**
- **Methodological development of STEMs**

2.1. Introduction to new method conceptualization

The Life Cycle Management (LCM) approach, according to ISO14001:2015, is becoming the reference to manage environmental performance at industrial level (Graudreault et al., 2009). It requires the use of different EMTs in order to make this concept operational (Graudreaoult et al., 2009). However, the question on how to combine or integrate different EMTs, is open. One may ask the question whether it is feasible to aim at the development of one method for multiple EMTs use which can embrace all kinds of questions (EMDs and EMBs) on environmental management or at least the major part of them. In, fact, there are two major reasons for combining tools. One reason is to avoid problem shifting, since no single concept or tool is able to address all relevant questions (EMD and EMB) and depict all kinds of problem shifting. Another, related reason is to compensate for a tool weakness in a given decision situation (Wrisberg et al., 2012). Furthermore, given the quite fundamental differences between model types and the related modes of analysis of EMTs comprise, it is considered more realistic to aim to develop a method to combine and use of existing EMTs while it is considered impossible to aim to develop one super-tool that integrate all EMTs features. Actually, there is no "one-size-fitsall" method for multiple EMTs use that incorporates all capabilities to face all EMDs and EMBs in order to achieve comprehensive environmental (Almeida et al., 2015). In fact, often EMDs and EMBs are faced and studied as single issues, there is a lack of investigation assuming a holistic perspective. Therefore, in the last years has growth the need to develop a method for multiple EMTs use, especially at industrial level, to achieve this holistic view on environmental management (Journeault et al., 2016; Longoni et al., 2015). In the present chapter, according with the research goals, a proposal of a new method for multiple EMTs use will be done. In order to conduct the research, as a first step it is necessary to conceptualize the new method. As second step, it has been chosen a single real industrial case study, to apply the new method to the "Acqua Minerale San Benedetto S.p.A." organization, the Italian leader in the sector of bottle packed water and soft drinks. The new method for multiple EMTs use, proposed in this research, faces the issue related to EMTs selection. In fact, as emerged during the scientific literature review one of the most important EMB is related to the large availability of EMTs (Rossi et al., 2016).

2.2. New method conceptualization procedure

The development of the new method has been based on a methodological procedure specifically elaborated following these stages:

1. **EMTs and STEMs selection** based on:
    - Evidences and gaps emerged from scientific literature;
    - Identification of additional selection criteria;
2. **New method scheme developed**;
3. **Definition of interfaces between EMTs**;
4. **Development of new specific STEMs** inserted in the proposal.
5. **Comparative analysis of capabilities to face EMDs and EMBs** between the new method and already available methods (directly in the discussion chapter).

In the following paragraphs, a detailed description for each methodological step will be presented.

2.2.1. EMTs and STEMs selection

In this paragraph has descripted the methodology that has been followed for the selection of the EMTs used successively for the development of the proposal of the new method for multiple EMTs use. It has also descripted the STEMs introduced to support and improve the implementation of selected EMTs. The EMTs selection represents the first step of the procedure elaborated for the development of the new method.

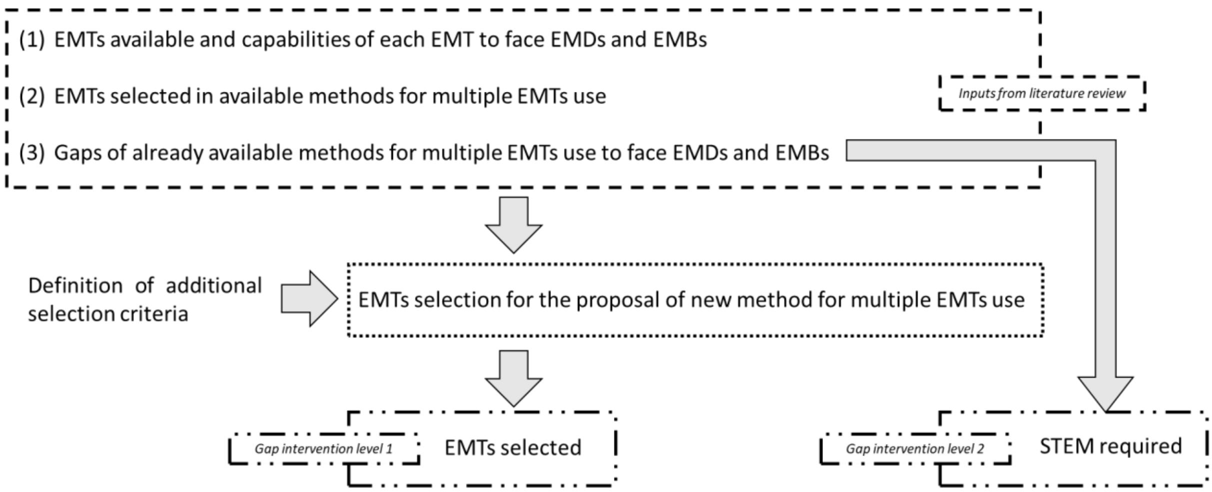


Figure 23 Conceptual diagram for the procedure steps followed for EMTs selection and STEMs required identification (Personal elaboration, 2017)

As shows in the previously figure, the EMTs selection is based on elements emerged from literature review and on additional selection criteria. The inputs deriving from literature review are essentially of three types:

1. **EMTs available and capabilities of each EMT to face EMDs and EMBs:** this input permits to have a comprehensive view of the available EMTs and the knowledge regarding EMTs capabilities permits of to assess if a specific EMT could be useful in the new method in order to solve critical areas emerged;
2. **EMTs selected in available methods for multiple EMTs use:** this input permits to assess which EMTs are implemented in already available methods for multiple EMTs use in order to include these EMTs as a basic starting point recognized by scientific community experiences;
3. **Critical areas and gaps of already available methods for multiple EMTs use to face EMDs and EMBs:** this input permits to assess the need of include EMTs on the basis of critical area and gaps emerged from the analysis of already available methods;

Regarding the first point, without to copy here the emerged results, refer to paragraph 1.4 of the chapter one. Regarding the second point emerged that already available methods for multiple EMTs use are based on the selection of three EMTs: LCA, EMS and Eco Design. In the most evolved already available method, named POEMS, there is an additional EMT, the Communication & Label EMT. Therefore, these four EMTs will be selected as a starting point for the development of the proposal of the new method. Finally, regarding the third point the identified gaps have been analysed in order to assess two different level of intervention:

- **Gap Intervention Level 1**: The specific gap is due to not use of some EMTs? In this case, the gap solution required the selection of pertinent EMTs and the inclusion of them in the proposal of new method;
- **Gap Intervention Level 2**: The specific gap, although all pertinent EMTs are use, is due to issues emerged during the implementation stage of EMTs? In this second case, the gap solution proposed requires the introduction of specific Supportive Tools to Environmental Management (STEMs) able to overcome the limits emerged during EMTs implementation. The STEMs have been defined as tools developed in order to improve the applicability and the use of EMTs used in the new method for multiple EMTs use proposed. The introduction of STEMs constitutes an innovation in the development of methods for multiple EMTs use and responds to the need for practical tools that enable and support organizations to implement EMTs (Geibler et al., 2016).

The gap intervention level 1 is relevant for the objective of this stage inasmuch it identifies clearly needing to select specific EMTs to be included in the proposal of new method for multiple EMTs use.

The gap intervention level 2 will be considered in the next paragraphs of the present chapter for the conceptualization of the new method.

In fact, in order to answer in a deeply and complete way to the research object of propose a new method for multiple EMTs use, the work has not been limited to the identification to the formulation of the new method's scheme (gap intervention level 1) but it has been extended to give methodological answers to EMBs emerged during the implementation of EMTs (gap intervention level 2). This aspect is fundamental for increase the utility and innovation degree of the new method for multiple EMTs use proposed. Therefore, the new methodological elements developed at gap intervention level 2, are elements that have been included at the level of specific EMTs in order to solve emerged EMBs and improve EMTs applicability, improving the overall applicability of the new method for multiple EMTs use proposed. The relation between specific EMTs and the new methodological elements will be shown in the following paragraphs.

It is important to underline that according to the research objective of developing and testing a new method for multiple EMTs use, the analysed methodological aspects and the reported results are mainly focused on relevant applicability issues. For this reason, the selected EMTs will be briefly described (e.g. ISO 14001, ISO 14040-44, etc) and therefore for a full comprehension the reader must have a scientific knowledge background on ISO standards and on their requirements (Appendix A).

Life Cycle Management Critical Areas	Identified gaps	Gap Intervention Level 1	Gap Intervention Level 2
1. Environmental impacts assessment	1) Lack of Environmental Impact Assessment – Product Level 2) Lack of Environmental Impact Assessment – Organizational Level 3) Correlation between product and organizational scale not considered 4) Lack of comprehensive impact assessment (Multi-indicators) 5) Issues on hotspots identification and on burdens shifting 6) Lack of Life Cycle Management approach 7) Impact assessment based on inventory indicators	EMTs required: LCA & OLCA -	New STEM proposed: Multiscale LCA (MLCA) model
	8) Technical difficulties in large impact assessment data management	-	New STEM proposed: Environmental Results Database (ERD)
2. Inventory resources consumptions assessment	9) Technical difficulties in large inventory data management	-	New STEM proposed: Environmental Inventory Database (EID)
3. Performance evaluation & performance tracking	10) Lack of OPIs for environmental performance evaluation related to life cycle management 11) Difficulties in performance tracking and OPIs trends analysis	EMTs required: EPE	New STEM proposed: Eco Environmental KPI Analyzer (Eco-EKA)
4. Ecoinnovation	13) Lack of indicators for ecoefficiency assessment	EMTs required: EcoEfficiency	New STEM proposed: Index of Work Environmental Efficiency (IWEE)
	12) Difficulties in implementation of practical ecodesign processes and new eco-friendly alternative solutions comparison	EMTs required: EcoDesign	New STEM proposed: EcoDesign Simulation Dashboard (Eco-DSD)
5. Strategic decision making	15) Difficulties in the assessment of environmental performance of investments		
	14) Lack of use of Decision making Tools (MCDA, optimization, statistical techniques, etc.)	-	New STEM proposed: Strategic Environmental Decision Making module (SEDM)
6. Strategy & Management	16) Unbalanced environmental management strategies 17) Divergence between intended and realized environmental management strategy	EMTs required: EMS, Communication & Labels tools, EcoEfficiency, EcoDesign	New STEM proposed: Environmental Sustainability Strategy Model (ESSM)
7. Market differentiation	18) Difficulty in highlighting the differences in terms of environmental performance of their products respects those of competitors	Partially faced, considering PEF	Not introduced, considered for future perspective*

Table 18 Specific proposed solutions to overcome identified scientific gaps.

As shown in the previous table, have been proposed solutions for each gap identified during the scientific literature review. The gap 18 has been faced, making the new method developed compatible with the Product Environmental Footprint (PEF) framework, the new tool introduced by European commission for the comparison of product performance but without introducing specific STEM (e.g. new labels built on ISO14024 for reasons related to timing in terms of industrial applicability). In this paragraph, it is important to focus on solutions proposed regarding the first level of gap intervention that have the scope of identified additional EMTs respect to the traditional used in the past for the development of already available method for multiple EMTs use (LCA, EMS, EcoDesign, Communication & Labels). Therefore, in order to face emerged gaps, the selection of the following EMTs are need:

- OLCA to face gaps number: 1, 2, 3, 4, 5, 6 and 7;
- EcoEfficiency to face gaps number: 13 and 16;
- EPE to face gaps number: 10 and 11;

Furthermore, the EMTs selection stage has been conducted considering additional selection criteria that are summarized in the following table:

Selection criteria	Meaning
1) Global diffusion	The EMT is already adopted and well know at industrial level?
2) Consensual level	The EMT has been developed with an international process during which stakeholders have participated?
3) Third party recognition	The EMT could be certifiable and verifiable by third part?
4) Comprehensive	The EMT support a comprehensive assessment or it is specific oriented (e.g. footprint)?
5) Minimizing of overlapping	The overlapping of capabilities of different EMT must be minimized during EMT selection stage.
6) High relevance level	The EMT have a recognized high level of relevance?

Table 19 Additional selection criteria for EMTs selection stage.

The selection criteria number 2 and 3 are generally intrinsically satisfy by all EMTs considered thanks to the choice of focus the EMTs selection stage on the EMTs developed by ISO. The criterion related to global diffusion (1) is tool specific and in the case for example of MFCA, EASO, etc. the diffusion is securely lower than LCA, EcoDesign and other EMTs. Regarding the selection criterion number 4, relating to specific EMTs category, has been assessed in a qualitative way if the EMT supports a comprehensive approach. For example, relating to environmental impact assessment EMTs category, the Footprint (e.g. Water Footprint, Carbon Footprint) are EMTs that focus on specific areas of concern (e.g. Water management, Climate change) and therefore are not considered comprehensive respect to LCA and OLCA that assess environmental impacts considering a profile of many impact categories that include also categories considered from water and carbon footprints as well as other categories on for example human toxicity, land occupation, resources depletion, etc. Regarding the selection criterion number 5, has been assessed there is potential overlapping between EMTs and in this way the selection criterion has been assigned positive to EMTs that include features of other EMTs. An example is the case of the environmental impacts assessment EMTs category where the features of Footprint are included in the assessment conducted within LCA (at product scale) and OLCA (at organizational scale) methodology.

Tool category	Standard/EMT	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5	Criterion 6	Criteria satisfied
Managerial tools	1) ISO 14001/Environmental Management System (EMS);	√	√	√	√	√	√	6
	2) ISO14015:2001/Environmental assessment of sites and organizations (EASO).		√	√				2
Communication tools	3) ISO14021/Environmental labels and declarations -- Type I (Label type I);	√	√	√	√	√		5
	4) ISO14024/Environmental labels and declarations -- Type II (Label type II);	√	√	√	√	√	√	6
	5) ISO14025/Environmental labels and declarations -- Type III (Label type III).	√	√	√	√	√	√	6
Performance evaluation & improvement tools	6) ISO14031/Environmental Performance Evaluation (EPE);		√	√	√	√	√	5
	7) ISO14034/Environmental Technology verification (ETV);		√	√		√		3
	8) ISO14045/Eco Efficiency (EcoE)		√	√	√	√	√	5
	9) ISO 14062/Eco Design (EcoD)	√	√	√	√	√	√	6
Environmental impact assessment tools	10) ISO14040 & ISO14044/ Life Cycle Assessment (LCA)	√	√	√	√	√	√	6
	11) ISO14046/Water Footprint (WF)	√	√	√			√	4
	12) ISO/TS 14072/Organizational LCA (OLCA)		√	√	√	√	√	5
	13) ISO 14064;/Organizational Carbon Footprint (OCF)	√	√	√			√	4
	14) ISO/TS 14067/Product Carbon Footprint (PCF)	√	√	√			√	4
	15) ISO 14051/ Material flow cost accounting (MFCA)		√	√			√	3

Table 20 Application of additional selection criteria to EMTs.

The last selection criterion is related to the relevance of EMT, the criterion has been assigned only to EMTs that are recognized relevant for environmental management at industrial level. In terms of relevance, almost all EMTs developed by ISO have high relevance except EMTs such as EASO and ETV that are poorly considered at industrial level because have marginal capabilities to respond to EMDs and EMBs. In the case of each EMT, one point has been assigned each positive assignment of the selection criteria and a total score equal or higher than 4/6 has been considered adequate for to consider the EMT for the EMTs selection stage. Merging discussed results from literature review and from the assessment of additional selection criteria have been selected to develop the proposal of new method for multiple EMTs use the EMTs and STEMs summarized in the table 21. Overall the seven EMTs has been selected plus eight STEMs that have been developed. As it is possible to notice, this EMTs selection permits to have a holistic approach to environmental management undergoes EMTs with managerial features, EMTs with communication features, EMTs that support performance evaluation, eco-design processes and ecoefficiency evaluation, EMTs with environmental impacts assessment features; supported by STEMs with capabilities of simplified data management, improve eco design and eco efficiency assessment, improve environmental performance evaluation, and improve decision making processes. The selection of EMTs is according to the positive relation between EMTs product oriented and EMTs Organizational oriented that as hypothesized by Ayres et al. (2002) in continuously increasing. The specific potential capabilities to face EMDs and EMBs will be discussed after the conceptualization of the new method for multiple EMTs use.

EMTs/STEMs category	Specific EMT/STEM
Managerial EMTs	1) EMS - Environmental Management System (ISO 14001);
Environmental impact assessment EMTs	2) OLCA - Organizational LCA (ISO/TS 14072); 3) LCA - Life Cycle Assessment (ISO14040 & ISO14044);
Performance evaluation & improvement EMTs	4) EPE - Environmental Performance Evaluation (ISO 14031); 5) Eco Design (ISO 14062); 6) Eco Efficiency (ISO14045);
Communication EMTs	7) Communication & Labels - Environmental labels and declarations (Type I, ISO 14021; Type II, ISO 14024; Type III, ISO 14025);
STEMs	A) MLCA model = Multiscale LCA model; B) EID = Environmental Inventory Database; C) ERD = Environmental Results Database; D) Eco-EKA = Eco Environmental KPI Analyzer; E) Eco-DSD = EcoDesign Simulation Dashboard; F) IWEE = Indicator of Work Environmental Efficiency; G) SEDM module = Strategic Environmental Decision Making module H) ESSM = Environmental Sustainability Strategy Model;

Table 21 EMTs and STEMs selected to develop the proposal of new method for multiple EMTs use.

2.2.2. New method scheme development

The EMTs selection stage has permitted to select the EMTs to be include in the proposal of new method for multiple EMTs use. It is possible to see these selected EMTs as a set of separate objects not interacting, while the new method can be seen as an ordered set where EMTs that interacts (see figure below).

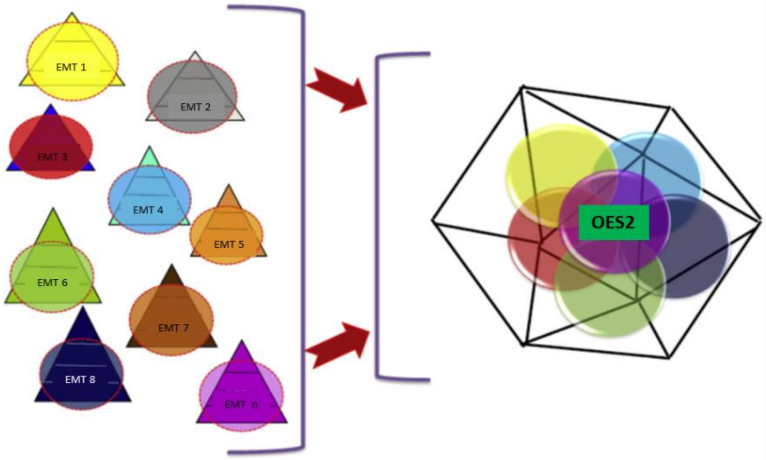


Figure 24 Development on the new method through combination of different EMTs

In this stage, starting from the results of EMTs selection stage, it has been designed the “new method scheme”, to establish the role of each EMT. This is a fundamental stage because permits to conceptualize the structure of the new method. The elaboration of the new method scheme has been obtained following three steps:

1. Selection of the mechanism for multiple EMTs use;
2. Definition of the roles of the EMTs selected;
3. Elaboration of the new method scheme.

2.2.2.1. Selection of the mechanism for multiple EMTs use

Regarding the first step, considering the elements emerged from literature review (see paragraph 1.5) has been decided to use the combination mechanism. Essentially, the combination approach is the most flexible and comprehensive. The flexibility deriving from the fact that the combination method permits to concentrate on individual solutions. In fact, it permits to the organization to decides to primarily apply one EMT and as a second step complements it in a problem oriented way with the other EMTs. While the comprehensiveness deriving from the fact that the combination method permits to include in the same method for multiple EMTs use a larger number of EMTs respect to integration method. In the specific, two types of combination have been used: the consecutive steps and the parallel steps. The first one is the combination method that has been manly used, while the second one has been used in order to permits to different independent processes such as performance evaluations, ecodesign and ecoefficiency to continue freely, without that one of which slow the others inasmuch they have intrinsically different cycles times of assessment.

2.2.2.2. Definition of the roles of the EMTs selected

The new combination method has been developed using 7 EMTs plus 8 STEMs and before to elaborate the method scheme it is fundamental to define the roles of these EMTs and STEMs. The role can be seen as the main function that the EMT does. While, the detailed functions of the selected EMTs have been identify during the literature review in the EMDs and EMBs correlation analysis (see paragraph 1.4). In the following two tables have been defined the roles of each selected EMT in the new combination method proposed and of each new proposed STEM.

EMTs	Roles
1) EMS - Environmental Management System (ISO 14001);	Management of activities and of the EMTs continues applications
2) OLCA - Organizational LCA (ISO/TS 14072)	Assessment of environmental impacts at organizational level
3) LCA - Life Cycle Assessment (ISO14040 & ISO14044);	Assessment of environmental impacts at product level
4) EPE - Environmental Performance Evaluation (ISO 14031);	Monitoring and evaluation of environmental performance on the base of key performance indicators
5) Eco Design (ISO 14062);	Introducing eco design approach in process for products development and for investments assessment
6) Eco Efficiency (ISO14045);	Assessment of ecoefficiency to improve environmental and economic performance
7) Communication & Labels - Environmental labels and declarations (Type I, ISO 14021; Type II, ISO 14024; Type III, ISO 14025);	Communication on environmental aspects and performance

Table 22 Role of each EMT included in the new combination model developed.

STEMs	Roles
A) Multiscale LCA (MLCA) model	Merging LCA and OLCA models in only one model all the environmental impact assessment scales (process, products, products families, sites, organization)
B) Environmental Inventory Database (EID)	Management of all data flows required by EMTs
C) Environmental Inventory Database (ERD)	Management of all results flows generated by EMTs
D) Eco Environmental KPI Analyzer (Eco-EKA)	Improve the use of environmental KPI for performance tracking and the analysis of their trends
E) EcoDesign Simulation Dashboard (Eco-DSD)	Support EcoDesign application, introducing a space where simulate scenarios with different eco-friendly alternatives
F) Indicator of Work Environmental Efficiency (IWEE)	Improve EcoEfficiency application, introducing a multisets indicator for process efficiency assessment
G) Strategic Environmental Decision Making module (SEDM)	Support decision making processes solving emerged issues promoting the use of best available decision making techniques
H) Environmental Sustainability Strategy Model (ESSM)	Support the EMS improving the process of environmental sustainability strategy definition

Table 23 Role of each STEM included in the new combination model developed.

The central role of **EMS (Environmental Management System - ISO 14001)** emerges from the previous table and derives from its comprehensiveness perspective to environmental management (Guerrero-Baena et al., 2015; Darnall et al., 2008). In fact, the EMS in the new combination method has the role of **strategical and managerial brain** who coordinates and manages all the activities and application of all EMTs and STEMs. In the specific the main functions entrusted to the EMS in the new method are:

- Define the environmental management strategy: define the environmental management strategy with a growth competitiveness view establishing the environmental policy and setting objectives and targets which must be: consistent, measurable, monitored, communicated and updated;
- Understand the context: determine external issues and potential pressure factors that are relevant to its objectives and targets;
- Understand stakeholders: determine the needs and the expectations of the stakeholders;
- Ensure legal compliance;
- Ensure the leadership (top management) commitment
- Promote continues improvement:
- Define organizational roles, responsibilities and authorities;
- Support activities ensuring human, financial and technical resources consistently with settled objectives and targets.
- Support and determine the training needs and plan training activities for the competence acquisition;

- Establish and manage an action plan: the plan must define all the actions planned in order to achieve objectives and targets settled;
- Support internal communication processes: in order to communicate to employees' environmental policy and the environmental performance in order to increase employees' awareness;
- Support external communication processes: in order to communicate to stakeholders environmental policy and relevant information on the basis of eco-branding strategy.
- Ensure operational control;
- Support the performance evaluation;
- Manage audits for each EMT and the relative nonconformity introducing corrective actions;
- Support the management review;
- Coordinate the application and functionality of EMTs and STEMs included in the new method.

The **OLCA (Organizational LCA - ISO/TS 14072) and LCA (Life Cycle Assessment - ISO14040 & ISO14044)** in the new combination method has the role of **elaborator engine** for environmental impact and resource consumption calculation. In the specific the main functions entrusted to the OLCA and LCA in the new method are:

- Permit the identification of environmental performance at product and organizational level according to international standardized environmental impact categories;
- Permit the identification of resource consumptions at product and organizational level according to international standardized environmental impact categories;
- Promote the life cycle management approach;
- Identify hotspots and opportunities to improve environmental performance and environment management strategy.

The **EPE (Environmental Performance Evaluation - ISO 14031)** in the new combination method has the important role of **analytical monitoring observer** who analyse environmental performance. In the specific the main functions entrusted to the EPE in the new method are:

- Establish key performance indicators to compare an organization's past and present environmental performance with its environmental objectives and targets. The indicators are established considering two categories:
    - Environmental condition indicators (ECIs) that provide information about the condition of the environment;
    - Environmental performance indicators (EPIs) that provide information about the performance. Two types of EPIs can be established: the management performance indicators (MPIs) provide information about management efforts to influence the environmental performance of the organization's management; the operational performance indicators (OPIs) provide information about the environmental performance of the organization's operations which could be impacted by the organization;
- Identify hotspots and opportunities to improve environmental performance and environment management strategy;
- Support an exhaustive but intuitive and fast representation of environmental performance trend;

The **Eco Design (ISO 14062)** in the new combination method has the important role of **analytical tool for alternatives assessment** who analyse environmental performance for the development of new products or for investments assessment. In the specific the main functions entrusted to the Eco Design in the new method are:

- Ensure the integration of environmental aspects in process and product design;
- Support the improvement of environmental and economic performance;
- Support strategic decision making regarding new investments and the development of new products;
- Promote the life cycle management approach.

The **Eco Efficiency (ISO14045)** in the new combination method has the important role of **analytical tool for eco efficiency assessment**. In the specific the main functions entrusted to the Eco Efficiency in the new method are:

- Establish eco-efficiency indicators in order to assess the ecoefficiency of processes and products;
- Identify hotspots and opportunities to improve environmental performance and environment management strategy;
- Support environmental and economic performance optimization.

The **Communication & Labels (Environmental labels and declarations Type I, ISO 14021; Type II, ISO 14024; Type III, ISO 14025)** in the new combination method has the important role of **environmental performance communicator**. In the specific the main functions entrusted to the Communication & Labels in the new method are:

- Permit the external communication of pre-verified self-declared claims on environmental aspects (Type II environmental labelling);
- Permit the use of symbols to support the communication of claims (Type II environmental labelling);
- Permit the labelling of products regarding environmental characteristics (Types I and III environmental labelling);
- Communication and Benchmark of products' environmental performance (Type III environmental labelling). Therefore, OES2 is able to support the certification of products in accordance with main environmental labels schemes such as PEF (Product Environmental Footprint) and EPD (Environmental Performance Declaration).

The STEM "**Multiscale LCA (MLCA) model**" in the new model has the important role of **reference model for environmental impacts and damages assessment for all assessment scales (process, products, product families, sites, organization)**. In the specific the main functions entrusted to the MLCA model in the new method are:

- Permit with only one model to assess the environmental performance for all assessment scale in order to respond to all possible assessment need;
- Correlate the environmental performance of macro scales (e.g. organization, sites) to the environmental performance of meso scales (product families) and to the environmental performance of micro scales (products and processes).
- Reduce the resources requirements in terms of time and human resources that they would managing separately product LCA models and the OLCA model.
- Simplify the performance baseline restore action needed for the performance tracking.

The STEMs "**Environmental Inventory Database (EID)**" and "**Environmental Inventory Database (ERD)**" in the in the new combination method have the important role of **database for inventory and results data**. In the specific the main functions entrusted to the EID and ERD in the new method are:

- Permit the automatic data collection and data management for all data required from EMTs;
- Permit the automatic data feed of MLCA model;
- Generation of historical dataset for the performance tracking;
- Simplify the performance baseline restore action needed for the performance tracking;
- Permit the management of all results on environmental performance produced by EMTs.

The STEM "**Eco Environmental KPI Analyzer (Eco-EKA)"** in the new model has the important role of **Analyzer of Environmental KPI trends consistently with the multiscale approach**. In the specific the main functions entrusted to the Eco-EKA in the new method are:

- Identify the environmental KPI needed to ensure the good understand of the performance trend and to satisfy specific needs in terms of monitoring (e.g. specific strategic products although not relevant in terms of incidence);
- Permit the performance tracking for all the assessment scales and all life cycle stages.

The STEM "**EcoDesign Simulation Dashboard (Eco-DSD)**" in the new model has the important role of **Ecodesign simulation space for eco-friendly alternative solutions comparison**. In the specific the main functions entrusted to the Eco-DSD in the new method are:

- Give a simulation space to assess and compare the environmental performance of different eco design scenarios;
- Simplify the communication of eco-design projects to top management;
- Permit the assessment of the effects on environmental performance of new investments;
- Support the consistency verification of the environmental sustainability strategies assessing the potential improvements of environmental performance deriving from planned ecoefficiency activities.

The STEM "**Indicator of Work Environmental Efficiency (IWEE)**" in the new model has the important role of **Indicator for the monitoring and analysis of process environmental performance**. In the specific the main functions entrusted to the IWEE in the new method are:

- Assess the environmental efficiency of processes;
- Identify hot spots and give feedback for promote the improvement of ecoefficiency and economic performance levels through the reduction of resources consumptions.

Finally, the STEM "**Strategic Environmental Decision Making module (SEDM module)**" has the important role of **decision making supporter.** In the specific the main functions entrusted to the SEDM module in the new method are:

- Permit the choice of the more appropriate decision making techniques in order to support the decision making process. In fact, the method that can be used depends strongly by the type of decision making process and are not determinable beyond. This module is inserted in OES2 in order to promote the use of the best available techniques for the decision making in function of specific decision issues. Methods that can be used are: mathematical optimization, statistical techniques, MCDA, etc.
- Permit the development of specific models, in function of the method selected, in order to give results to the decision making process. The results can be: optimized solutions, statistical results, etc.

It is a module that can be activated or disactivated in function of the specific strategical needs. In fact, for example, the use of optimization models or statistical methods is not required always for all decision making processes because the results that emerged from EPE, EcoDesing and EcoEfficiency are sufficient. Other times instead the activation is essential for improve the robustness of the decision making process.

The STEM "**Environmental Sustainability Strategy Model (ESSM)**" in the new model has the important role of **reference model for the definition of the environmental sustainability strategy**. In the specific the main functions entrusted to the ESSM in the new method are:

- Establish the environmental strategy on the two components: EcoEfficiency component and EcoBranding component;
- Setting goals & targets for the two strategy components;
- Verify the consistency of goals and targets in function of planned improvement activities (e.g. eco design projects);
- Identify deadlines for ecoefficiency activities and ecobranding activities.

2.2.2.3. Elaboration of the new method scheme

On the base of the roles defined for each EMT selected and STEMs has been possible to elaborate the scheme elaborated of the new combination method. The figure 25 shows the scheme. The new combination method proposed has been named:

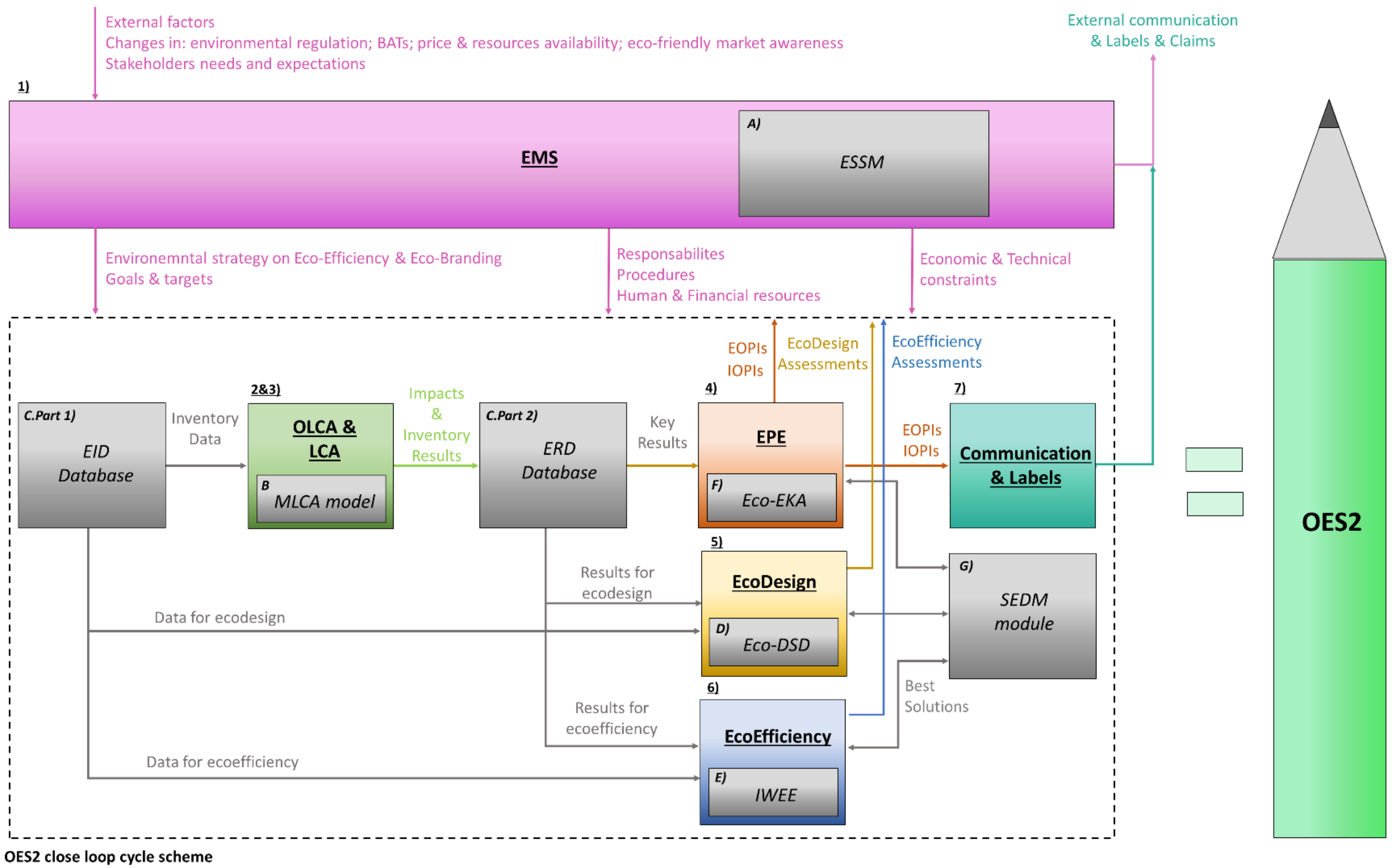
Organizational Environmental Sustainability System (OES2)

The name deriving from the attitude of the new combination method to promote the environmental sustainability of the organization. The sense of system deriving from the strong important of systematic approach for continues improvement of environmental performance entrusted to the EMS. OES2 has the particularity to combine organizational oriented EMTs with product oriented EMTs and it can be a relevant proposal for ISO 14000 ISO standards series. In fact, to promote a broader use of the ISO 14000 series, a framework for a complementary approach shall be established and OES2 is a proposal. In this context, ISO/TC 207, the technical committee that focus on Environmental Management, has developed a lot of EMTs grouped in the ISO 14000 ISO standards series, but actually there is not a proposal of how combine these EMTs born for to be used together. Therefore, OES2 is a new proposal on how combine EMTs developed by ISO for environmental management. OES2 is a multiscale method that is able to assess and manage the environmental performance of industrial processes, of a product, of a set of products, of a multisite organization as a whole. OES2 is based on a close loop cycle scheme. The OES2 has the characteristic to consider all relevant factors to increase the possibility of success of environmental management: i) management and leadership; ii) strategic plan; iii) capacity to monitor and analyse the environmental performance; iv) capacity to improve the environmental performance; v) customer focus (Guimaraes et al., 2013; Tseng et al., 2009).

OES2 focuses on the concept of eco-innovation. In fact, OES2 through the exploiting the capabilities of EMS, Ecodesign and Ecoefficiency permits the continuous generation/adoption of eco-innovation (Demirel et al., 2011; Wagner, 2007). The eco-innovation can be defined as the "production, application or exploitation of a good, service, production process, organizational structure, or management or business method that is novel to the firm or user, that in a lifecycle perspective, permits the reduction of environmental impacts and the reduction of natural resources consumptions (including materials, energy, water and land) (EIO, 2012; Kemp et al., 2007). Furthermore, the OES2 method, combining OLCA and EMS internalizes the most recent development directions identified by researchers (Lo-Iacono-Ferreira et al., 2017).

Finally, OES2 is based on four fundamental pillars of the environmental management:

1. The **monitoring** of environmental performance with a multiscale approach in a life cycle perspective;
2. The **eco-innovation** to realized new eco-friendly products and technologies;
3. The **ecoefficiency** in order to reach the best environmental performance from the already existing products and processes;
4. The **communication** to customers and relevant stakeholders of environmental performance of products and of organization.



EMTs:
1) EMS = Environmental Management System (ISO 14001)
2&3) OLCA & LCA = Organizational Life Cycle Assessment & Product Life Cycle Assessment (ISO/TS 14072 ; ISO14040-44)
4) EPE = Environmental Performance Evaluation (ISO 14031)
5) EcoDesisgn = (ISO/TR 14062)
6) EcoEfficiency = (ISO 14045)
7) Communication & Labels = Environmental labels and declarations (Type I, ISO 14021; Type II, ISO 14024; Type III, ISO 14025);

STEMs:
A) ESSM = Environmental Sustainability Strategy Model
B) MLCA model = Multiscale LCA model
C part 1) EID = Environmental Inventory Database
C part 2) ERD = Environmental Results Database
D) Eco-DSD = EcoDesign Simulation Dashboard
E) IWEE = Indicator of Work Environmental Efficiency
F) Eco-EKA = Eco Environmental KPI Analyzer
G) SEDM module = Strategic Environmental Decision Making module

Figure 25 OES2 (Organizational Environmental Sustainability System) combination method scheme.

2.2.3. Definition of interface between EMTs

The interfaces between EMTs are a fundamental aspect to define the interaction rules between combined EMTs and STEMs. As shown in the following figure different types of interfaces have been distinguished.

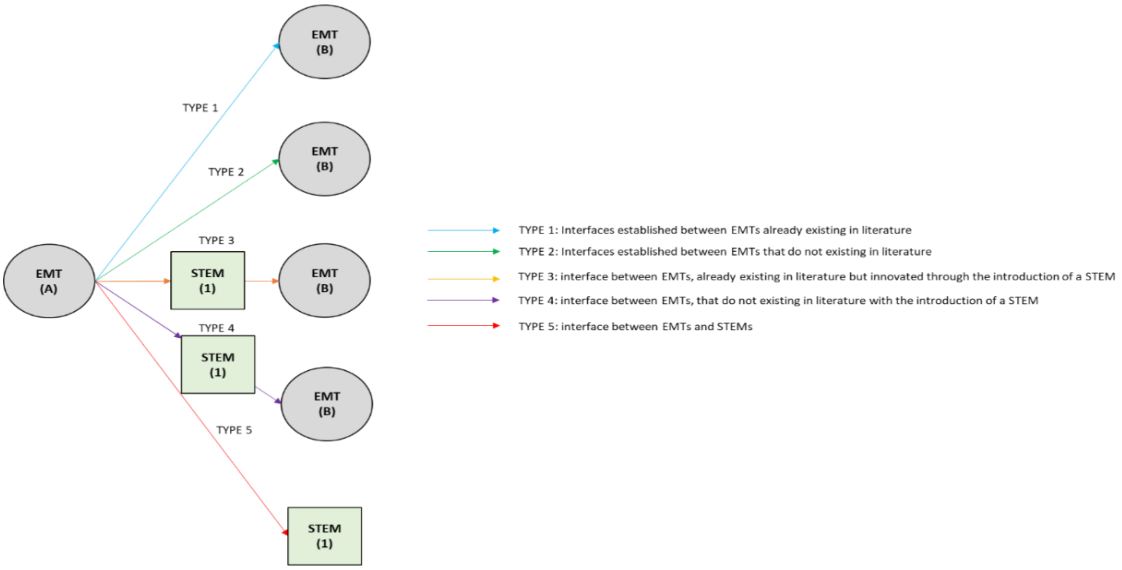


Figure 26 Different types of interfaces distinguished (Personal elaboration, 2017)

The interfaces have been designed starting from the stages that characterize each EMTs in order to describe the combination model (Mazzi et al., 2017), detailing every interaction between couple of EMTs and between EMTs and STEMs.

2.2.3.1. Interfaces EMS - EPE

In the case of the combination of EMS and EPE, as shown in the following figure, have been established six different interfaces.

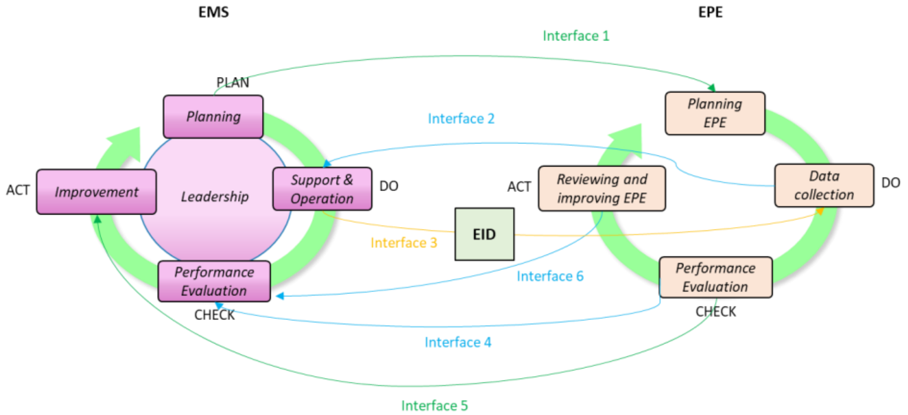


Figure 27 Interfaces established between EMS and EPE (Personal elaboration, 2017)

Interface 1: the EMS plans in function of the goals and targets set by Environmental Sustainability Strategy (Ecoefficiency and EcoBranding strategy components), the required activities of performance evaluation for all assessment scales (e.g. organizational, product, process) and the required environmental performance indicators (EPIs).

Interface 2: The EMS identifies the data required for the assessment.

Interface 3: The EMS requires that EID collects and make available data necessary for the assessment.

Interface 4: The EMS assess the results of EPE.

Interface 5: The EMS assess the hotspots identified and the improvement opportunities.

Interface 6: The EMS assess the necessity of reviewing of EPIs.

2.2.3.2. Interfaces EMS - EcoDesign

In the case of the combination of EMS and EcoDesign, as shown in the following figure, have been established five different interfaces.

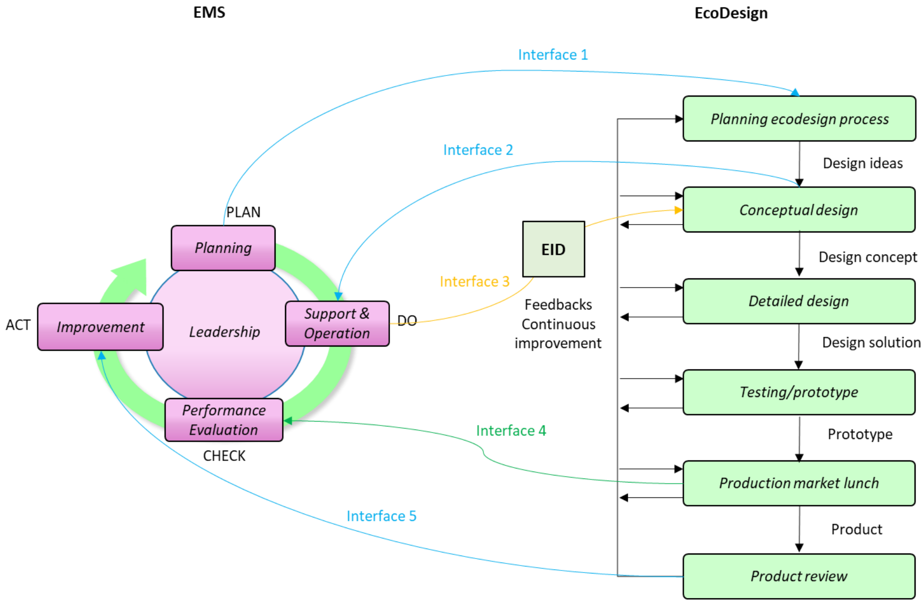


Figure 28 Interfaces established between EMS and EcoDesign (Personal elaboration, 2017)

Interface 1: the EMS plans in function of the goals and targets set by Environmental Sustainability Strategy (Ecoefficiency strategy component), the activities and projects of ecodesign.
Interface 2: The EMS identifies the data required for the assessment.
Interface 3: The EMS requires that EID collects and make available data necessary for the assessment.
Interface 4: The EMS assess the results of eco design projects.
Interface 5: The EMS assess the hotspots identified and the improvement opportunities for new ecodesign projects.

2.2.3.3. Interfaces EMS - EcoEcoefficiency

In the case of the combination of EMS and EcoEfficiency, as shown in the following figure, have been established four different interfaces.

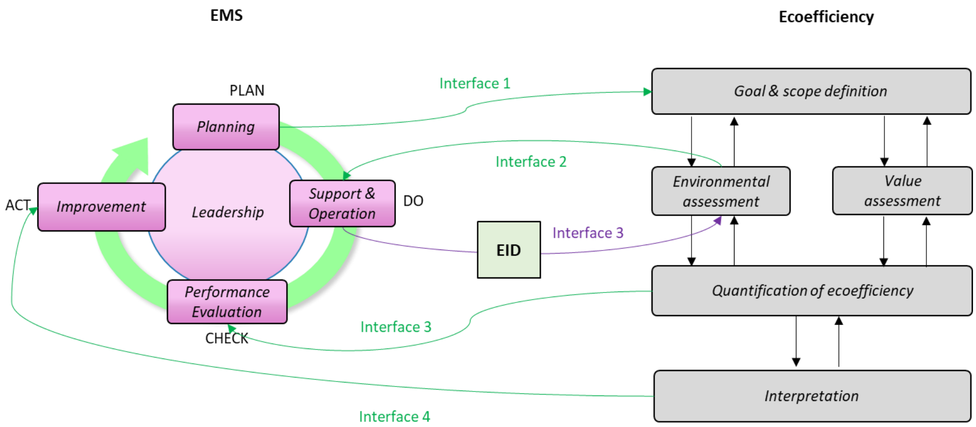


Figure 29 Interfaces established between EMS and EcoEfficiency (Personal elaboration, 2017)

Interface 1: the EMS plans in function of the goals and targets set by Environmental Sustainability Strategy (Ecoefficiency strategy component), the activities and projects of ecoefficiency.
Interface 2: The EMS identifies the data required for the assessment.
Interface 3: The EMS requires that EID collects and make available data necessary for the assessment.
Interface 4: The EMS assess the results of eco design project.
Interface 5: The EMS assess the hotspots identified and the improvement opportunities for new ecoefficiency projects.

2.2.3.4. Interfaces EMS – Communication tools

In the case of the combination of EMS and Communication tools, as shown in the following figure, have been established two different interfaces.

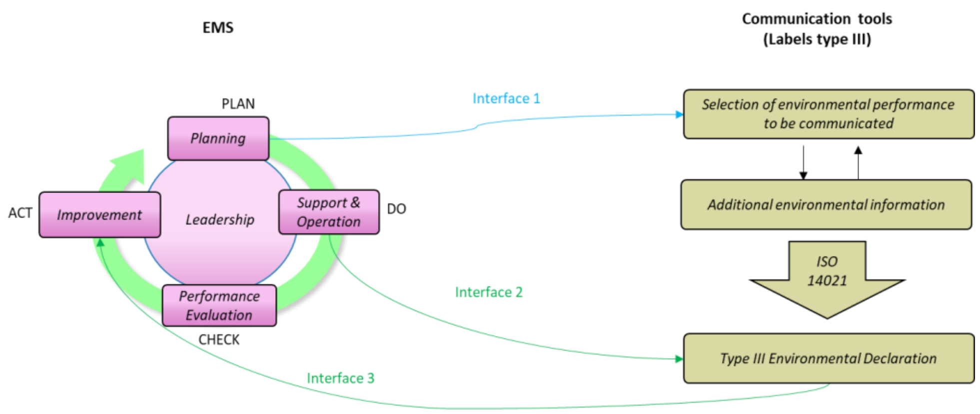


Figure 30 Interfaces established between EMS and Communication tools (Personal elaboration, 2017)

Interface 1: the EMS plans in function of the goals and targets set by Environmental Sustainability Strategy (EcoBranding strategy component), the activities of communication and environmental labelling (e.g. PEF, EPD).
Interface 2: the EMS support the elaboration of the communicative contents (e.g. claims)
Interface 3: The EMS assess the results of communication and environmental labelling activities identifying issues and improvement opportunities.

2.2.3.5. Interfaces EMS – LCA & OLCA

In the case of the combination of EMS and LCA, as shown in the following figure, have been established four different interfaces.

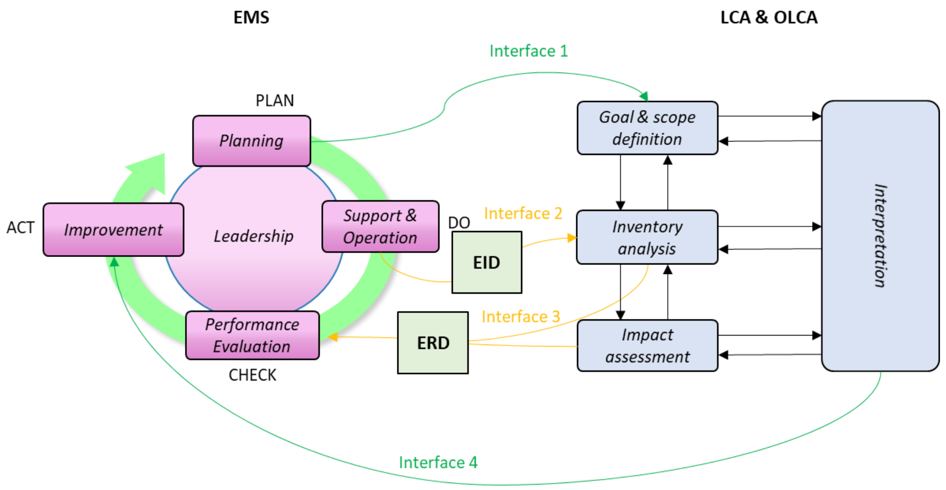


Figure 31 Interfaces established between EMS and LCA & OLCA (Personal elaboration, 2017)

Interface 1: The EMS plans the application of LCA & OLCA, considering goals and targets set by Environmental Sustainability Strategy, planned EPE activities, planned EcoDesign projects, planned EcoEfficiency projects and planned communication activities. EMS guides the definition of all methodological elements (e.g. system boundaries, functional unit, application of consolidation method, etc).
Interface 2: The EMS requires that EID collects and make available data necessary for the assessment.
Interface 3: The EMS requires that ERD stored and make available all results of inventory analysis (e.g. resource consumptions) and impact assessment analysis. The results are the base of performance evaluation.
Interface 4: The EMS assess the hotspots identified and the improvement opportunities deriving from interpretation of LCA & OLCA results.

2.2.3.6. Interfaces LCA & OLCA - EPE

In the case of the combination of LCA & OLCA and EPE, as shown in the following figure, have been established two different interfaces.

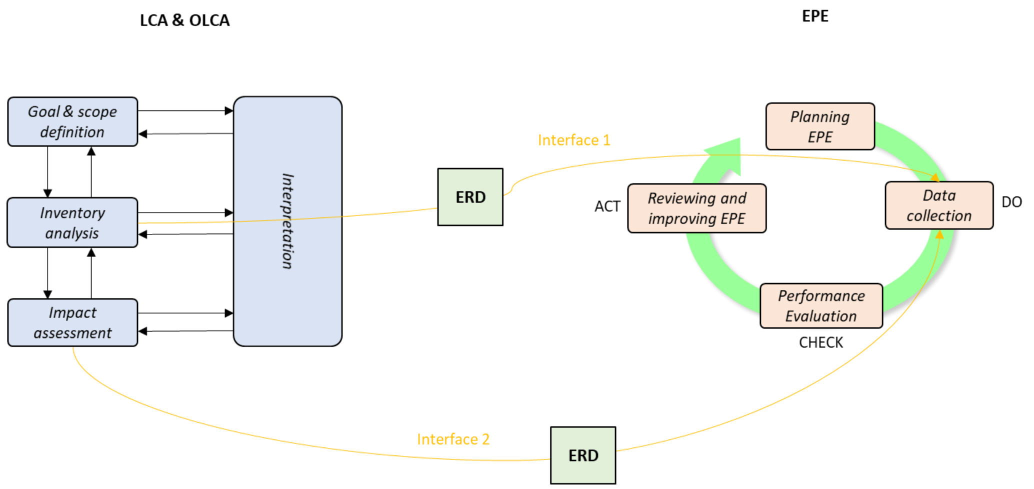


Figure 32 Interfaces established between LCA & OLCA and EPE (Personal elaboration, 2017)

Interface 1: The LCA & OLCA generates inventory results (e.g. resource consumptions) that are stored by ERD and feed to EPE for all assessment scales (e.g. organizational, product, process) in order to calculate EPIs.
Interface 2: The LCA & OLCA generates impact assessment results that are stored by ERD and feed to EPE for all assessment scales (e.g. organizational, product, process) in order to calculate EPIs.

2.2.3.7. Interfaces LCA & OLCA - EcoDesign

In the case of the combination of LCA & OLCA and EcoDesign, as shown in the following figure, have been established three different interfaces.

Interface 1: According to ecodesign projects planned by EMS, the Ecodesign tool influences the definition of methodological elements used to applied LCA and OLCA (e.g. system boundaries, functional unit, application of consolidation method, etc).
Interface 2: The results generated by inventory analysis and by impact assessment analysis are all stored by ERD. The results relevant for ecodesign projects are make available in order to be used for to simulate ecodesign alternatives during the conceptual design stage.
Interface 3: The information acquired by LCA interpretation stage are used to identifiy design concept, to refine the design solutions or to solve any hotspots identified in order to finalized the design solutions.

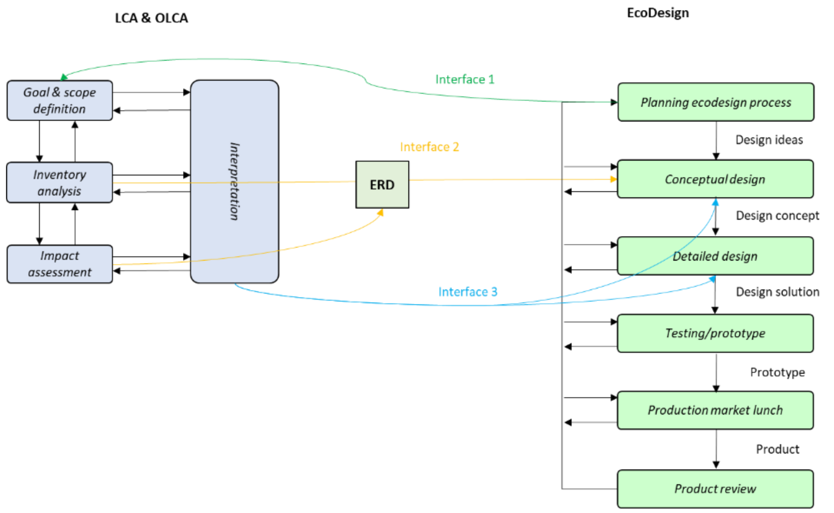


Figure 33 Interfaces established between LCA & OLCA and EcoDesign (Personal elaboration, 2017)

2.2.3.8. Interfaces LCA & OLCA - EcoEfficiency

In the case of the combination of LCA & OLCA and EcoEfficiency, as shown in the following figure, have been established two different interfaces.

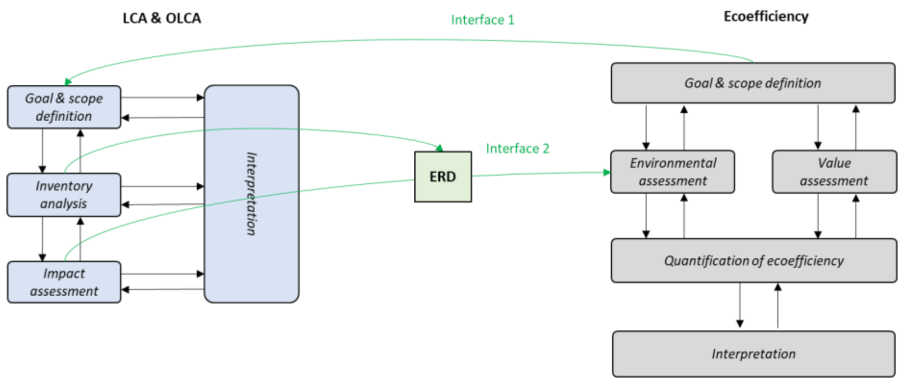


Figure 34 Interfaces established between LCA & OLCA and EcoEfficiency (Personal elaboration, 2017)

Interface 1: According to ecoefficiency projects planned by EMS, the Ecoefficiency tool influences the definition of methodological elements used to applied LCA and OLCA (e.g. system boundaries, functional unit, application of consolidation method, etc).
Interface 2: The results generated by inventory analysis and by impact assessment analysis are all stored by ERD. The results relevant for ecoefficiency projects are make available in order to be used to assess ecoefficiency performance.

2.2.3.9. Interfaces EPE – Communication tools

In the case of the combination of EPE and Communication tools, as shown in the following figure, has been established one interface.

Interface 1: According to goals and targets regarding EcoBranding strategy component provide by EMS, the communications tool acquires by EPE the required environmental performance at inventory level (e.g. resource consumptions) and at impact assessment level, for all assessment scales (e.g. organizational, product, process).

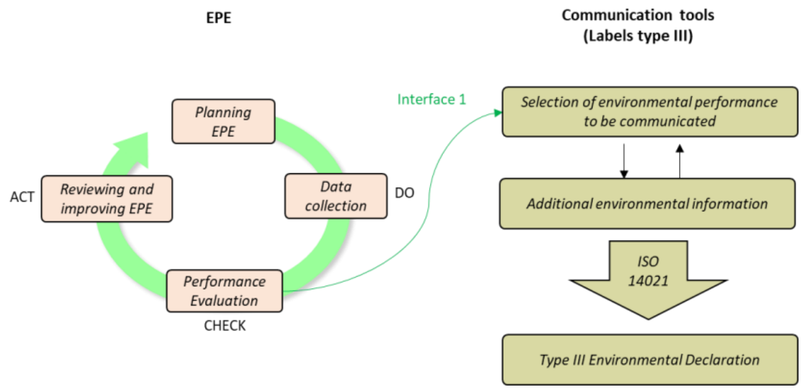


Figure 35 Interfaces established between EPE and Communication tools (Personal elaboration, 2017)

2.2.3.10. Interfaces EMS - ESSM

In the case of the combination of EMS and Environmental Sustainability Strategy Model (ESSM), as shown in the following figure, have been established two interfaces.

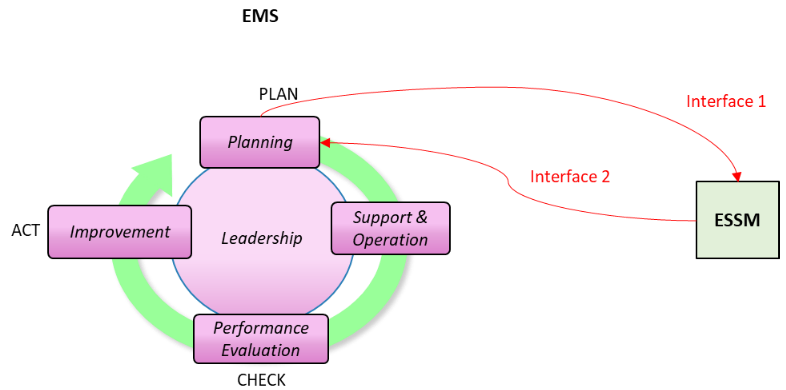


Figure 36 Interfaces established between EMS and ESSM (Personal elaboration, 2017)

Interface 1: The EMS gives in input goals and targets to ESSM regarding the ecoefficiency component of the strategy and the ecobranding component of the strategy. Furthermore, the EMS provides to ESSM previously environmental performance for the different assessment scales (e.g. organizational, product, process) and all planned ecodesign and ecoefficiency projects (ecoefficiency strategy component) and all planned communication activities (ecobranding strategy component).
Interface 2: The ESSM gives feedbacks to EMS planning stage to improve and calibrate correctly the environmental sustainability strategy of the organization.

2.2.3.11. Interfaces LCA & OLCA – MLCA model

In the case of the combination of LCA & OLCA and Multiscale LCA model (MLCA), has shown in the following figure, have been established five interfaces.

Interface 1: The methodological elements (e.g. system boundaries, functional unit, application of consolidation method, etc) defined by EMS (considering planned EPE activities, planned EcoDesign projects, planned EcoEfficiency and planned communication activities) guide the creation of the MLCA model.
Interface 2: The data provides by EID to inventory LCA analysis are feed to MLCA model.
Interface 3: The MLCA model returns results at inventory level (e.g. resource consumptions) for all the assessment scales required such as organizational, site, family of product, single products and specific life cycle processes.

Interface 4: The environmental impact assessment methods are applied to MLCA model in order to calculate the environmental impacts or environmental damages respectively for each midpoint impact category or endpoint damage category.
Interface 5: The MLCA model returns results at impact assessment level for all the assessment scales required such as organizational, site, family of product, single products and specific life cycle processes.

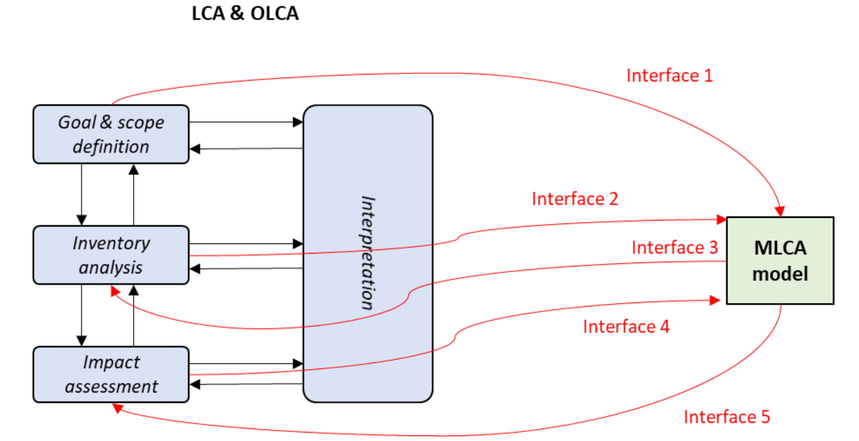


Figure 37 Interfaces established between LCA & OLCA and MLCA model (Personal elaboration, 2017)

2.2.3.12. Interfaces EPE – Eco-EKA

In the case of the combination of EPE and Eco Environmental KPI Analyzer (Eco-EKA), has shown in the following figure, have been established three interfaces.

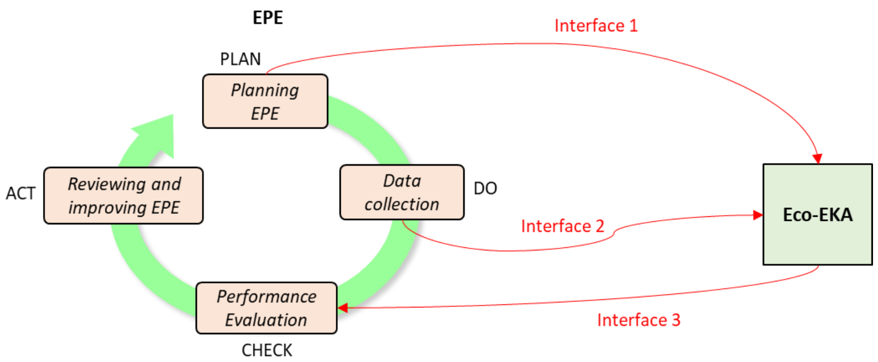


Figure 38 Interfaces established between EPE and Eco-EKA (Personal elaboration, 2017)

Interface 1: In function of the EPE activities planned by EMS for the different assessment scales (e.g. organizational, site, family of product, single products and specific life cycle processes) the Eco-EKA identify the required EPIs.

Interface 2: The data provides by ERD for the EPE data collection stage (inventory data and impact assessment data) are feed to Eco-EKA.

Interface 3: The Eco-EKA returns the results in terms of Inventory Operative Performance Indicators (IOPIs) and of Environmental Operative Performance Indicators (EOPIs) for all the assessment scales such as: organizational, site, family of product, single products and specific life cycle processes.

2.2.3.13. Interfaces EcoDesign – Eco-DSD

In the case of the combination of EcoDesign and EcoDesign Simulation Dashboard (Eco-DSD), has shown in the following figure, have been established five interfaces.

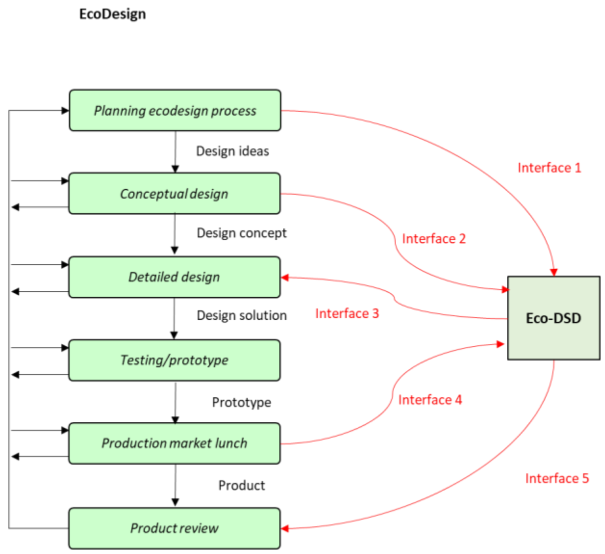


Figure 39 Interfaces established between EcoDesign and Eco-DSD (Personal elaboration, 2017)

Interface 1: In function of the Ecodesign projects planned by EMS the Eco-DSD identifies the LCA methodological elements (e.g. system boundaries, functional unit, cut-off criterion, other elements of goal &scope definition LCA stage relevant for this tool) for each ecodesign project that must be assessed.
Interface 2: The data provides by ERD for the ecodesign assessment (inventory data and impact assessment data) are feed to Eco-DSD in the case of each ecodesign project for the assessment of the environmental performance of design concept.
Interface 3: The Eco-DSD returns the results in terms of environmental performance, functional performance and economic performance for all ecodesign alternatives assessed in order to support the identification of the design solution for each ecodesign project.
Interface 4: Consolidated data are feed to Eco-DSD in order to assess the consolidated real environmental performance of each ecodesign project realized.
Interface 5: The Eco-DSD returns the consolidated results on environmental performance of each ecodesign project in order to verify the respect of the expected environmental performance.

2.2.3.14. Interfaces EcoEfficiency - IWEE

In the case of the combination of EcoEfficiency and Indicator of Work Environmental Efficiency (IWEE), has shown in the following figure, have been established four interfaces.

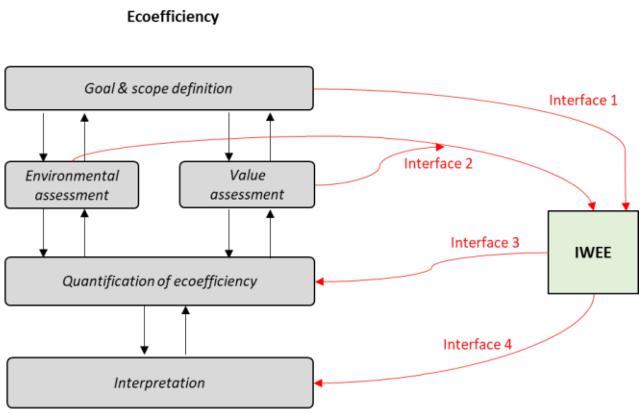


Figure 40 Interfaces established between EcoEfficiency and IWEE (Personal elaboration, 2017)

Interface 1: In function of the Ecoefficiency projects and activities planned by EMS regarding core processes performed by organization, the IWEE identifies the LCA methodological elements required for the assessment (e.g. system boundaries, reference flow, cut-off criterion, other elements of goal &scope definition LCA stage relevant for this tool). As core processes are intended the productive processes performed by the organization inside its organizational system boundaries.

Interface 2: The data provides by ERD for the ecoefficiency assessment (inventory data and impact assessment data) are feed to IWEE for the assessment of the ecoefficiency of the core processes performed by the organization.

Interface 3: The IWEE returns the results on ecoefficiency for each core processes assessed.

Interface 4: The IWEE returns feedbacks to support the comprehension of ecoefficiency trends and to support the identification of hotspots and improvement opportunities

2.2.3.15. Interfaces EPE, EcoDesign, EcoEfficiency – SEDM Module

In the case of the combination of EPE, EcoDesign, EcoEfficiency and Strategic Environmental Decision Making module (SEDM module), has shown in the following figure, have been established six interfaces.

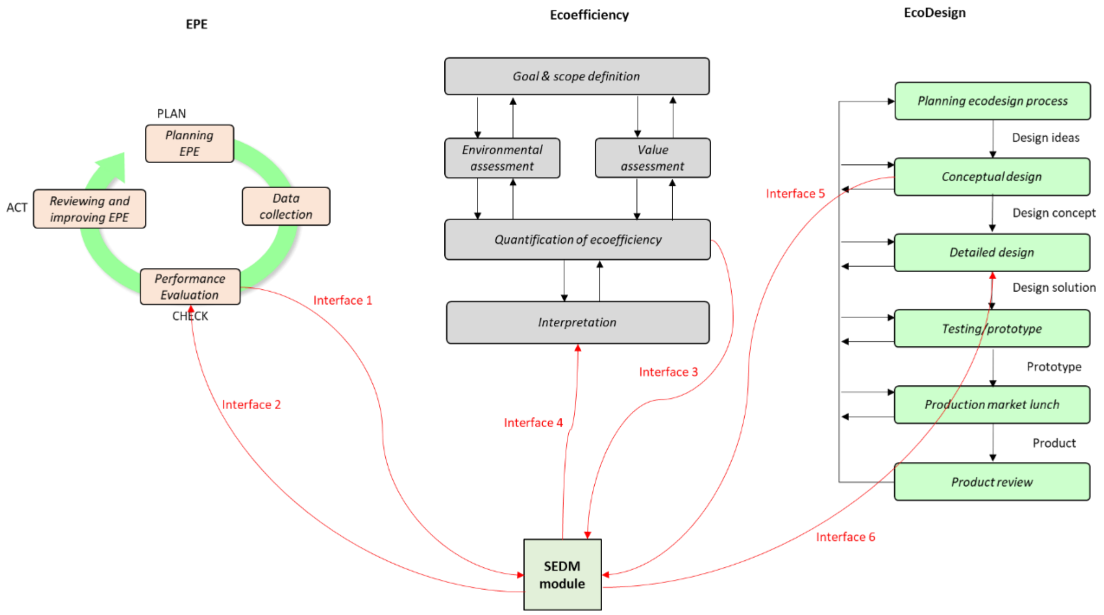


Figure 41 Interfaces established between EPE, EcoDesign, EcoEfficiency and SEDM module (Personal elaboration, 2017)

Interface 1: data on EPE that must be statistically analysed or mathematically optimized are fed to SEDM module.

Interface 2: SEDM module returns statistical criteria or optimized solutions to define improvement scenarios of environmental performance.

Interface 3: data on Ecoefficiency projects that must be statistically analysed or mathematically optimized are fed to SEDM module.

Interface 4: SEDM module returns statistical criteria or optimized solutions to define improvement scenarios of ecoefficiency performance.

Interface 5: data on Ecodesign projects that must be statistically analysed or mathematically optimized are fed to SEDM module.

Interface 6: SEDM module returns statistical criteria or optimized solutions to define improvement ecodesign solutions.

2.2.4. Development of new specific STEMs

The Organizational Environmental Sustainability System (OES2), beyond proposes a new method to combine EMTs, is based on the introduction of innovative specific STEMs. The STEMs represent an innovation in the development of methods for multiple EMTs and they have been introduced in order to solve gaps emerged at the second level of intervention (see table 18, paragraph 2.2.1) mainly related to the implementation of EMTs, increasing the capacity of OES2 to propose operative solutions to face those issues. Furthermore, being the research object the propose of a new method to combine EMTs, the STEMs can be seen as supportive methodological elements in order to improve the operative use of the new method proposed. Totally have been developed eight STEMs:

- STEM 1: Multiscale LCA (MLCA), mathematical model for multiscale approach;
- STEM 2: Environmental Inventory Database (EID);
- STEM 3: Environmental Results Database (ERD);
- STEM 4: Eco Environmental KPI Analyzer (Eco-EKA);
- STEM 5: Eco-Design Simulation Dashboard (Eco-DSD);
- STEM 6: Indicator of Work Environmental Efficiency (IWEE);
- STEM 7: Environmental Strategic Decision Making module (SEDM).
- STEM 8: Environmental Sustainability Strategy Model (ESSM);

In the following paragraphs have been descripted all STEMs development by the methodological perspective while in the next chapter will be presented the results obtained from the application to the single case study regarding the Acqua Minerale San Benedetto S.p.A. multisite organization.

2.2.4.1. STEM 1: Multiscale LCA (MLCA) model

The Multiscale LCA (MLCA) model has been introduced in OES2 in order to solves the issue related to the mathematical correlation between the different assessment scales (organizational, site, product, process) of the life cycle environmental performance. Furthermore, it supports operatively, in combination with OLCA (ISO/TS 14072) and LCA (ISO14040-44) methodologies, the solution of the other gaps. The following table shows the specific gaps related to environmental impact assessment:

Life Cycle Management Critical Areas	Identified gaps
Environmental impacts assessment	Lack of Environmental Impact Assessment – Product Level
	Lack of Environmental Impact Assessment – Organizational Level
	Correlation between product and organizational scale not considered
	Lack of comprehensive impact assessment (Multi-indicators)
	Issues on hotspots identification and on burdens shifting
	Lack of Life Cycle Management approach
	Impact assessment based on inventory indicators

Table 24 Gaps faced by the STEM “Multiscale LCA (MLCA) model”

The birth of OLCA methodology (ISO, 2015; UNEP, 2015) has introduced a new paradigm on the relationship between life cycle impact of an organization and the life cycle impact of its products. This aspect has been underlined also from the new revision of ISO14001:2015. The following figure shows the three-dimensional relationship between products life cycles and the organizational life cycle in the case of more than one environmental impact category.

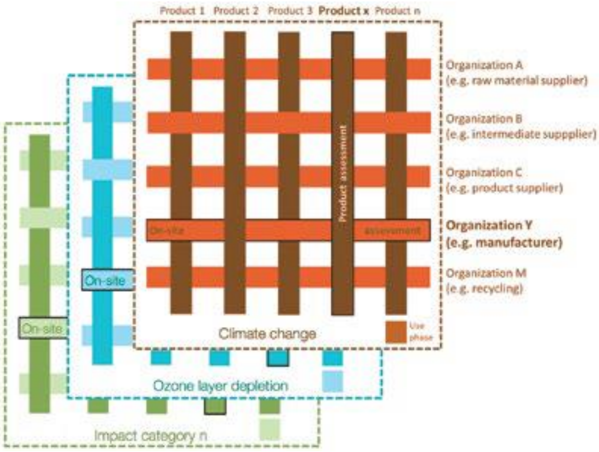


Figure 42 Qualitative representation of the relationships between organizational life cycle and the life cycles of its products (UNEP, 2015)

In this context, the development of a new mathematical model to assess environmental impacts and resource consumptions with a multiscale approach is a very key innovative methodological element introduced by OES2. The multiscale approach is essential to solve the potential contradictions between the environmental performance of products and of the organization. The comprehensive evaluation of the organization is a very strategic point in order to have a global management view and increase the opportunity to improve environmental and economic performance.

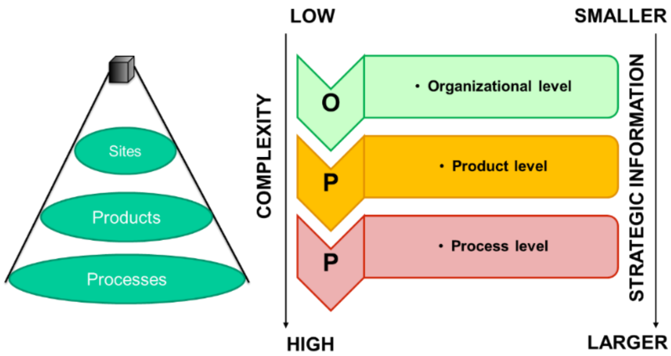


Figure 43 Multiscale assessment approach on which is based OES2 (Personal elaboration, 2016)

When an organization exposes its image, sponsoring the environmental performance of some products, it must ensure that also its global environmental performance is good. In fact, case where the organization has a bad environmental performance despite some its products have good environmental performance can be seen by stakeholders as a green washing communication. Also, the case where the global performance of organization is good but the environmental performance of some products are bad, should be avoided when the products are positioning in a market where competitors' products have better performance and where the stakeholders' awareness is high. Focusing on life cycle methodology, that in the field of environmental impact assessment is more comprehensive considering a profile of impact categories, until 2015, LCA were applied only to products as shown in the following figure.

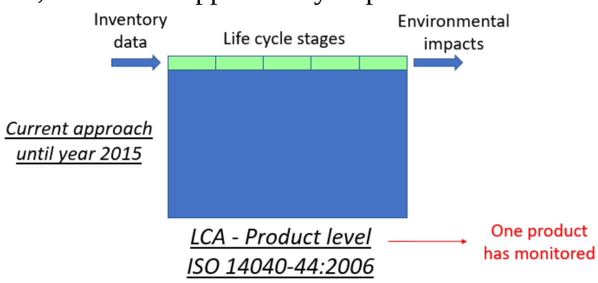


Figure 44 LCA environmental impact assessment approach until year 2015, only applied to product. (Personal elaboration, 2016)

Therefore, whit this application, are possible to assess the environmental impacts of a product for each life cycle stages. During the year 2015, the new ISO/TS 14072 has been lunched by ISO in order to extend the application of LCA to organization. The following figure shows the effects.

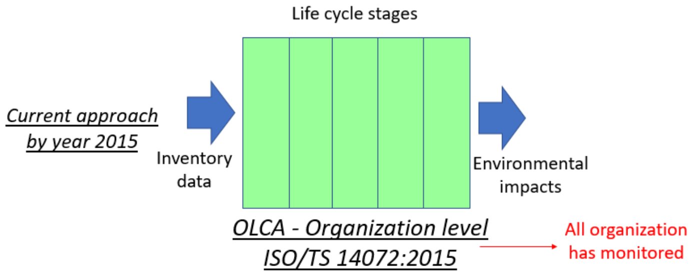


Figure 45 LCA environmental impact assessment approach by year 2015, applied also to organization. (Personal elaboration, 2016)

Whit this application it is possible to assess the environmental impacts of the whole organization or a part of it (using the consolidation method) for each life cycle stages. Analysing the two approaches for LCA application, emerge clearly two very weak points. In order to understand the weaknesses, it is important to consider the following two aspects:

1. The environmental performance of an organization is linearly dependent from environmental performance of the products;
2. The investments of an organization to improve its environmental and economic performance are generally focus on product (e.g. ecodesign) and process scale (e.g. new eco-friendly technologies). Therefore, products and processes can be seen as the most important levers to manage and improve the environmental and economic performance of an organization.

Therefore, considering these two aspects, it is possible to understand the weaknesses:

1. The application of LCA methodology (ISO 14040-44:2006) to product and the application of LCA methodology (ISO/TS 14072:2015) to the same organization is not an efficient and comprehensive solution because: the separate application required the development of two impact assessment models, the link between environmental performance of organization and the performance of its products is missed. Therefore, the organization is not able to completely understand and explain the causes that have determine the environmental performance trend and is not able to identify all hotspots;
2. The organization do not acquire information on the potential effects of its investments at product and process scale on its environmental performance. It exposes the organization to two main risks: do not select the better investments to improve environmental performance, generate some burdens shifting problems (improve the environmental performance of a product but worse the performance of the organization or of another products).

The MLCA model, permitting to assess concurrently all the assessment scales, permits to obtain the same results using only one model. In this way the MLCA model, beside improve the stage of model development, requiring only one model, simplifies also the maintenance over the time of the model reducing the activities for the model update (data entry and modification of the model structure) that will not be repeated twice but only one. This issue is one of the most important EMB that an organization must be faced as emerged during the scientific literature review (Zvezdov et al, 2016).

Basically, in this context, the environmental impact assessment performed by OES2 is based on a multiscale mathematical model that has been developed following the change of approach shows in the following figure. This new mathematical model, has been developed also considering the request emerged from Martine-Blanco et al. (2016) of to establish a framework to link outputs calculated in terms of resources consumption and environmental impacts to the different components of the products portfolio (Zvezdov et al., 2016).

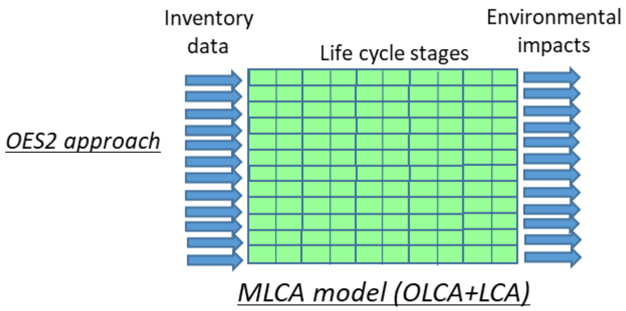


Figure 46 Multiscale life cycle environmental impact assessment approach introduced by OES2. (Personal elaboration, 2016)

This mathematical model works in the same time as process, product, single site and whole organization permitting a full-scale assessment. It has been developed following these steps:

1. Mathematical conceptualization;
2. Development of the model in a software space;
3. Test of the model in a real case study (application to the Acqua Minerale San Benedetto S.p.A. organization).

2.2.4.1.1. Mathematical conceptualization

The mathematical description of the model is the first important step and start by considering the three dimensions that the model shall to consider (see figure below).

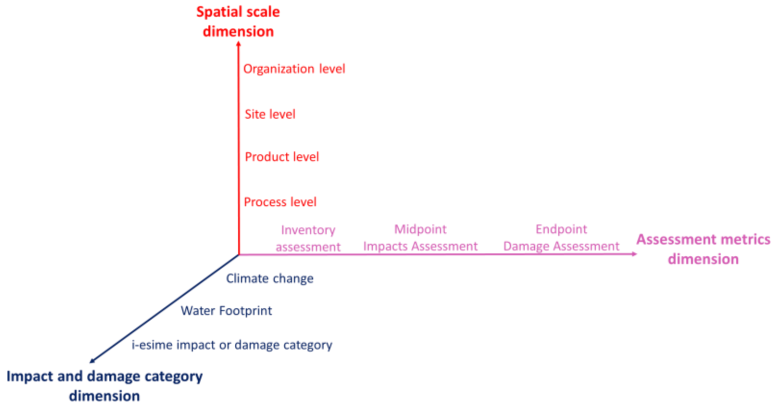


Figure 47 Three dimensions at the base of mathematical conceptualization of the model. (Personal elaboration, 2016)

The previous figure introduces the three dimensions considered to develop the model:

- **The spatial scale dimension:** is related to the capacity of the model to consider different scale of assessment and ensure the mathematical relationships between the different scales of aggregation;
- **The assessment metric dimension:** is related to the capacity of the model to assess the inventory results, mainly related to resource consumptions, and to assess the environmental impacts results generated;
- **The impact and damage category dimension:** is related to the capacity of the model to assess the environmental impacts generated in function of international standardized impact and damage categories in order to obtain a comprehensive impact assessment profile.

Following has been conceptualized the mathematical description for a general case of a multisite organization that include j sites that produce k different products. The following variable can be introduced:

$\beta_{k,j}$ = is the number of unit of the $k-esime$ product produced by the $j-esime$ site in a year.

A reporting period of one financial year has been used as reference. Each product' life cycle is constituted by p life cycle processes. Each process is characterized by input and output material and energy flows. Therefore, the following variables can be introduced:
$c_{s,l,p}$ = is the consumption of the $s-esime$ substance from the $l-esime$ environmental compartment generated for the production of one unit of the output of process $p-esime$ (e.g. 1 kg of plastic, 1 kWh of electricity);
$e_{s,l,p}$ = is the emission of the $s-esime$ substance in the $l-esime$ environmental compartment generated for the production of one unit of the output of process $p-esime$ (e.g. 1 kg of plastic, 1 kWh of electricity);
The environmental compartments considered are: air, water, land and natural resources. In fact, each process related to transform material (e.g. plastic) or energy flow (e.g. electricity) is bring back to the elementary material (e.g. natural available chemicals substances) and energy flows (e.g. natural available energy resources) that are extracted from the environmental compartments (Ecoinvent, 2017). In order to transform the inventory consumptions and emissions of the $s-esime$ substance in environmental impacts have been introduced a specific impact assessment method for each $i-esime$ impact category considered. The impact assessment methods are mathematical functions specific for each $i-esime$ impact category that permits to transform the inventory consumptions and emissions of the $s-esime$ substance in environmental impacts. These mathematical functions could be linear or nonlinear and are generally named characterization factors. It is possible to distinguish characterization factors related to midpoint impact categories ($f_{s,l,mi}$) from characterization factors related to endpoint damage categories ($f_{s,l,ei}$).

$$i_{s,l,mi,p} = \left(c_{s,l,p} + e_{s,l,p}\right) \cdot f_{s,l,mi} \quad [2.1]$$

$$d_{s,l,ei,p} = \left(c_{s,l,p} + e_{s,l,p}\right) \cdot f_{s,l,ei} \quad [2.2]$$

The total environmental impact at midpoint level on the $mi-esime$ midpoint impact category and the total damage at endpoint level on the $ei-esime$ endpoint category has been obtained in the following way (Goedkoop et al., 2013):

$$i_{mi,p} = \sum_{l=1}^{l}\left(\sum_{s=1}^{s} i_{s,l,mi,p}\right) \quad [2.3]$$

$$d_{ei,p} = \sum_{l=1}^{l}\left(\sum_{s=1}^{s} d_{s,l,mi,p}\right) \quad [2.4]$$

The terms $i_{mi,p}$ and $d_{ei,p}$ represent the environmental impacts and damages generated by the $p-esime$ processes for the generation of a unit of output respectively on the $mi-esime$ midpoint impact category and on the $ei-esime$ endpoint damage category. These terms area also commonly named emission factors and damage factors.
The production of the $k-esime$ product produced by $j-esime$ site required different consumptions of the flows generated by the $p-esime$ processes that characterized its life cycle. These consumptions have been descripted with the variable $\alpha_{p,k,j}$.
Therefore, the inventory resource consumptions and emissions of the $s-esime$ substance generated in each $l-esime$ environmental compartment from the production of a single unit of product $k-esime$ produced by the $j-esime$ site considering the whole life cycle is given by:

$$C_{s,l,k,j} = \sum_{p=1}^{p}\left(\alpha_{p,k,j} \cdot c_{s,l,p}\right) \quad [2.5]$$

$$E_{s,l,k,j} = \sum_{p=1}^{p}\left(\alpha_{p,k,j} \cdot e_{s,l,p}\right) \quad [2.6]$$

And the environmental impacts and damage are given by:

$$I_{mi,k,j} = \sum_{p=1}^{p} \left(\alpha_{p,k,j} \cdot i_{mi,p} \right) \quad [2.7]$$

$$D_{ei,k,j} = \sum_{p=1}^{p} \left(\alpha_{p,k,j} \cdot d_{ei,p} \right) \quad [2.8]$$

As first attempt, it is possible to calculate the environmental impacts and damages generates by the $j-esime$ production site as the sum of environmental impacts and damages generates by each $k-esime$ production:

$$I_{mi,j}{}' = \sum_{k=1}^{k} \left(\beta_{k,j} \cdot i_{mi,k,j} \right) \quad [2.9]$$

$$D_{ei,j}{}' = \sum_{k=1}^{k} \left(\beta_{k,j} \cdot d_{ei,k,j} \right) \quad [2.10]$$

These two equations could be potentially incomplete because it would not allow to consider the environmental impacts and damages deriving by other activities commonly performed by organizations such as: creation of stocks, production of semi-finished products that will be used in the next reporting period. In other to include this aspect the variables $\varphi_{mi,j}$ and $\varphi_{ei,j}$ have been introduced. The calculation of these contributions starting from the resource consumption and emissions generates by these additional activities following the same previously calculation procedure. The correct equations are therefore:

$$I_{mi,j} = I_{mi,j}{}' + \varphi_{mi,j} = \sum_{k=1}^{k} \left(\beta_{k,j} \cdot I_{mi,k,j} \right) + \varphi_{mi,j} \quad [2.11]$$

$$D_{ei,j} = D_{ei,j}{}' + \varphi_{ei,j} = \sum_{k=1}^{k} \left(\beta_{k,j} \cdot D_{ei,k,j} \right) + \varphi_{ei,j} \quad [2.12]$$

Finally, the environmental impacts and damages for the whole organization have been modelled as the sum of the contribution generated by each production site.

$$I_{mi} = \sum_{j=1}^{j} \left(I_{mi,j}{}' + \varphi_{mi,j} \right) = I_{mi}{}' + \varphi_{mi} \quad [2.13]$$

$$D_{ei} = \sum_{j=1}^{j} \left(D_{ei,j}{}' + \varphi_{ei,j} \right) = D_{ei}{}' + \varphi_{ei} \quad [2.14]$$

The equations set previously shown constitutes the multilinear equations system that permits to correlate the environmental performance of the different assessment scales (process, product, site, organization), to assess inventory resource consumptions, the environmental impacts at midpoint level and the damages at endpoint level considering different impact and damage categories. The variables I_{mi} and D_{ei} can be mathematically described also as vectors with many components as are the environmental impact categories and the environmental damage categories considered.

2.2.4.1.2. Developed of the model in a software space

In order to apply the mathematical model conceptualized, is necessary to develop the model in a software space. For the present research work it has been chosen the SimaPro (Prè; 2017), the most diffuse software in the field of LCA worldwide.

A short description on this software has been provided at the end of this paragraph. In this software space it is possible to develop life cycle models for the calculation of life cycle environmental impacts of products and organizations. In order to develop the MLCA model, has been used a novel multiparametric programming approach using the SimaPro programming language to write the equations that links flows and modules that characterize the life cycle model. This approach requires high expertise on SimaPro programming and has required the SimaPro licence type "Developer" (see example figures 105 and 106). This type of modelling strategy is very important to build a model able to manage of large products portfolio (Zvezdov et al., 2016) with high efficiency in computational terms and in terms of simplicity of maintenance for the updating.

In fact, the present model has been developed in order to face an ambitious task to manage product portfolio of hundreds or thousands of products produced in many sites (Zvezdov et al., 2016; Meinrenken et al., 2012).

The SimaPro undergoes a modular approach where each process and each material and energy flow can be modelled as a module. Therefore, the number of modules will be equal to the total number of processes and material/energy flows included in the model.

1. **Processes and flows characterization**: in this first step, all the processes and material/energy flows are identified and associated to each $k - esime$ product produced by the $j - esime$. This step requires the detailed study of the life cycles of different products and the visit of the most relevant production sites. The processes and flows analysis will be presented in the next chapter for the case study on the organization Acqua Minerale San Benedetto S.p.A.;
2. **Data collection and database selection**: for each process and material/energy flows shall be collected all data. A part of the processes and material/energy flows are outside to the organization boundaries and requires the use of international recognized database. Primary data are collected for all processes under control of the organization and for some processes outside the organization' boundaries when collaborative data exchange activities are realized for example with suppliers. Maintaining the parallelism with the mathematical model this step permits of obtain the variables:

   $c_{s,l,p}$ (generally secondary data from database);

   $e_{s,l,p}$(generally secondary data from database);

   $\alpha_{p,k,j}$(primary data for processes under organization' control, secondary or tertiary data for others processes*);

   $\beta_{k,j}$(primary data).

   *In some cases, data are obtained from tertiary sources that are scientific international papers & books; reports of national and international organizations, etc. An example can be the scenarios of national waste disposal scenarios. In the case of the present research, the Ecoinvent database has been used and at the end of this paragraph a short description has been provided.

   Regarding the primary data, with the OES2 method the data collection process has been automatized thanks to the introduction of the EID (Environmental Inventory Database) that will be presented in the following paragraph.
3. **Modules building**: for each process and material/energy flow is built a module. The module can be seen as the base list of the processes and material/energy flows that occur in order to obtain a specific process of material/energy transformed flow (e.g. the production of a plastic bottle requires the PET plastic production and the process of blow moulding which in turn require the consumptions of electricity and other material/energy flows). In the following figure has been shown an example of empty SimaPro module.

   The module is the basic unit to model in the SimaPro software space and permits to identify the inputs and the outputs that characterize the process. The inputs can be material and energy transformed flows (e.g. plastic, electricity) mainly in the case of the modules built by the user or substances extracted by the different environmental compartments as in the case of databases (e.g. Ecoinvent). The outputs can be material and energy transformed flows (e.g. plastic bottle, steam) mainly in the case of the modules built by the user and substances emitted in the different environmental compartments as in the case of punctual emissions or in the case of databases. In the SimaPro it is possible to distinguish 5 different categories of modules (that contain more than 100 subcategories) in function of the content: material modules, energy modules, transport processes modules, transformation modules and disposal processes modules. The user can be build new modules and it is advisable that maintain coherence with these types. Normally, it is better to build modules following the sequence before reported.

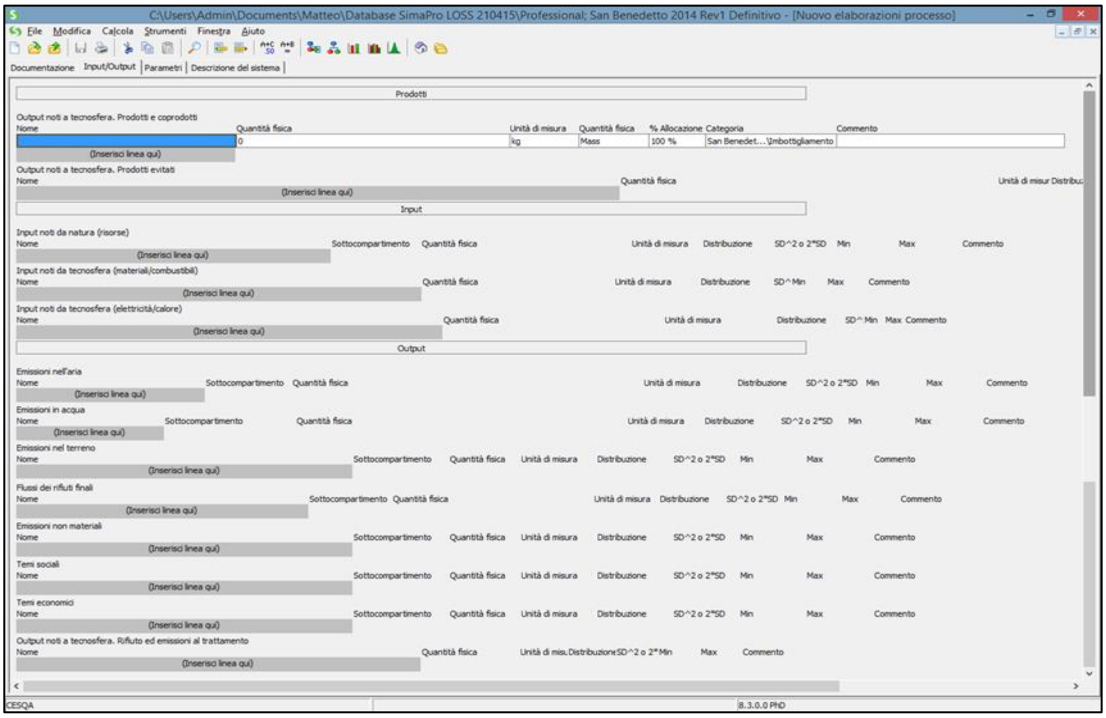


Figure 48 Example of multiparametric SimaPro programming

4. **Life cycle modules connection structure**: the previously built modules must be now connected. The connection is established with recalling as input one module in a another module. The connections must be established coherently with the real processes sequence. When all the modules related to one product are connected one complete product life cycle system is obtained. Maintaining the parallelism with the mathematical model this step permits of obtain the following equations for the production of a single unit of product $k-esime$ produced by the $j-esime$ site:

$$c_{s,l,k,j} = \sum_{p=1}^{p} \left(\alpha_{p,k,j} \cdot c_{s,l,p}\right) \quad [2.15]$$

$$e_{s,l,k,j} = \sum_{p=1}^{p} \left(\alpha_{p,k,j} \cdot e_{s,l,p}\right) \quad [2.16]$$

5. **Standardization of life cycle modules connection structure:** in the case of organization characterized by product portfolios with a large number of products the standardization of the structure of the model of the single product is a fundamental step in order to ensure the fast replication of the software code in order to extend the model to other products. The following methodological steps are required:
   - Product category identification: with an approach based on opportunities and efforts the organization must be groups the products of product portfolio in homogenous categories.
   - Model structure standardization: one standardized model structure is defined for each product category identified. Therefore, all products of the same category will have the same SimaPro life cycle model structure. This modular approach to modelling has been already positively applied in different fields, such as Water Footprint calculation (Manzardo et al., 2016b). The information that distinguish the products of the same categories can be generally associated to differences in the model structure and differences in the data used. Starting from the only one

model structure realized at step **4** modifies are introduced in order to completely ensure the transfer of the information on differences only into the data. In this way products of the same category have the same model structure but maintain the differences that characterized them into the data used. The transfer of the information on differences to data generally require an important work of creation of mathematical functions to diversify the different consumptions of the same material/energy flow related to different products of the same category. For example, products of the same category could be produced with technologies that have different consumptions of the same auxiliary utility (e.g. cooling water), therefore a rule to diversify the consumption must be modelled. This aspect will be faced in the paragraph on the creation of a new inventory data management database (EID).

6. **Data feeding**: the collected data must be feeding to the modules. In OES2 the process of feeding is automatic thanks to the introduction of the EID (Environmental Inventory Database) that will be presented in the following paragraph. In order to feed external data to SimaPro software the special license "Developer" is required (see figure 106). The data feeding process is realized establish a programmable link between the modules and the different sections of the EID.
7. **Replication of standardized life cycle modules connection structures:** in this methodological step, the standardized life cycle modules connection structures are replicated in order to model all products for each products category. The replication process requires the modification of programmable links because in the EID the data related to each product have a different section.
   The same procedure can be applied to the different production site. Maintaining the parallelism with the mathematical model this step permits of obtain the global equations for consumptions and emissions:

$$c_{s,l} = \sum_{j=1}^{j}\left(\sum_{k=1}^{k}(\beta_{k,j} \cdot c_{s,l,k,j})\right) \quad [2.17]$$

$$e_{s,l} = \sum_{j=1}^{j}\left(\sum_{k=1}^{k}(\beta_{k,j} \cdot e_{s,l,k,j})\right) \quad [2.18]$$

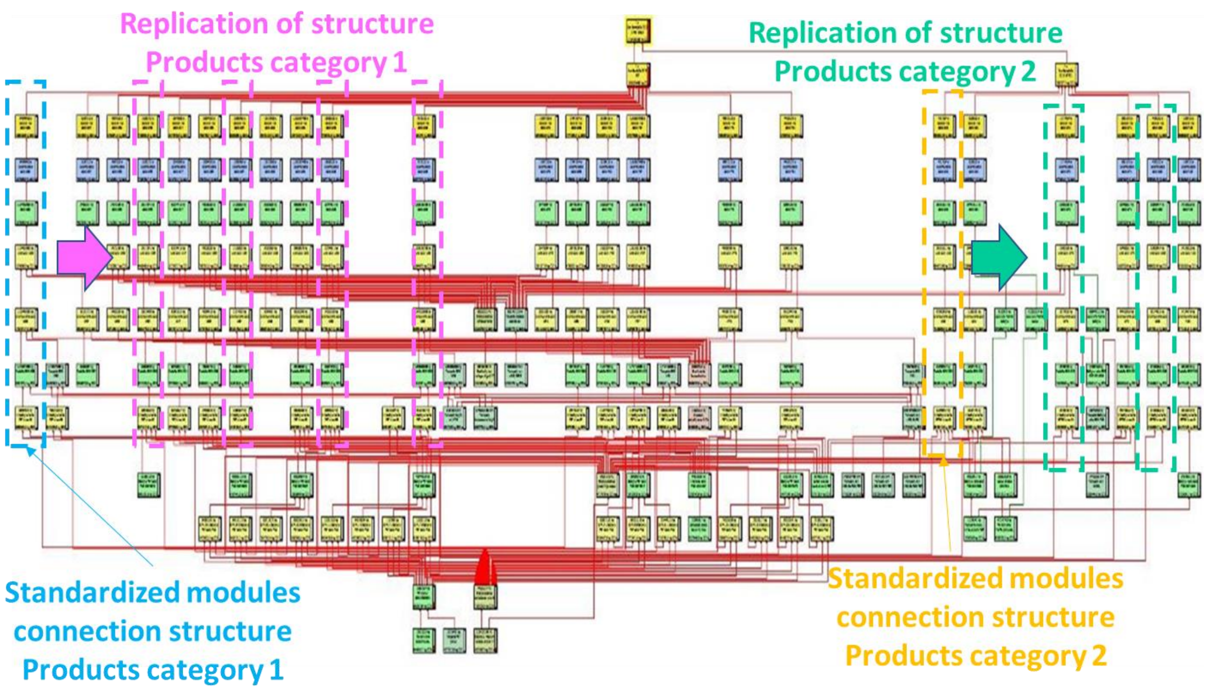


Figure 49 Process of replication of the standardized life cycle modules connection structures. (Personal elaboration, 2016)

8. **Environmental impacts and damages calculation:** in order to complete the model, the methods for environmental impacts and damages assessment must be introduced. The methods for environmental impact assessment have been brief description at the end of this paragraph for each impact category considered.
   The terms relative to other activities (φ_{mi} and φ_{ei}) are assessed separately with streamline LCA in order to evaluate the relevance. In fact, a cut-off rule has been applied in order to decide if is required the inclusion into the model of these activities. The cut-off rule establishes that the terms related to φ_{mi} and φ_{ei} are included in the model if their estimated contribution is greater than 5% in terms of environmental impacts. Maintaining the parallelism with the mathematical model this step permits of obtain the global equations for environmental impacts and damage:

$$I_{mi} = \sum_{l=1}^{l}\left(\sum_{s=1}^{s}(c_{s,l} \cdot f_{s,l,mi})\right) + \varphi_{mi} = I_{mi}' + \varphi_{mi} \quad [2.19]$$

$$D_{ei} = \sum_{l=1}^{l}\left(\sum_{s=1}^{s}(e_{s,l} \cdot f_{s,l,mi})\right) + \varphi_{mi} = D_{ei}' + \varphi_{ei} \quad [2.20]$$

The figure below shows an example of the global model for LCA environmental impact assessment on which is based OES2.

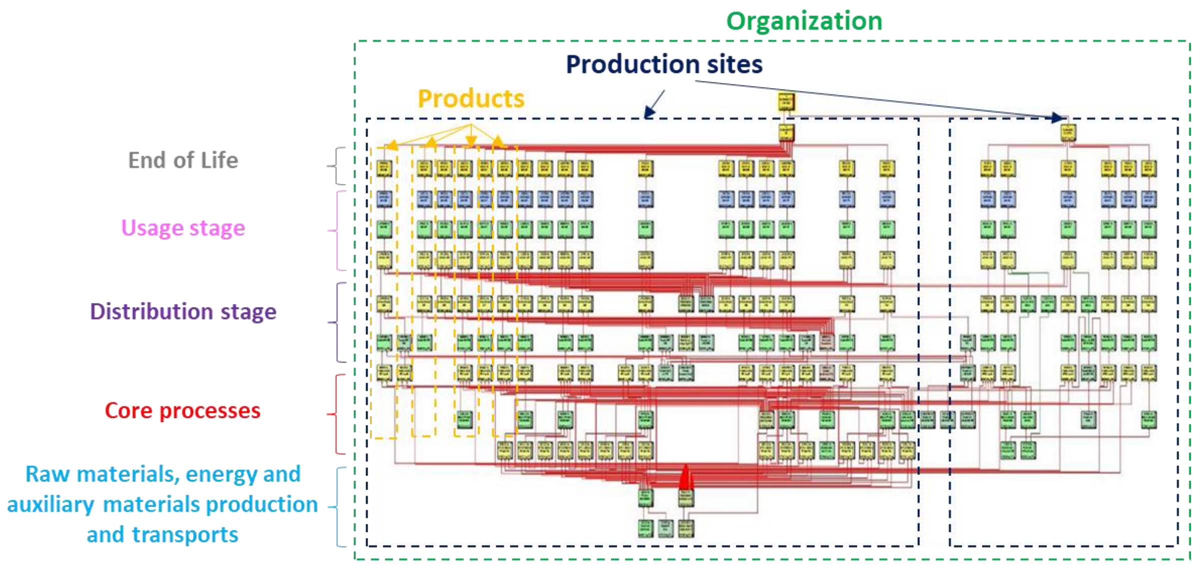


Figure 50 Example of global structure of the life cycle model in OES2. (Personal elaboration, 2016)

The previously graph describes the tree of process contribution of the whole system considered in a life cycle perspective in the case of a specific impact category. Many representations such this, can be obtained in function of the impact category considered, identifying different process contributions. The SimaPro software can be seen as a powerful software for the creation of mathematical multilinear models. In fact, the use of modules provides in SimaPro simplify the writing of the mathematical model that otherwise could be potentially very more complex with other software (e.g. Matlab). Therefore, the MLCA model developed with SimaPro is a new alternative to models developed with Data Envelopment Analysis (DEA) technique for the assessment of environmental performance of all the life cycle of the organization, permitting the also the supply chain management, as performed by other mathematical models such as the one proposed by Badiezadeh, et al., 2017.
Aspects related to specific methodological requirements of ISO14040-44 and ISO/TS 14072, such as functional unit, reporting unit, system boundaries, cut-off, etc., have been discussed in the next chapter directly during the application of these methodologies to the case study of San Benedetto S.p.A.

2.2.4.1.3. Test of the MLCA model in a real case study

The description of the test strategy to verify applicability and effectiveness of OES2 method and its components is available in the paragraph 2.3 of the present chapter.

2.2.4.1.3.1. SimaPro LCA software description

SimaPro is the professional tool you need to collect, analyse and monitor the sustainability performance data of your company's products and services. The software can be used for a variety of applications, such as sustainability reporting, carbon and water footprinting, product design, generating environmental product declarations and determining key performance indicators.

The software permits the easily model and analyse complex life cycles in a systematic and transparent way, to measure the environmental impact of products, services and organizations across all life cycle stages, and to identify the hotspots in every link of supply chain, from extraction of raw materials to manufacturing, distribution, use, and disposal.

SimaPro is a software developed and distributed by PRé Sustainability.

For more information: https://simapro.com

SimaPro version used: Developer v8.4.0.

2.2.4.1.3.2. Ecoinvent LCA Database

The Ecoinvent Centre distributes the world's leading database of consistent and transparent up-to-date Life Cycle Inventory (LCI) data. Ecoinvent database is the largest, most consistent and most comprehensive LCI database for LCA on the market.

In fact, with over 12,800 LCI datasets in the areas of energy supply, agriculture, transport, biofuels and biomaterials, bulk and specialty chemicals, construction materials, packaging materials, basic and precious metals, metals processing, ICT and electronics, dairy, wood, and waste treatment, Ecoinvent v3 is one of the most extensive international LCI databases.

This database is developed and updated by Ecoinvent that is a not-for-profit association founded by institutes of the ETH Domain and the Swiss Federal Offices.

For more information: http://www.ecoinvent.org/

Ecoinvent version used: v3.3

2.2.4.1.3.3. Selection of methods to perform the assessment of environmental impacts

The impact categories shown in the following table, were considered to be relevant for the impact assessment.

Impact assessment categories	Impact assessment methods collections used.
Climate change	IPCC 2013 GWP 100a v 1.00 (IPCC, 2016)
Ozone depletion	ReCiPe 2008, Europe Midpoint (H) (Goedkoop et al., 2013)
Terrestrial acidification	ReCiPe 2008, Europe Midpoint (H) (Goedkoop et al., 2013)
Terrestrial ecotoxicity	ReCiPe 2008, Europe Midpoint (H) (Goedkoop et al., 2013)
Water scarcity.	Water footprint scarcity (Boulay et al., 2011)
Aquatic eutrophication	IMPACT 2002+ (Joliet et al., 2005)
Aquatic ecotoxicity	IMPACT 2002+ (Joliet et al., 2005)
Aquatic acidification	IMPACT 2002+ (Joliet et al., 2005)
Human toxicity	ReCiPe 2008, Europe Midpoint (H) (Goedkoop et al., 2013)
Land occupation	IMPACT 2002+ (Joliet et al., 2005)
Metal depletion	ReCiPe 2008, Europe Midpoint (H) (Goedkoop et al., 2013)
Fossil depletion	ReCiPe 2008, Europe Midpoint (H) (Goedkoop et al., 2013)

Table 25 Environmental impact assessment methods used to quantify environmental impacts at midpoint level.

Climate change: set of mathematical expressions that permits the calculation of the potential environmental impacts on climate change phenomenon due to the emissions of GHG (Greenhouse gasses). This method has been developed by IPCC (Intergovernmental Panel on Climate Change). The potential environmental impacts are expressed in kg CO2 eq.

Ozone depletion: set of mathematical expressions that permits the calculation of the potential environmental impacts of destruction of the ozone layer due to the emissions of ODS (Ozone Depletion Substances). The stratospheric ozone acts as a filter for UV-B radiation coming from the sun, which can cause harm to human health and the environment (increased risk of skin cancer and cataracts, as well as potential damage to terrestrial plants and aquatic organisms). This method is based on technical considerations of WMO (World Meteorological Organization). The potential environmental impacts are expressed in kg CFC-11 eq.

Terrestrial acidification: set of mathematical expressions that permits the calculation of the potential environmental impacts the conditions of acidity of soil due to the emissions in atmosphere of inorganic substances such as sulphates, nitrates and phosphates. This method combines the EUTREND, an air transport model, and the SMART2, a model for soil dynamics. The potential environmental impacts are expressed in kg SO2 eq.

Terrestrial ecotoxicity: set of mathematical expressions that permits the calculation of the potential environmental impacts on ecosystem due to the emissions of toxic substances. This method is based on the USES-LCA (Uniform System for the Evaluation of Substances adapted for LCA purposes) model. The potential environmental impacts are expressed in kg di 1,4-DB eq.

Water scarcity: set of mathematical expressions that permits the calculation of the potential environmental impacts on local water scarcity due to consumptions of water (water withdrawn and not returned to the system). The potential environmental impacts are expressed in m3 eq.

Acquatic eutrophication: of mathematical expressions that permits the calculation of the potential environmental impacts of eutrophication of water systems due to the emissions of eutrophic substances. The method in based on the methodologies proposed by Hauschil et al. (1998) and Guinee et al. (2002). The potential environmental impacts are expressed in kg PO4 P-lim eq.

Acquatic ecotoxicity: set of mathematical expressions that permits the calculation of the potential environmental impacts of acidification of water systems due to the emissions of acidification substances. The method in based on the AMI (Assessment model Mean Impacts) model that considers the HC50 average effect. The potential environmental impacts are expressed in TEG water.

Acquatic acidification: set of mathematical expressions that permits the calculation of the potential environmental toxicological impacts on water systems due to the emissions of toxic substances. The method in based on the methodologies proposed by Hauschil et al. (1998) and Guinee et al. (2002). The potential environmental impacts are expressed in kg SO2 eq.

Human toxicity: set of mathematical expressions that permits the calculation of the potential environmental impacts on human health due to the emissions of toxic substances. This method is based on the USES-LCA (Uniform System for the Evaluation of Substances adapted for LCA purposes) model. The potential environmental impacts are expressed in kg di 1,4-DB eq.

Land occupation: set of mathematical expressions that permits the calculation of the potential environmental impacts of land occupation and land use transformation. The method in based on the methodologies proposed by Kollner (2001) and Goedkoop et al. (2000). The potential environmental impacts are expressed in m2org.arable.

Metal depletion: set of mathematical expressions that permits the calculation of the potential environmental impacts of mineral resources depletion. The method in based on the use of data from World Metal Deposits Database of the US Logical Survey that contains historical data from more than 3.000 mines and 50 deposits.). The potential environmental impacts are expressed in kg Fe eq.

Fossil depletion: set of mathematical expressions that permits the calculation of the potential environmental impacts of fossil resources depletion (considering all forms, gaseous (e.g. methane), liquid petroleum or non-volatile materials (e.g. coal)). The method in based on the use of data from the International Energy Agency (EIA). The potential environmental impacts are expressed in kg oil eq.

2.2.4.2. STEMs 2 & 3: Environmental Inventory Database (EID) and Environmental Results Database (ERD)

The Environmental Inventory Database (EID) and the Environmental Results Database (ERD) have been introduced in OES2 in order to face the gaps related to data management (see following table).

Life Cycle Management Critical Areas	Identified gaps
Environmental impacts assessment	Technical difficulties in large impact assessment results management
Inventory resources consumptions assessment	Technical difficulties in large inventory data management

Table 26 Gaps faced by the STEMs "Environmental Inventory Database (EID)" and "Environmental Results Database (ERD)".

The management of inventory data and of results generated in OES2 by life cycle environmental performance assessment activities conducted through the application of the multiscale LCA (MLCA) model and through ecodesign and ecoefficiency activities is a very fundamental aspect. The inventory data collection is one of the most important effort for the application of EMTs, especially in the case of LCA, in terms of time requirements (Zvezdov et al., 2016; Hack et al., 2014; Witezak et al., 2014). This large amount of data can be divided in different data areas:

1. Supply chain data area: this area includes all data regarding suppliers and transport processes of consumed raw materials and auxiliary materials;
2. Production data area: this area includes all data regarding productive processes, raw materials and auxiliary materials consumptions, and bills for the production of all products included in the product portfolio of the organization.
3. Energy data area: this area includes all data regarding the energy consumptions and the energy vectors characterization;
4. Logistic data area: this area includes all data regarding the characterization of the transport vehicles used for the distribution of the products and the characterization of the distances delivered;
5. Environmental services data area: this area includes all data regarding waste management, punctual emissions (e.g. emission into air), wastewater treatment and other relevant information for Environmental management.
6. R&D data area: finally, this data area includes all data regarding new specifications of products or processes under assessment for ecodesign activities.

Generally, at industrial level, the data collection processes for LCA application (or other EMTs) are characterized by the following criticalities:

- **<u>Not optimized data flows</u>**: The data flows are not optimized, and more than one data sources exist for the same information. Additional data flows are required and manage as standalone processes (figure 51).

  In red are shown the standard data flows (systematically managed) and in blue are shown the additional data flows (managed as standalone processes). Therefore, the standard data flows are not able to satisfy data requirements of LCA and other EMTs applied. There is redundancy between data flows.

  There is the need of optimized data flow management;

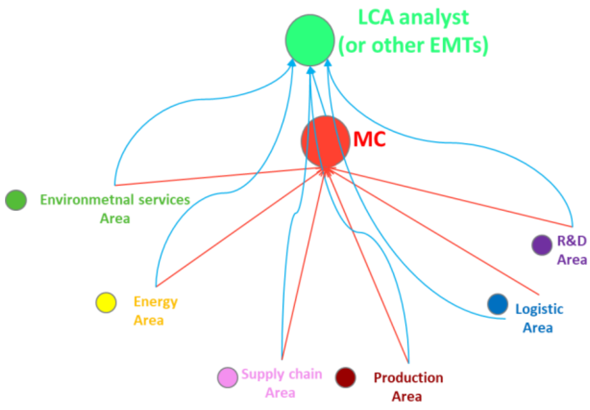


Figure 51 Common data management criticality related to not optimized data collection processes. (Personal elaboration, 2016)

- **Manual data collection routes**: processes of data collection, data re-elaboration (in order to obtain data in the correct format to feed the MLCA SimaPro model or other EMTs applied) and data entry are managed manually as standalone processes (see figure below
- **Manual results management routes**: results obtained by MLCA SimaPro model and from other EMTs are managed manually as standalone processes;

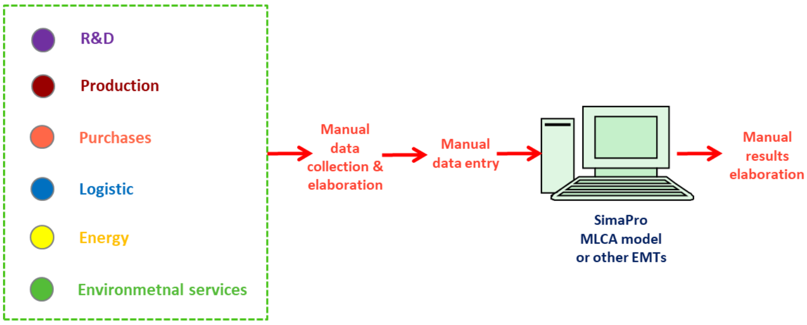


Figure 52 Common data management criticality related to manual inventory data and results management (Personal elaboration, 2016)

Manual data management is a very critical aspect for the expenditure of time and human resources and for the increasing of potential human errors during data collection, re-elaboration and data entry processes.

In fact, considering that OES2 is based on the MLCA model that considers a large product portfolio manufactured in different productivity sites and that OES2 requires a large application of EMTs combined (e.g. EcoDesign, EcoEfficiency, etc.) it is not realistic to collect and manually enter all inventory data required.

Since these are usually signed for stand-alone operation, i.e. not geared to the systematic, the automatic computer extraction of environmental information from a variety of company-internal and external BIS (Business Informatic Systems) is a promising solution.

There is the need to automatize processes related to data (collection, re-elaboration and data entry processes) and results (re-elaboration);

- **Not systematic data validation process**: the data validation process is managed as a standalone activity limited only to a sample of data therefore is generally conducted without an automatic system without a systematic approach and not applied to all data. The application to all data it is important because a sampling of data using a statistical approach consistent with the organization scale in many cases could be inconsistent for the product scale. In fact, an error that determine an acceptable error in calculation of environmental performance at organization

scale could be an unacceptable error for the calculation of the performance of the specific product assessed.
There is the need to automatize the data validation process;

- **Data management system based on a pull approach**: the data management is based on a pull approach instead of a push approach. In this case, the inventory data are collected only if requested and therefore only after a request without a systematic approach. This aspect implies a time delay not treasurable between the moment when the environmental performance assessment is required for management reasons and the moment when the results will available. Especially in the case of eco design, that is one of the fastest and applicated process, this delay is a critical point. Furthermore, in some cases this aspect can to determine that the collected inventory data refer to a previous state (e.g. previous product specification) respect to the new actual state (e.g. the new product specification due to ecodesign intervention) (see figure 53). ***There is the need to shift the data management approach from a pull approach to a push approach***;

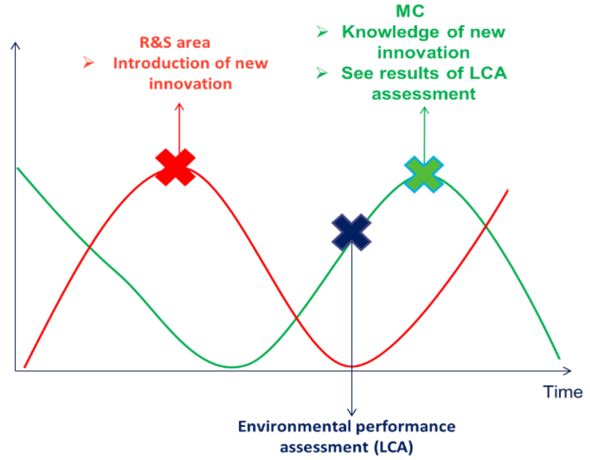


Figure 53 Common data management criticality related to the pull data management approach. (Personal elaboration, 2016)

In order to cross these criticalities, have been developed and introduced in OES2 two STEMs: The Environmental Inventory Database (EID) for the management of inventory data and the Environmental Results Database (ERD) for the management of results. In the following paragraph have been descripted the development of EID and ERD. In order to develop the EID has been proposed the following methodological procedure:

1. Identification and selection of data sources for each data area;
2. Conceptualization of EID;
3. Development of general structure of interface for EID;
4. Test of EID in a real case study (application to the Acqua Minerale San Benedetto S.p.A. organization).

Instead, to develop the ERD has been proposed the following methodological procedure:

1. Identification and selection of results sources;
2. Conceptualization of ERD;
3. Development of general structure of interface for ERD;
4. Test of ERD in a real case study (application to the Acqua Minerale San Benedetto S.p.A. organization).

2.2.4.2.1. Identification and selection of data sources for each data area

The first step for the development of EID and ERD components is the identification and selection of data sources. Generally, in the case of each data area (Supply chain, Production, Energy, Logistic, Environmental services, R&D) it is possible to identified more than one sources of data. The objective is those of select only one source for each data in order to eliminate redundancy. In order to select the data sources, the following important aspects must be assessed:

- Data structure and format: the first most important difference is between data informatized and data available on paper documents. Regarding the informatized data the format can be very different in function of BIS software (e.g. SAP). Generally, the data can be extracted in excel format. The EID has been developed for this common case;
- Data update frequency: this is an important aspect in order to set correctly the periodicity of queries lunch for data extraction;
- Identification of specific query: in the case of many BIS software (e.g. SAP) the query are the functions that permit to extract the required data from data source.

The data source selection must maximize the use of informatized data and prefer the choice of raw data that have not been re-elaborated.

2.2.4.2.2. Conceptualization of EID

The EID (Environmental Inventory Database) The EID component collects all inventory data required by the MLCA model and from the other EMTs automatically through individual extraction routines from a multitude of databases (data sources previously selected) in form of excel visual basic files for easy exchange. The choice to use the excel visual basic program code has been made in order to simplify the initial development stage. The structure developed for EID data acquisition STEM, as shown in the following figure, is based on seven interfaces one for each data area except for the production area that have two interfaces. The interfaces permit the automatic data load, re-elaboration, validation and data entry of MLCA SimaPro model and of other EMTs. The developed interfaces and their main re-elaboration functions are:

Figure 54 List of the interfaces and their main functions of data re-elaboration (Personal elaboration, 2016)

In the case of each interface a single battery of loading processes integrates the data into EID, ensuring system integrity by a set of cross-checking and unit conversion processes. In fact, beyond the automatic data collection, the interfaces perform the re-elaboration of data permitting to transform the raw data ($U_{p,j}$) in the data required from MLCA SimaPro model or from other EMTs ($\alpha_{p,k,j}$). The operation of this function of the interfaces has been descripted in the following paragraph. The interface performs also the validation of data on the base of statistical criteria that must be establish setting rules such as the interface generates a warning (the data cell is red) if the data value is higher or lower than one time the standard deviation (SD) calculated using all data of the set. For example, considering the weight of a plastic bottle of a specific product of a product category (Mineral water still 0,5L), this data is compared with the SD of the set that considers all products of this product category. As shown in figure 55, a few data, that is not informatized into the business information system of the organization require routes for manual data entry. The elaboration interface generates a file that include all data generated by re-elaboration. The file is created periodically, generally each year (but if it is necessary it is possible to use a smaller time frame) and it permits the historical saving of data that could will reuse in the future for the performance tracking assessment or other performance comparisons. The creation of historic file data is a very important feature especially in the case of performance tracking and permits to recalculate the baseline very easily also in the case of methodological changes such as update of characterization factors, changes of transfer functions due to increase of technical knowhow. The transfer functions are mathematical functions that permit to face allocation issues and it has been presented in the next paragraph. The result is a set of interfaces, one for each data area, filled with all required data in the format required by the MLCA SimaPro model and from other EMTs combined in OES2. The MLCA SimaPro model and the other EMTs combined in OES2 obtain as input the data and connect them in order to assess: environmental performance at organizational, product and process scale, eco design processes, and eco efficiency level. The set of these interfaces constitute the database of life cycle inventory data of whole organization and all products of its portfolio. The applied EID interfaces have been showed in the following chapter.

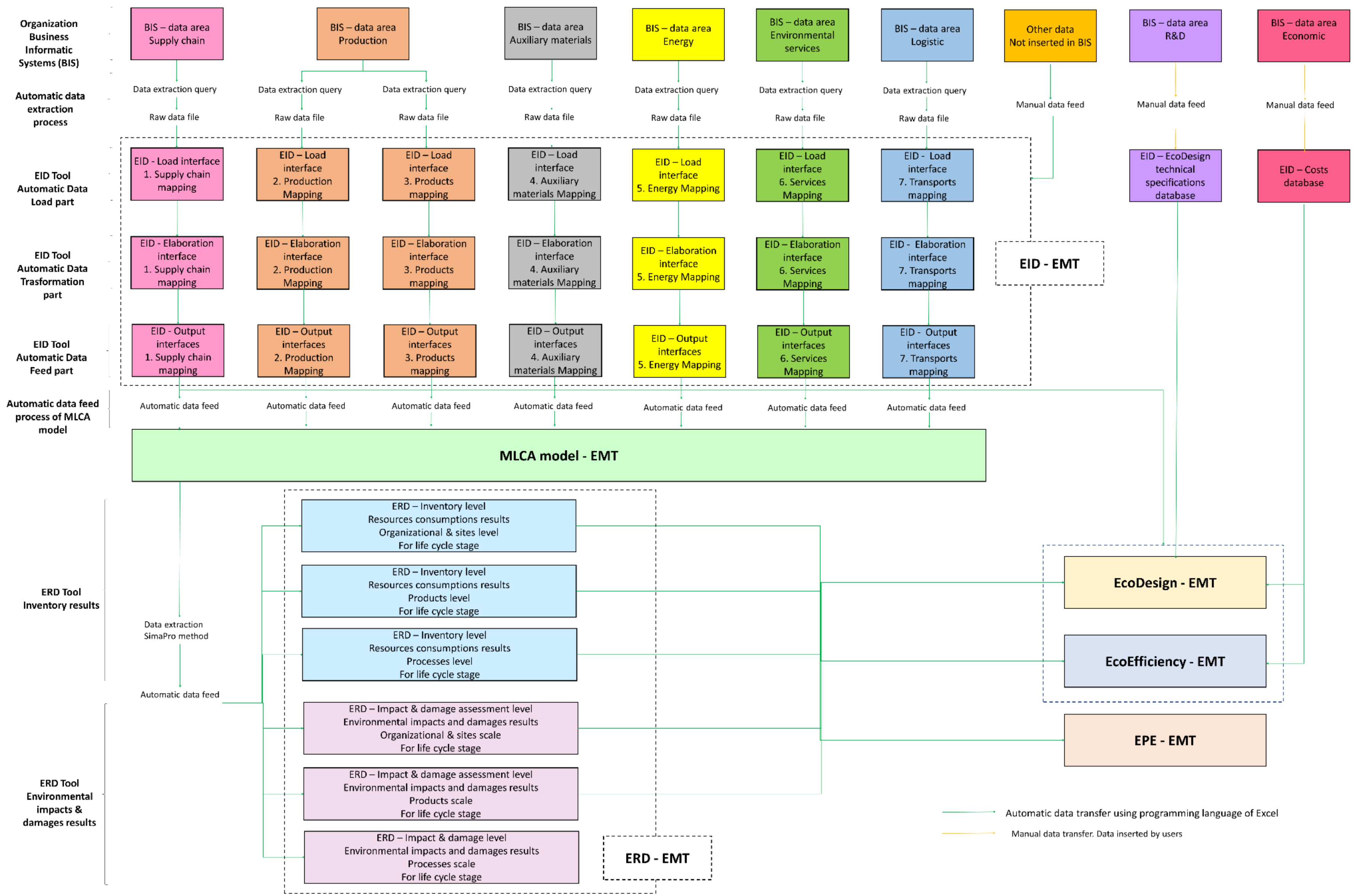


Figure 55 Structure of EID interfaces to manage all life cycle primary inventory data. (Personal elaboration, 2016)

2.2.4.2.3. Development of a general structure of interface for EID

The EID component has based on seven different interfaces. In the present paragraph has been descripted the general structure of the interface. The general structure of on which are based the interfaces is composed by four different sub-interfaces organized on three different levels as shown in the following figure.

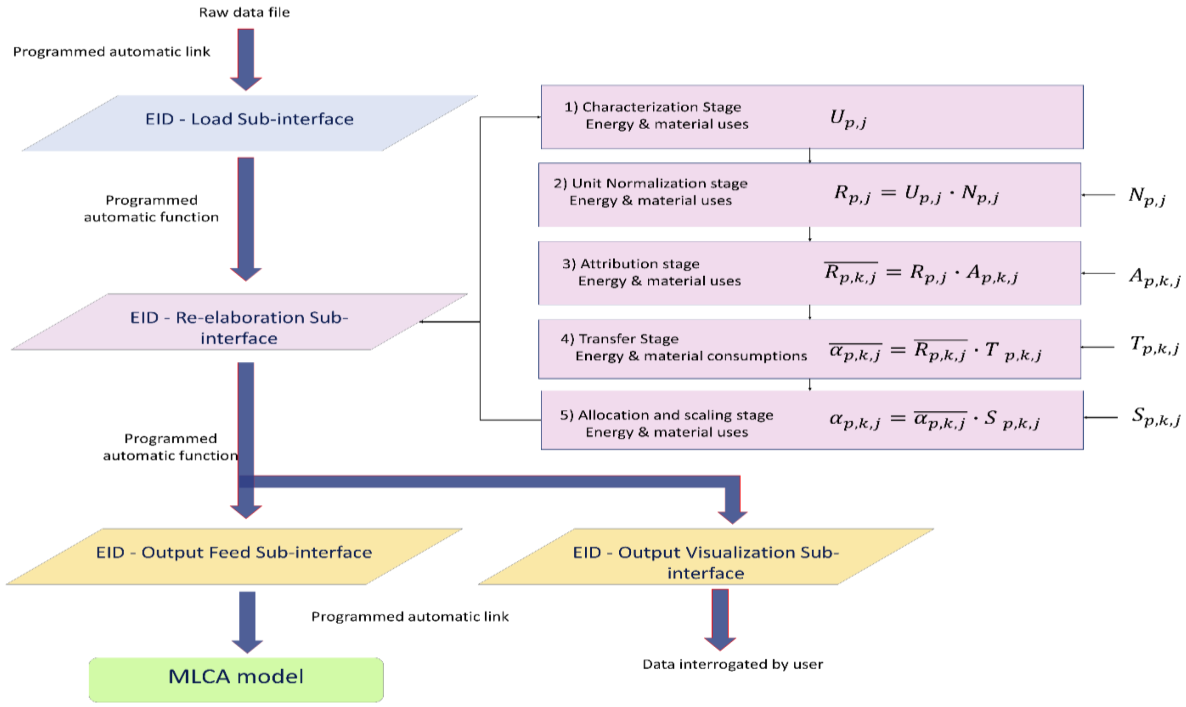


Figure 56 Logic structure and general functions of data re-elaboration implemented in the interfaces (Personal elaboration, 2016)

The "Load sub-interface" is programmed to load all required raw data from the extraction files obtained by query of BIS.
The "Re-elaboration sub-interface" is programmed to transform raw data loaded with the "Load sub-interface" into data format required by MLCA model and by other EMTs combined in OES2. The transformation process is multistep re-elaboration process:

1. Characterization stage: The "Re-elaboration sub-interface" load a specific data ($U_{p,j}$) characterized by "Load sub-interface" (e.g. electrical consumption of chiller 7°C).
2. Unit normalization stage: if the measure unit of the raw data is different by the unit required by MLCA model a normalization factor is applied in order to convert the measure unit;
3. Attribution stage: in this stage, is established if the normalized raw data ($R_{p,j}$) is attributable to a specific product category (sub set of homogenous products). The attribution is obtained through the application of an attributional matrix that contains attributional coefficients ($A_{p,k,j}$) that have values equal to 1 if there is attribution or equal to 0 if there is not attribution;
4. Transfer stage: in this stage is applied the transfer function ($T_{p,k,j}$) that permits to assess the entity of the consumption that must be attribute to the specific $k - esime$ product. The transfer functions are mathematical functions that permit to face allocation issues. In fact, the transfer functions are established in order to assess on the base of technical consideration the material and energy consumptions of a specific product respect to the other products that share the same process. In the results chapter will be shown an example of transfer functions built for the process of preforms production. The implementation of transfer functions in the interfaces boosts the utility of interfaces. The transfer functions can be developed with different degree of detail following a benefits/efforts approach;

5. Allocation & scaling stage: finally, if the data required in output is for unit of $k - esime$ product, they are required operations of allocation in order to scale the value. It is important underline that in this case the operation of allocation is globally very different from traditional allocation in LCA because the transfer stage permits of increase very much the detail of the attributions.

Finally, two output sub-interfaces have been inserted in the structure. This choice has been due to specific requirements of SimaPro software. In fact, when a programmed link is established between the MLCA SimaPro model and an interface, the structure of dataset cannot be modified. In order to understand better this aspect, suppose that establishing a programmed link between the MLCA model and the dataset' cell in position E20, if a row is delated or added in the dataset, the programmed link continues to load the data in position E20 but the true data has been moved in the rows 19 or 21. In order to overcome this issue the "Output Feed Sub-interface" has been developed with a "rigid structure" where a specific data loaded always occupies the same position. However, this sub-interface has not a comfortable structure for data visualization by user but is only suitable to MLCA model feed. Therefore, the "Output Visualization Sub-interface" has been introduced in order to ensure a comfortable visualization and query of the data by user. In this second output sub-interface has been also implemented the statistical for automatic data validation. It is clear that the application of EID interfaces requires a customization specific for each organization because, in every organization could change: the business informatic systems, software sources and specific needs of data re-elaboration in function of the starting data characteristics. The EID interfaces have been developing in excel programming language making extensive use of most of excel formulas and functions. The excel language programming permits to develop with very low cost, using a well-known language and providing a high level of transparency due to the possibility for user to understand the implemented formulas and logics.

2.2.4.2.4. Test of the EID in a real case study

The description of the test strategy to verify applicability and effectiveness of OES2 method and its components is available in the paragraph 2.3 of the present chapter.

2.2.4.2.5. Identification and selection of results sources

According with the structure shown in figure 55, the ERD interface elaborate data in output from the MLCA model and in this case, provide by SimaPro. The ERD interface automatize this type of data results management. The results returned by SimaPro MLCA model are for all assessment scales (organizational, site, product, process) and request to be organized in a database to be available and usable for analysis, interpretation, hotspot identification and other purposes such as ecodesign and ecoefficiency. The results for each site, product and process are returned with the specific level of aggregation determined by the group analysis set by the user in the SimaPro. A briefly description of group analysis has been shown in the next paragraph of the present chapter.

2.2.4.2.6. Conceptualization of ERD

The ERD interface has been programmed in order to compiles in automatic the following matrixes starting from results returned by MLCA SimaPro model at environment impact level and the inventory resource consumption:

- Matrixes of environmental impact at organizational level considering the different life cycle processes for every environmental impact category;
- Matrix of inventory resources consumptions at organizational level considering the different life cycle processes;

- Matrixes of environmental impact at product level considering all products included in the portfolio of the organization for every environmental impact category.
- Matrix of inventory resources consumptions at product level all products included in the portfolio of the organization.

The figure 55 shows this multiscale organization of the results both for inventory results on resources consumptions than for environmental impacts results. In the case of the organization perform also the assessment of damages at end-point level an additional portion of database exist.

2.2.4.2.7. Development of the structure of interface for ERD

The ERD has been developed in excel programming language. It works, according with MLCA model, with a multiscale perspective for to manage all results generated. In the following figure the general structure of ERD has been proposed.

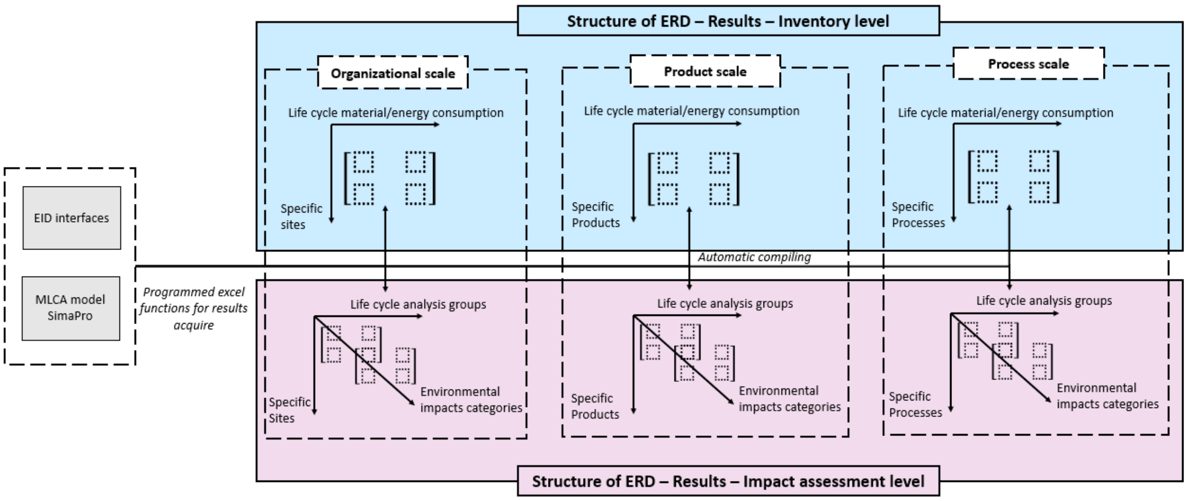


Figure 57 Logic structure of the ERD interface. (Personal elaboration, 2016)

2.2.4.2.8. Test of the ERD in a real case study

The description of the test strategy to verify applicability and effectiveness of OES2 method and its components is available in the paragraph 2.3 of the present chapter.

2.2.4.3. STEM 4: Eco Environmental KPI Analyzer (Eco-EKA)

The Eco Environmental KPI Analyzer (Eco-EKA) have been introduced in OES2 in order to face the gaps related to performance tracking and trend analysis (see following table).

Life Cycle Management Critical Areas	Identified gaps
Performance evaluation & performance tracking	Lack of OPIs for environmental performance evaluation related to life cycle management
	Difficulties performance tracking and in OPIs trends analysis

Table 27 Gaps faced by the STEM "Eco Environmental KPI Analyzer (Eco-EKA)".

These gaps identified during the scientific literature review constitute relevant EMBs related to the difficulties of organizations to assess their environmental performance and relative trend at the different assessment scales (organization, product, process). The use of Key Performance Indicators (KPIs) is limited in industrial organizations (Pilouk et al., 2017). The KPI can be seen as a simpler and faster quantitative approach for environmental performance measurement, monitoring and improvement (Bovea et al., 2012). The organization encounter various issues mainly related to:

- Issues in environmental performance assessment;
- Issues in environmental performance trend analysis;
- Issues in the correlation between changes at inventory level and changes of environmental performance;
- Issues in the correlation between changes in product performance and organizational performance;
- Issues in comparison of the performance of products of the same product portfolio.

It is evidence that the use of KPIs is fundamental for to support organizations by quantifying processes, highlighting potential vulnerabilities and evaluating and benchmarking them (Meier et al., 2013). These quantifiable and strategic measures are essential for understanding and improving manufacturing performance, achieving strategic goals which are most critical for current and future success (Parmenter, 2010). The KPI analysis may be performed for all assessment scale, but the application at product scale are few (Bovea et al., 2012; Herman et al., 2007; Krajnc et al., 2003). The ISO 14031:2013 gives detailed methodological instructions on how establish environmental KPI.

In this context, where the OES2 method promotes the use of Environmental Performance Evaluation (EPE - ISO 14031:2013), the Eco Environmental KPI Analyzer (Eco-EKA) has been proposed as a STEM for EPE in order to overcome the issues previously descripted. Furthermore, the Eco-EKA gives a proposal to KPI selection process.

The development of Eco-EKA has been conducted following the methodological procedure:

1. Identification of required features;
2. Definition of a procedure to identify OPIs;
3. Development of the Eco-EKA software structure;
4. Test of Eco-EKA in a real case study (application to the Acqua Minerale San Benedetto S.p.A. organization).

It is Important to specify that the EPE (ISO14031:2013) considers Environmental condition indicators (ECIs) and Environmental Performance Indicators (EPIs). The first ones provide information about the condition of the environment which could be impacted by the organization. Instead the EPIs are distinguished in management performance indicators (MPIs), which provide information about management efforts to influence the environmental performance of the organization’s management, and operational performance indicators (OPIs), which provide information about the environmental performance of the organization’s operations. The Eco-EKA focus on the analysis of OPIs that are essential for the analysis of environmental performance.

2.2.4.3.1. Identification of required features

Before to start with the development of the structure of Eco-EKA have been identified all the desired features that must be implemented in order to ensure that the Eco-EKA responds to the previously identified objectives of improvement. Following are reported the selected features:

a) *Procedure for OPIs identification:* the selection of OPIs performed by Eco-EKA must be based on a procedural process (Issa et al., 2015);
b) *Automatic data feed and selection:* the Eco-EKA must select automatically the data from ERD;
c) *Multiscale OPIs:* according to MLCA SimaPro Model, the Eco-EKA must work with a multiscale assessment framework (organization, site, product, process) (Bovea et al., 2012; Herman et al. 2007; Krajnc et al., 2003);
d) *To assess the Inventory resource consumptions and environmental impact assessment levels:* according to MLCA SimaPro Model, the Eco-EKA must be based on inventory OPIs (IOPIs) related to resource consumptions and environmental impacts OPIs (EOPIs) related to the environmental impacts generated on mi-esime midpoint impact categories (Dorn et al., 2016; Lior et al., 2008).
e) *Automatic performance tracking:* the OPIs must be analysed respected to baseline, targets and average values in order to assess the trend correlating the different assessment scales and the inventory and impact assessment levels.

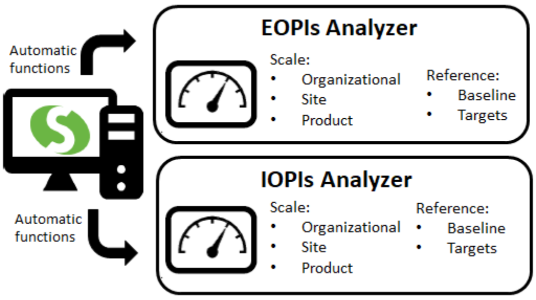


Figure 58 Simplified representation of main features of Eco-EKA (Personal elaboration, 2017).

2.2.4.3.2. Definition of a procedure to identify OPIs required

The identification of a procedure to identify OPIs, is the first essential step (*feature a*). In the case of a complex organization that characterized by many sites, many products, many processes and many flows along its life cycle it is essential to identify which sites, products, processes and flows it is required to monitor, developing OPIs, in order to assess the environmental performance trend.

The procedure has been based on the concept of relevance assessed through two tests as shown in figure 59. The first test assesses the relevance in terms of contribution. In this test, the relevance was assessed with a multiscale approach in terms of contribution of the lower scale to the global environmental impact of the upper scale. According to MLCA model proposed in OES2, different assessment scales has been distinguished using a classic pyramid scheme: organizational scale, site scale, product scale, process scale. For each assessment scale, it is possible to identify an assessment unit. The assessment unit is the base element used to calculate the environmental impact of a specific scale. Therefore, in the case of all scales have been identified assessment units that respectively are: whole organization, *j-esime* site, *k-esime* product, and *p-esime* product. The contribution of each assessment unit has been considered relevant if it impacts results greater than the impacts generated multiplying the overall impact of the upper scale for the cut-off parameter. The cut-off parameter has the relevance threshold chosen by organization and generally is set equal to 1%. Therefore, for example, the *k-esime* product is considered relevant if its impact is greater than the 1% of the global impact of the *j-esime* site where the product has been realized. The calculation of environmental impacts has been performed through a screening analysis of the MLCA SimaPro model that permits to obtain the environmental impacts for each mi-esime midpoint impact category for each j-esime sites, k-esime products and p-esime processes. This run of the MLCA SimaPro model is considered a screening analysis because it is the first evaluation run performed by the organization and it serves to assess the contributions relevance and to setup the groups that will be used for group analysis. These results are not saved by ERD. The relevance test is applied to each scale and permits to identify the identification of relevant: *j-esime* sites, *k-esime* products, *p-esime* processes and *l-esime* flows. The *l-esime* flows are the material and energy flows, the smaller assessment unit, that constitute the input to life cycle processes (e.g. electricity, natural gas, PET plastic). This first test must be iterated for each mi-esime midpoint impact category selected by the organization.

The second test assesses the relevance in term of strategic considerations. In fact, although an assessment unit (e.g. product) do not resulted relevant in terms of contribution, it can be result relevant according to strategical considerations (e.g. new eco-friendly product just launched on the market). Obviously, in function of the environmental sustainability strategy defined by the organization, specific assessment requirements may emerged, such as, the assessment of environmental performance of a family of products. It will simply assessed through the combination of results emerged from the assessment scales previously listed. Using the identifications of processes and flows it is possible to define the groups for the groups analysis that it will be performed using LCA software (SimaPro) in order to obtain the results correctly grouped.

This procedure permits to obtain:

- the list of sites, products and processes for which are required OPIs;
- the list of groups that must be used for group analysis in MLCA SimaPro model.

The pyramid-related approach in terms of relevance promoted by this procedure encourages the improvement of the understanding of environmental performance trend assessments.

2.2.4.3.3. Development of the Eco-EKA software structure

The software structure of Eco Environmental KPI Analyzer (Eco-EKA), as shown in the figure 60, has been based on three components:

1. Results selector;
2. OPIs and SOPIs calculator;
3. OPIs and SOPIs comparator.

The "Results selector" component permits to acquire from ERD results related to inventory resource consumptions and environmental impacts (*feature b*). The results are automatically selected and extracted on the basis of the results returned by the application of the procedure (list of identification of relevant assessment units: *j-esime* sites, *k-esime* products, *p-esime* processes) (*feature c*). The results are stored in ERD database in matrix structures and two types of matrix exist for each assessment scale (organizational, site, product, process):

- **The inventory consumption matrix [C]**: where for each assessment units are contained the results in terms of inventory consumptions in function of each group defined in the LCA groups analysis for the t-esime year;
- **The environmental impact matrix [I]**: where for each assessment units are contained the results in terms of environmental impacts in function of each group defined in the LCA groups analysis and each mi-esime midpoint impact category considered for the t-esime year.

The choice of structure these two types of matrices is essential in order to permit the successive calculation of IOPIs and EOPIs. Only the matrices C and I relative to the assessment unit with the selected identification are feed to the OPIs calculator (*feature d*). The "OPIs and SOPIs calculator" component permits the calculation of IOPIs and EOPIs. Furthermore, it permits the calculation of SOPIs (Supportive OPIs). The SOPIs are indicators build using variables that characterize the product portfolio (S) of the organization and are very important in order to support the correct interpretation of OPIs. The variables that characterize the product portfolio can be for example: average format, products mix realized, etc. In fact, these variables can be relevant exogeny pressure factors (related for example to stakeholders and market demand) that can influence significantly the environmental performance of organization and of the productive sites. The influence may be positive, when amplifies the performance improvement that would has been achieved through ecoefficiency and ecodesign activities performed by organization, or negative, when the effect is opposite respect to improvement activities performed by organization. The "OPIs calculator" require the identification of a reference flow that characterize physically the products and the processes under study (e.g. a number of product units, a mass, a volume, etc.). Also in this case, in addition to the reference flow, a scale factor is applied in order to scale the OPIs values (e.g. kWh/1000 products unit, in this case the scale factor is 1000). In other words, the "OPIs calculator" performs a process of normalization.

Finally, the "OPIS and SOPIs comparator" component permits to perform automatically the performance tracking (*feature e*). The analysis of the performance is conducted using a multiscale approach, starting from the higher scale (organizational scale) for arriving to the smallest scale (process scale) considering both the inventory resource consumption perspective and the environmental impact perspective. Each performance analysis has performed comparing the performance of t-esime year with three different values: the target performance, the performance of baseline year and the average performance of last years. The analysis is performed also for SOPIs in order to assess also their trends.

2.2.4.3.4. Test of the Eco-EKA in a real case study

The description of the test strategy to verify applicability and effectiveness of OES2 method and its components is available in the paragraph 2.3 of the present chapter.

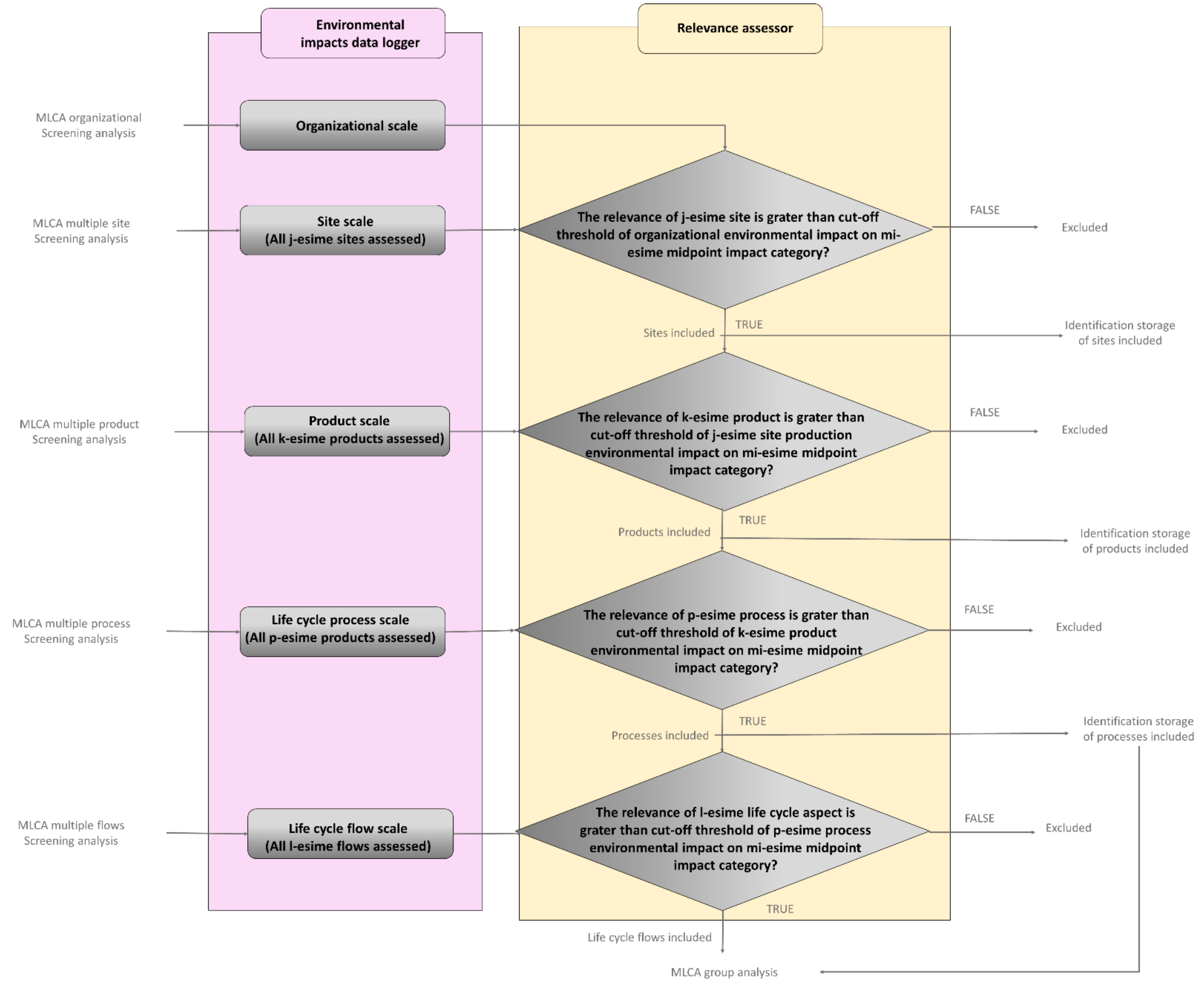


Figure 59 Procedure to identify OPIs on which is based Eco-EKA proposed in OES2 (Personal elaboration, 2017).

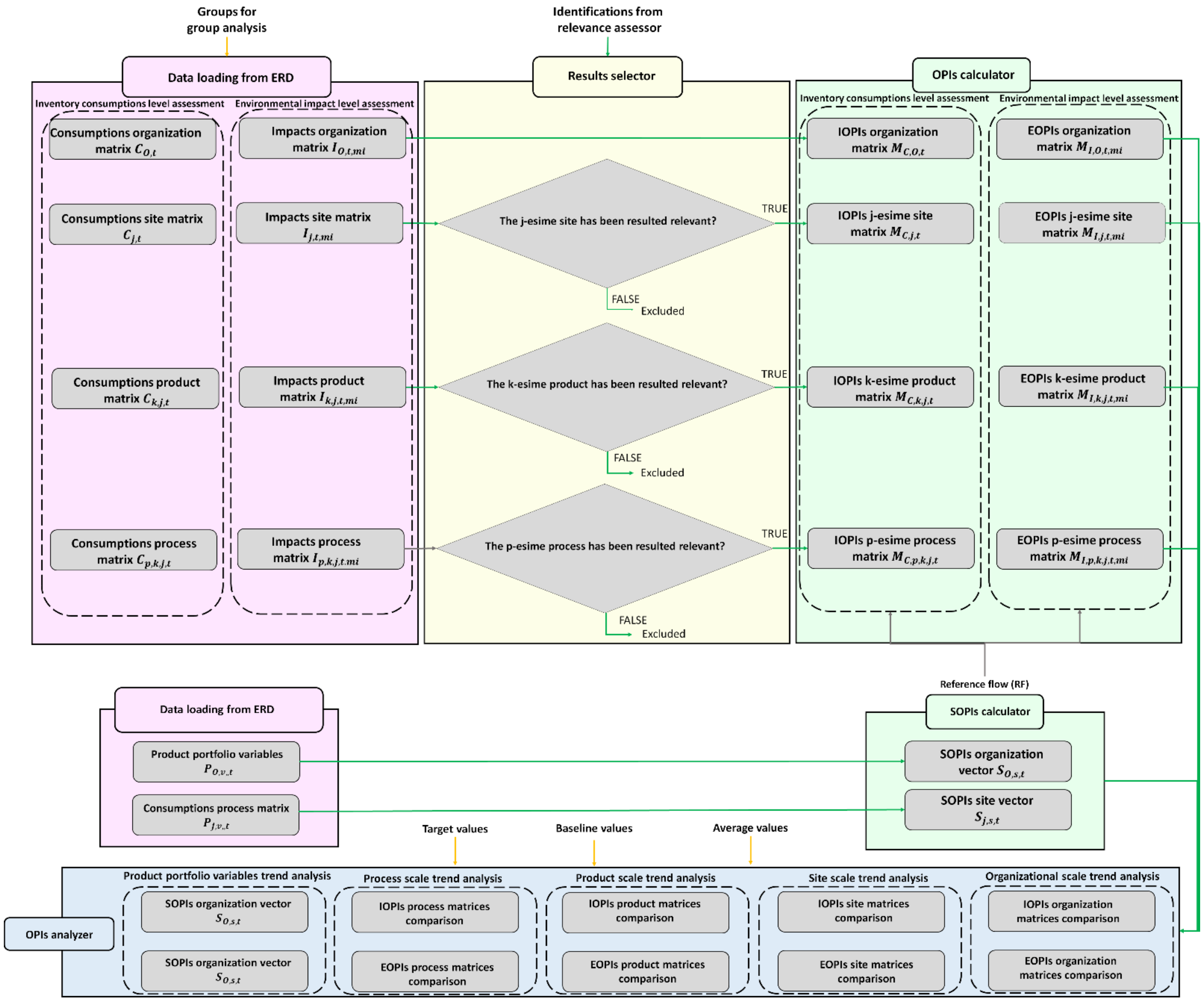


Figure 60 Software structure of Eco-EKA proposed in OES2 (Personal elaboration, 2017).

2.2.4.4. STEM 5: EcoDesign Simulation Dashboard (Eco-DSD)

The EcoDesign Simulation Dashboard (Eco-DSD) have been introduced in OES2 in order to face the gaps related to eco-design implementation (see following table).

Life Cycle Management Critical Areas	Identified gaps
Ecoinnovation	Difficulties in implementation of practical ecodesign processes and new eco-friendly alternative solutions comparison
Strategic decision making	Difficulties in the assessment of environmental performance of investments

Table 28 Gaps faced by the STEM "EcoDesign Simulation Dashboard (Eco-DSD)".

These two gaps identified during the scientific literature review constitute two relevant EMBs related to the difficulties of organizations to implement and use ecodesign as a tool to support the choice between different design and investment alternatives. The detailed description of the two gaps is reported in the chapter 1 related to scientific literature review. The ISO/TR 14062:2012 standard describes the requirements in terms of activities and documents to implement an ecodesign process. However, in function of the ecodesign maturity levels of the organizations, the implementation degree of ecodesign in manufacturing activities can be very different.

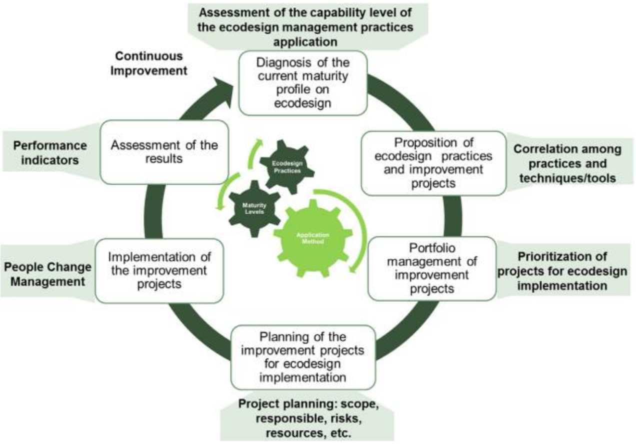


Figure 61 Ecodesign maturity level model proposed by Pigosso et al. (2013).

Ecodesign maturity levels represent successive stages for incorporating environmental issues into the product development and related processes. The maturity levels are defined by a combination of the evolution level in eco-design and the capability level.

The evolution levels describe a recommendation of the stages to be followed for ecodesign implementation (Pigosso et al., 2013; Boks et al., 2007; Alakeson et al., 2004; De Caluwe, 2004;) while the capability levels qualitatively measure how well a company applies an ecodesign management practice (Pigosso et al., 2013; Chrissis et al., 2003). Organizations with a low ecodesign maturity level are characterized by a very little experience in ecodesign and does not yet completely apply ecodesign practices to improve the environmental performance of products. The environmental issues of products and the benefits of adopting ecodesign are not yet exploited. Instead organizations with a high ecodesign maturity level are characterized by a systematic incorporation of ecodesign practices into the product development and related processes, starting from the initial phases (e.g. idea generation and portfolio management). The ecodesign and environmental issues are fully incorporated into the company's corporate, business and product strategies. Environmental issues are considered jointly with technical and economic issues to reinforce the decision-making processes. The organization aims at system innovation, through the development of new products and services that require changes in its business models and infrastructure (Pigosso et al., 2013). However, in this case, the ecodesign is applied to a large number of activities:

- Projects to develop new eco-friendly products (Laperche et al., 2013);
- Projects to improve already exist products (Laperche et al., 2013);
- Projects to improve processes (Pigosso et al., 2013);
- Projects to process renewal through new process technologies (Loss et al., 2016b).

The very high number of application, which can exceed dozens of times in function of the organization size, requires solutions to fast applied, assess and communicate to top management the results of ecodesign alternative solutions in order to overcome the gaps previously identified (table 28). In this context, where the OES2 method promotes a high level of ecodesign maturity, the Ecodesign Simulator Dashboard (Eco-DSD) has been proposed as a solution to speed up the assessment of ecodesign projects and to permit a smart communication of the results to top management in order to support the decision making process. This STEM point to maximize comprehensibility, the speed of use and the easy usability.

The Eco-DSD can be used to estimate before the effects on environmental performance of improvement projects and investments or can be used to verify the results in terms of performance of implemented projects and realized investments. In this way the Eco-DSD is according to ESSM and supports it. The Eco-DSD provides a user-friendly space to simulate the different ecodesign alternative solutions in the case of all kind of ecodesign projects. The development of Eco-DSD has been conducted following the methodological procedure:

1. Identification of required features;
2. Development of standardized structure;
3. Test of Eco-DSD in a real case study (application to the Acqua Minerale San Benedetto S.p.A. organization).

The development of the Eco-DSD joins efforts to develop eco-design tools tailored specifically for SMEs (Andriankaja et al., 2015; Arzoumanidis et al. 2013; Buttol et al. 2012; Lofthouse et al., 2006; Masoni et al. 2004), which in the light of the changes proposed in ISO 14001:2015 may become significant. (Lewandowska et al., 2014). Furthermore, the development of this tool has been realized according to ISO/TR 14062 on ecodesign.

2.2.4.4.1. <u>Identification of required features</u>

Before to start with the development of the structure of Eco-DSD have been identified all the desired features that must be implemented in order to ensure that the Eco-DSD responds to the previously objectives of improvement of the ecodesign implementation stage. These features have been identified through an iterative brainstorming process that has involved also San Benedetto. In fact, with an iterative approach the initial proposed version has been upgraded in order to overcome emerged limits and issues in its applicability. In many cases, emerged limits and issues were related to the need of introduce new features. Following are reported the final selected features:

a) *Automatic inventory calculation*: the inventory data fed must be automatically elaborated;
b) *Automatic environmental impacts calculation*: the environmental impact must be automatically calculated;
c) *Automatic ecodesign alternative results comparison*: the results of the assessment must be compared automatically;
d) *Inclusion of economic performance*: the performance assessment must be included also the economic performance related to the cost of inventory flows considered;
e) *Ecodesign alternative results comparison must be distinguished*:
    - Environmental performance: comparison of the global environmental performance;

   - Environmental savings: comparison of the environmental performance for life cycle process;
   - Functional savings: comparison of relevant resource consumptions;
   - Economic savings: comparison of relevant economic costs related to inventory flows considered.

f) *Smart results representation*: the results must be easy understandable and viewable by top management.
g) *Automatic rescale for functional unit changes*: the results must be rescaled automatically for changes of functional unit in order to have rapidly the assessment for different functional units;
h) *Automatic update of emissions factors*: any updates of emissions factors of life cycle processes must be automatically transposed in the Eco-DSD;
i) *Maximization of automatic inventory data fed*: the inventory data used for ecodesign assessments and stored in EID must be fed to Eco-DSD automatically.
j) *Custom selection of environmental impact categories*: in function of the ecodesign project' assessment goals in terms of environmental performance improvement the environmental impact categories considered could be customized.

2.2.4.4.2. Development of a standardized structure

In order to provide a ecodesign simulation space the standardized structure of Ecodesign Simulator Dashboard (Eco-DSD), as shown in the figure 62, has been based on four components:

1. Simulation data logger;
2. Inventory calculator;
3. Impacts calculator;
4. Performance comparator.

The "Simulation data logger" component of Eco-DSD permits the data entry for each ecodesign alternative assessed. Two types of data can be loaded, inventory data deriving from EID that is fed in automatic (*feature i*) and data deriving from technical specifications on ecodesign alternatives that is manually entered.

The "Inventory calculator" component of Eco-DSD permits the automatic calculation off all consumptions of materials and energy and the calculation of the quantity requested of specific processes (e.g. transports) (*feature a*). The inventory results are organized following standard inventory categories:

- Raw materials;
- Upstream raw materials transports;
- Chemicals;
- Auxiliary materials
- Energy;
- Delivery transports
- Wastes.

New inventory categories could be added on need (e.g. is requested less generalization in data category nomenclature). The organization of inventory categories follows the life cycle logic. This component permits to assess the total consumptions of materials, energy and the total quantities requested of specific processes (e.g. transport processes), $(\varepsilon_{a,p,j} + \alpha_{p,j})$, according to the functional unit chosen for the eco design assessment $(fu_{a,j})$ (*feature g*). Therefore, in this component is required to define the functional unit used as reference unit for the assessment of results. Finally, this component present also a space for the description of the project and of the ecodesign assessed alternatives.

The "impacts calculator" component of Eco-DSD permits to automatically calculate the environmental impacts (*feature b*) and the economic costs (*feature d*) associated to inventory data on consumptions loaded for each $a - esime$ ecodesign alternative. In order to perform these calculations, this component

has been connected to ERD, for the acquisition of the environmental impact factors ($i_{mi,p}$) specific for each $mi - esime$ midpoint impact category and for each $p - esime$ process (e.g. the environmental impacts factors of 1 kg of PET plastic for the climate change impact category is about equal to 3,0 kg CO2eq/kg). The variables $i_{mi,p}$ are stored in the ERD and deriving from the MLCA SimaPro model. The automatic acquisition of the environmental impacts factors from ERD permits to automatically transpose to Eco-DSD every update of them (*feature h*). They are updated every year or every time a relevant change is implemented (e.g. software update that produces the upgrade of databases or of environmental impact assessment methods). Similarly, this component is connected to a cost database for the acquisition of the economic costs related to specific process or material and energy consumption (e.g. price of 1kg of PET plastic, price of 1 kWh of electricity). The $mi - esime$ midpoint environmental impacts categories must be selected in function of the specific project' objective. The selection is obtained with a filter that command the activation and the visualization of specific impact categories (*feature j*).
Finally, the "Performance comparator" component of Eco-DSD permits to easily and intuitively visualize and automatically compare the performance of the different alternatives (*features c and f*). The results are organized in four categories (*feature e*):

- Environmental performance: the percentage of environmental impact reduction of each $a - esime$ ecodesign alternative for each $mi - esime$ midpoint impact category;
- Environmental savings: the saving in terms of absolute environmental impacts generated by each $a - esime$ ecodesign alternative for each $mi - esime$ midpoint impact category;
- Functional savings: the saving in terms of absolute material, energy e process quantity generated by each $a - esime$ ecodesign alternative for each $mi - esime$ midpoint impact category;
- Economic savings: the economic saving generated by each $a - esime$ ecodesign alternative for each $mi - esime$ midpoint impact category;

Regarding the impact assessment, it is possible to select one or more environmental impact categories to compare the performance of the ecodesign alternatives in function of specific needs. Finally, for each ecodesign project has been calculate the Environmental Pay Back Index as:

$$EPBI_{t,a,mi} = \frac{I_{t,a,mi}}{\Delta_{t,a,mi}} \quad [2.21]$$

This index varies from 1 to higher values, and represents how many functional unit shall be produced with the specification of the $a - esime$ ecodesign alternative in order to have a quantity equal to the functional unit with zero environmental impacts.
The informatic implementation of the tool has been performed using excel programming language in order to automatize all the features requested and permits to have to designers a portable tool easy to use during design stage and during the meetings with top management to present results of eco design projects.
As shown in the next chapter, the operative application of Eco-DSD has been performed applying requirements of LCA methodology (ISO 14040-44), according to ISO/TR 14062.

2.2.4.4.3. Test of the Eco-DSD in a real case study

The description of the test strategy to verify applicability and effectiveness of OES2 method and its components is available in the paragraph 2.3 of the present chapter.

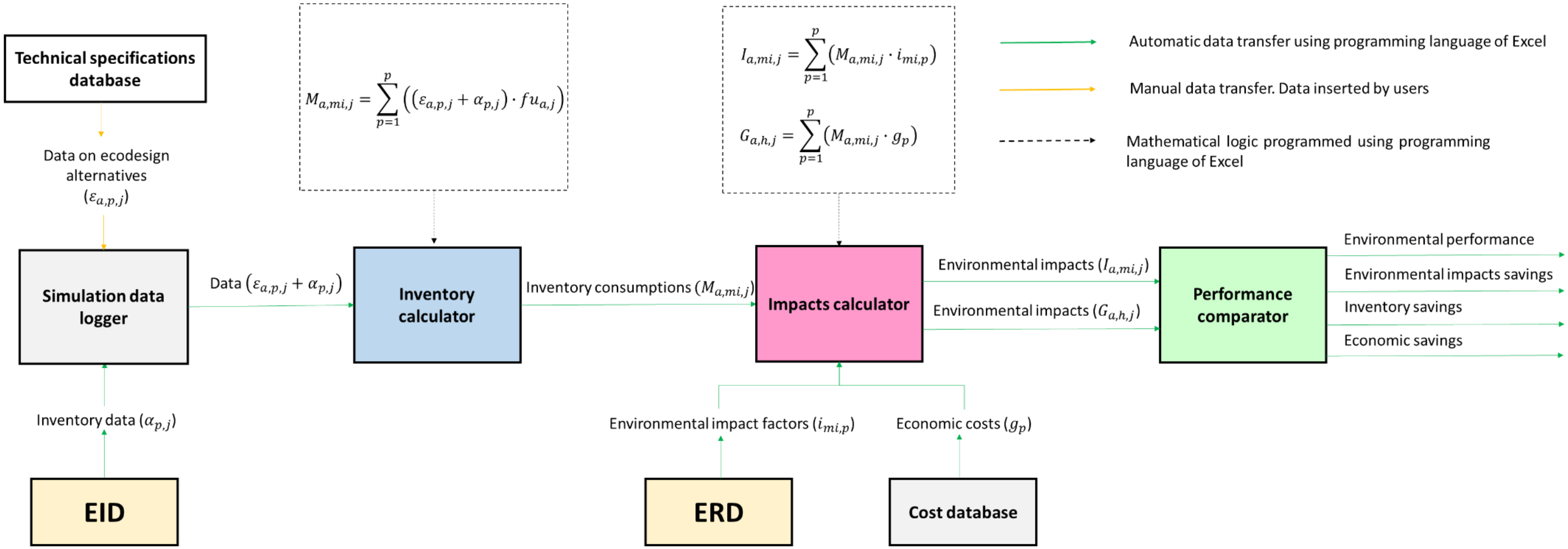


Figure 62 Structure of the EcoDesign Simulator Dashboard (Eco-DSD) proposed in OES2 (Personal elaboration, 2017).

2.2.4.5. STEM 6: Indicator of Work Environmental Efficiency (IWEE)

The Indicator of Work Environmental Efficiency (IWEE) have been introduced in OES2 in order to face the gaps related to ecoefficiency assessment (see following table).

Life Cycle Management Critical Areas	Identified gaps
Ecoinnovation	Lack of indicators for ecoefficiency assessment

Table 29 Gaps faced by the STEM "Indicator of Work Environmental Efficiency (IWEE)".

This gap identified during the scientific literature review constitutes a relevant EMBs related to the difficulties of organizations to assess the ecoefficiency level of production processes in order to improve environmental and economic performance of them. The measurement of the efficiency of material and energy flow consumptions is an essential step in order to improve the environmental and economic performance of industrial processes according to sustainable development principles (Lior, 2008). However, many times the industries explore partially its efficiency focusing only on quantitative perspective using indicators where the Overall Equipment Effectiveness (OEE) is widely adopted and proven metric (Anvari et al., 2011; Gibbons et al., 2010; Wilson, 2009; Ahuja et al., 2008; Pintelon et al., 2008). Is defined a quantitative perspective because the efficacy is related to the capacity of the process to produce a quantity of product units respect to a theoretical production of units.

$$OEE_{p,j} = A_{p,j} \cdot P_{p,j} \cdot Q_{p,j} \quad [2.22]$$

$A_{p,j}$= Availability metric of the *p-esime* process of the *j-esime* site. It represents the availability of the operation as a percentage of scheduled time. It measures the uptime and is calculated by dividing Run Time by Total Time;

$P_{p,j}$= Performance metric of the *p-esime* process of the *j-esime* site. It represents the speed at which the operation runs as a percentage of its designed speed. It is computed by dividing Total Count by Target Counter;

$Q_{p,j}$= Quality metric of the *p-esime* process of the *j-esime* site. It represents the number of good parts that are produced as a percentage of the total parts produced. It is calculated by dividing Good Count by Total Count.

However, many authors are according that there is the need to side by side with the quantitative perspective measure of the process efficiency a qualitative perspective. The qualitative perspective is related to the capacity of a process to produce the same quantity of units generating lower environmental impacts (Ng et al., 2015; Sproedt et al., 2015; Niggeschmidt et al., 2010; Brown et al., 2014; Faulkner et al., 2014; Kurdve et al., 2014; Marimin et al., 2014) reducing resource consumptions (e.g. electricity, chemicals, etc.) (see figure 59). This point of view is sustained by the fact that effectively the same process with the same OEE value can be for example generates electricity consumptions very different. Another example can be the case of two machineries that produce the same product, with the same OEE but with different consumptions of electricity and chemicals. Therefore, the introduction of indicators that explore the environmental efficiency of productive processes is a very important task in order to promote and support the transition towards environmental sustainable industry.

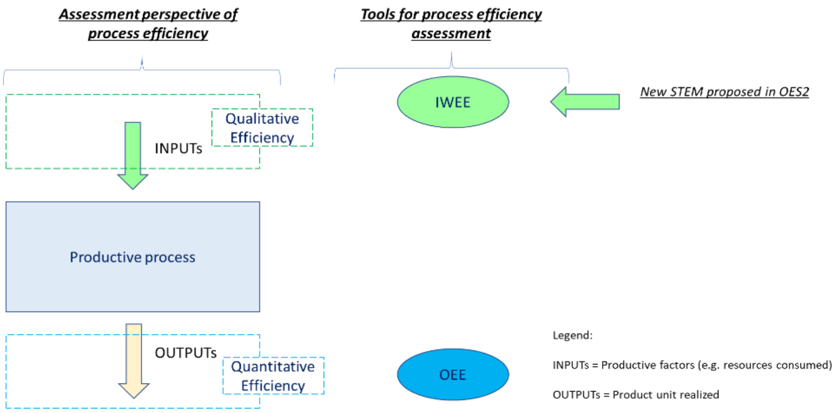


Figure 63 Methodological framework where the IWEE has been inserted (Personal elaboration, 2017).

In this context, where the OES2 method promotes the control of ecoefficiency of productive process, the Indicator of Work Environmental Efficiency (IWEE) has been proposed as a solution. The IWEE has been developed combining different parameters (e.g. electricity consumption, chemical consumptions, etc.) with a multi-criteria approach in order to give a comprehensive assessment of the environmental efficiency. This approach is according with the concept of industrial metabolism, in which natural resources (electricity, chemicals, etc.) are consumed by manufacturing processes (Favi et al., 2017). The introduction of this indicator can support also gain insight into the most significant production steps (Herman et al., 2007).

The development of IWEE has been conducted following this methodological procedure:

1. Definition of IWEE mathematical formulation;
2. Correlation between IWEE and productive configurations;
3. Development of the IWEE software structure;
4. Test of IWEE in a real case study (application to the Acqua Minerale San Benedetto S.p.A. organization).

The developed of IWEE has been realized according to ISO14045 on ecoefficiency.

2.2.4.5.1. Definition of IWEE mathematical formulation

The first step to develop the Indicator of Work Environmental Efficiency (IWEE) has been obviously the formulation of the mathematical description. The IWEE is obtained by a liner sum of weighted index:

$$IWEE_{p,j} = a_{E,p,j} \cdot E_{p,j} + a_{C,p,j} \cdot C_{p,j} + a_{W,p,j} \cdot W_{p,j} + a_{S,p,j} \cdot S_{p,j} \quad [2.23]$$

Where,

$E_{p,j}$= is the Index of environmental efficiency of energy resources use of the *p-esime* process of the *j-esime* site;

$C_{p,j}$= is the Index of environmental efficiency of auxiliary materials use (e.g. chemicals) of the *p-esime* process of the *j-esime* site;

$W_{p,j}$= is the Index of environmental efficiency of water resources use of the *p-esime* process of the *j-esime* site;

$S_{p,j}$= is the Index of environmental efficiency of raw materials use in terms of wastes generated of the *p-esime* process of the *j-esime* site.

All four indexes vary between 0 to 100%. Generally, it is possible, if an organization has the specific need, to add a new addendum to the formulation following the same mathematical structure. The current formulation has been chosen because it has been considered sufficiently exhaustive for general productive processes.

$a_{E,p,j}$; $a_{C,p,j}$; $a_{W,p,j}$; $a_{S,p,j}$: are the weighting coefficients in the case of the *p-esime* process of the *j-esime* site, that weight the influence of each index in function of the cost generated by this aspect respect to the total cost generated by all aspect considered by the four indexes.

$$a_{E,p,j} = \frac{\sum_{e=1}^{e}\left(cost_{e,j} \cdot \overline{E_{IKPI,e,p,J}}\right)}{\sum_{e=1}^{e}\left(cost_{e,j} \cdot \overline{E_{IKPI,e,p,J}}\right) + \sum_{z=1}^{z}\left(cost_{z,j} \cdot \overline{C_{IKPI,z,p,J}}\right) + \sum_{q=1}^{q}\left(cost_{q,j} \cdot \overline{W_{IKPI,q,p,J}}\right) + \sum_{y=1}^{y}\left(cost_{y,j} \cdot \overline{S_{IKPI,y,p,J}}\right)}$$

$$a_{C,p,j} = \frac{\sum_{z=1}^{z}\left(cost_{z,j} \cdot \overline{C_{IKPI,z,p,J}}\right)}{\sum_{e=1}^{e}\left(cost_{e,j} \cdot \overline{E_{IKPI,e,p,J}}\right) + \sum_{z=1}^{z}\left(cost_{z,j} \cdot \overline{C_{IKPI,z,p,J}}\right) + \sum_{q=1}^{q}\left(cost_{q,j} \cdot \overline{W_{IKPI,q,p,J}}\right) + \sum_{y=1}^{y}\left(cost_{y,j} \cdot \overline{S_{IKPI,y,p,J}}\right)}$$

$$a_{W,p,j} = \frac{\sum_{q=1}^{q}\left(cost_{q,j} \cdot \overline{W_{IKPI,q,p,J}}\right)}{\sum_{e=1}^{e}\left(cost_{e,j} \cdot \overline{E_{IKPI,e,p,J}}\right) + \sum_{z=1}^{z}\left(cost_{z,j} \cdot \overline{C_{IKPI,z,p,J}}\right) + \sum_{q=1}^{q}\left(cost_{q,j} \cdot \overline{W_{IKPI,q,p,J}}\right) + \sum_{y=1}^{y}\left(cost_{y,j} \cdot \overline{S_{IKPI,y,p,J}}\right)}$$

$$a_{S,p,j} = 1 - a_{E,p,j} - a_{C,p,j} - a_{W,p,j} \quad [2.24, 2.25, 2.26, 2.27]$$

As shown in the previously equations, the cost associated to each aspect has been calculated as the sum of the cost associated to every flow associated to the same aspect (e.g. every *e-esime* energy resources, every *z-esime* auxiliary materials, etc.). The costs are obtained to multiply the average consumptions of every specific resources (e.g. every *e-esime* energy resources) for the unit costs of the specific resources (e.g. $cost_{e,j}$). The weighting approach permits to taking into account the combination of different parameters with a multi-criteria approach easily (Herman et al., 2007). In fact, although exist more accurate multi-criteria mathematical approach that can be undergoes to combine different criteria (e.g. Technique for Order of Preference by Similarity to Ideal Solution - TOPSIS), in the case of the formulation of indicators of this type, foresting simple approaches helps a lot in rising comprehension by users (e.g. process engineers, production experts, managers, etc.). Instead, the choice of use a weighting approach based on economic logic has been done in order to reduce the potential contradictions with the organization' objective of cost reduction. In fact, all the indexes promote the reduction of resources consumptions and therefore the reduction of environmental impacts and costs, however this weighting approach permits to prioritize the improvement pathway that generates a faster cost reduction (see the green ones in the following figure). However, it is important to underline that the weighting approach can be characterized based on the requirements and goals of each organization (Michelsen et al., 2010).

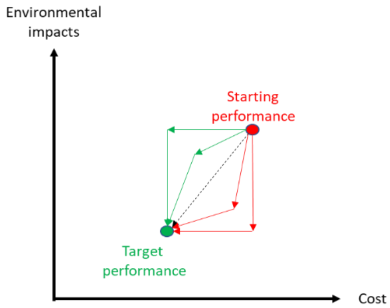


Figure 64 Potential pathways to improve the process performance (Personal elaboration, 2017).

The calculation of the four indexes is important in order to assess also separately the performance of the process. The four indexes are calculated with the following equations:

$$E_{p,j} = \sum_{e=1}^{e} \left(b_{e,j} \cdot E_{e,p,j} \cdot 100\right) \quad [2.28]$$

$$C_{p,j} = \sum_{z=1}^{z} \left(d_{z,j} \cdot C_{z,p,j} \cdot 100\right) \quad [2.29]$$

$$W_{p,j} = \sum_{q=1}^{q} \left(h_{q,j} \cdot W_{q,p,j} \cdot 100\right) \quad [2.30]$$

$$S_{p,j} = \sum_{y=1}^{y} \left(v_{y,j} \cdot S_{y,p,j} \cdot 100\right) \quad [2.31]$$

Where,

$E_{e,p,j}$= is the Sub-index of environmental efficiency of *e-esime* energy resource use of the *p-esime* process of the *j-esime* site;

$C_{z,p,j}$= is the Sub-index of environmental efficiency of *z-esime* auxiliary material use (e.g. chemicals) of the *p-esime* process of the *j-esime* site;

$W_{q,p,j}$= is the Sub-index of environmental efficiency of *q-esime* water resource use of the *p-esime* process of the *j-esime* site;

$S_{y,p,j}$= is the Sub-index of environmental efficiency of *y-esime* raw material use in terms of wastes generated (scraps) of the *p-esime* process of the *j-esime* site.

$$E_{e,p,j} = \frac{E_{Ref\ IOPI,e,p,j}}{E_{IOPI,e,p,j}} \cdot 100 \quad [2.32]$$

$$C_{z,p,j} = \frac{C_{Ref\ IOPI,z,p,j}}{C_{IKPI,z,p,j}} \cdot 100 \quad [2.33]$$

$$W_{q,p,j} = \frac{W_{Ref\ IOPI,q,p,j}}{W_{IKPI,q,p,j}} \cdot 100 \quad [2.34]$$

$$S_{y,p,j} = \frac{S_{Ref\ IOPI,y,p,j}}{S_{IOPI,y,p,j}} \cdot 100 \quad [2.35]$$

Where,

$E_{Ref\ IOPI,e,p,j}$; $C_{Ref\ IOPI,z,p,j}$; $W_{Ref\ IOPI,q,p,j}$; $S_{Ref\ IOPI,y,p,j}$: are the reference values of Inventory Operative Performance Indicators (IOPIs) (ISO14031), (or reference consumptions) of the *p-esime* process of the *j-esime* site respectively for *e-esime* energy resource (e.g. electricity, thermal energy, etc.), *z-esime* auxiliary material (e.g. specific chemicals), *q-esime* water resource (e.g. ground water, surface water) and *y-esime* raw material in terms of waste (e.g. specific waste of raw material). The reference values of IOPIs can be set by the organization following different logics. With the target logic for example the organization sets as reference values for IOPIs specific improvement targets. Another case is the average logic, where the organization sets as reference values for IOPIs the last consolidated average consumptions.

$E_{IKPI,e,p,j}$; $C_{IKPI,z,p,j}$; $W_{IKPI,q,p,j}$; $S_{IKPI,y,p,j}$: are the actual measured values of IOPI of the *p-esime* process of the *j-esime* site respectively for *e-esime* energy resource (e.g. electricity, thermal energy, etc.), *z-esime* auxiliary material (e.g. specific chemicals), *q-esime* water resource (e.g. ground water, surface water) and *y-esime* raw material in terms of waste (e.g. specific waste of raw material).

Also in this case, the mathematical formulation of the sub-indexes, as a ratio between a reference IOPI and the actual IOPI, promotes the reduction of resources consumptions. Therefore, each sub-index is the ratio between two performance. According to OES2 method, has been distinguished two types of OPI, the Inventory Operative Performance Indicators (IOPIs) and the Environmental Operative Performance Indicators (EOPIs). The first one is related to the consumption of resources and therefore to inventory assessment level, the second one is related to environmental impacts and therefore to the impact assessment level. The distinction between these two types of indicator is according to ISO14031 and permit to distinguish performance in term of resource consumption from performance in term of environmental impacts. The choice to use IOPI for the formulation of IWEE can favour and simplify the understanding of results by users (e.g. process engineers, production experts, managers, etc.) and is according with ISO14045 that permits the choice between the inventory level and the impact assessment level (Sproedt et al., 2015). The IOPIs are calculated dividing the resource consumptions for a reference flow that characterize physically the process under study (e.g. a number of product units, a mass, a volume, etc.).

$$E_{IOPI,e,p,j} = \frac{\alpha_{e,p,j}}{RF_{p,j}} \cdot s_{p,j} \quad [2.36]$$

$$C_{IOPI,z,p,j} = \frac{\alpha_{z,p,j}}{RF_{p,j}} \cdot s_{p,j} \quad [2.37]$$

$$W_{IOPI,q,p,j} = \frac{\alpha_{q,p,j}}{RF_{p,j}} \cdot s_{p,j} \quad [2.38]$$

$$S_{IOPI,y,p,j} = \frac{\alpha_{y,p,j}}{RF_{p,j}} \cdot s_{p,j} \quad [2.39]$$

Where,

$\alpha_{e,p,j}$; $\alpha_{z,p,j}$; $\alpha_{q,p,j}$; $\alpha_{y,p,j}$: are respectively the consumptions, in a specific time period (e.g 1 day, 1 week), of the *p-esime* process of the *j-esime* site respectively of *e-esime* energy resource (e.g. electricity, thermal energy, etc.), *z-esime* auxiliary material (e.g. specific chemicals), *q-esime* water resource (e.g.

ground water, surface water) and *y-esime* raw material in terms of waste (e.g. specific waste of raw material)
$RF_{p,j}$= is the reference flow of the *p-esime* process of the *j-esime* site, referred to the same time period (e.g. number of products units/day; number of products units/week).
$s_{p,j}$= is a scale factor that permits to scale the IOPI value (e.g. kWh/1000 products unit, in this case the scale factor is 1000).

$$b_{e,j} = \frac{cost_{e,j} \cdot \overline{E_{IOPI,e,p,J}}}{\sum_{e=1}^{e}\left(cost_{e,j} \cdot \overline{E_{IOPI,e,p,J}}\right)} \quad [2.40]$$

$$d_{z,j} = \frac{cost_{z,j} \cdot \overline{C_{IOPI,z,p,J}}}{\sum_{z=1}^{z}\left(cost_{z,j} \cdot \overline{C_{IOPI,z,p,J}}\right)} \quad [2.41]$$

$$h_{q,j} = \frac{cost_{q,j} \cdot \overline{W_{IOPI,q,p,J}}}{\sum_{q=1}^{q}\left(cost_{q,j} \cdot \overline{W_{IOPI,q,p,J}}\right)} \quad [2.42]$$

$$v_{y,j} = \frac{cost_{y,j} \cdot \overline{S_{IOPI,y,p,J}}}{\sum_{y=1}^{y}\left(cost_{y,j} \cdot \overline{S_{IOPI,y,p,J}}\right)} \quad [2.43]$$

The previously equations show the calculation of the weighting coefficients used to weight the influence of each considered aspect (e.g. *e-esime* energy resource) to each index (e.g. $E_{p,j}$ Index of environmental efficiency of energy resources use). This weighting approach is according to the weighting approach previously descripted to weight the four indexes.
The calculation of the sub-indexes and of the relative weighting coefficients is an important aspect of the IWEE because permits to have a detailed perspective of the process performance and of the relevance of the single aspects. In fact, the IWEE shows a detailed picture of the main energy and materials resource consumptions of productive processes following a multi-criteria approach. Furthermore, it provides to users (e.g. process engineers, production experts, managers, etc.) a tangible support to monitor and assess the performance of productive processes trough an approach based on Inventory Operative Performance Indicators (IOPIs) (ISO, 2012; Jiang et al., 2012; Deif et al., 2011). With this mathematical formulation, the sub-indexes and the IWEE results are related with linear functions following a tree structure.

2.2.4.5.2. Correlation between IWEE and productive configurations

The standalone implementation of ecoefficiency indicators generally resulted low supportive to decision making processes because the indicators focus to monitor the process performance trend without explore the causes which have influence the performance deviations (Favi et al., 2017; Zust et al., 2016; May et al., 2015). This is a very important task in order to operatively connect the results of ecoefficiency assessment and the variables that constitute the lever on which the organization can act to improve the environmental performance of processes promoting the reduce of resources consumptions. In fact, generally exist two ways to reduce the resources consumptions of productive processes:

- The substitution of the process technologies that can modify radically the resource consumptions levels;
- The modify of process operative conditions that can promote the selection of operative conditions configurations who themselves promote the reduction of resource consumptions levels.

The second way, is interesting because do not requires investments in new technologies and permits to optimize the performance of the already existing processes and technologies. Many times, especially in the manufacturing industries, operative conditions are determinate by variables such as production rate, working shifts, working time, etc. (Diaz-Elsayed et al., 2013; Fang et al., 2011; Melnyk et al., 2001).

These variables depend mainly by production schedule and management. The possibility to improve ecoefficiency of industrial processes is rarely considered by researcher objectives in scheduling manufacturing systems (Favi et al., 2017). In this context, the IWEE has been correlate to production variables related to schedule and activities. The approach proposed is based on three methodological steps:

1. Correlation analysis between IWEE and productive variables;
2. Development of an index to discriminate productive configurations;
3. Classification of productive configuration and variables states.

2.2.4.5.2.1. Correlation analysis between IWEE and identified productive variables

In this methodological stage, the organization must identify all the potential productive variables related to schedule activities. Some examples of variables are shown in the following figure.

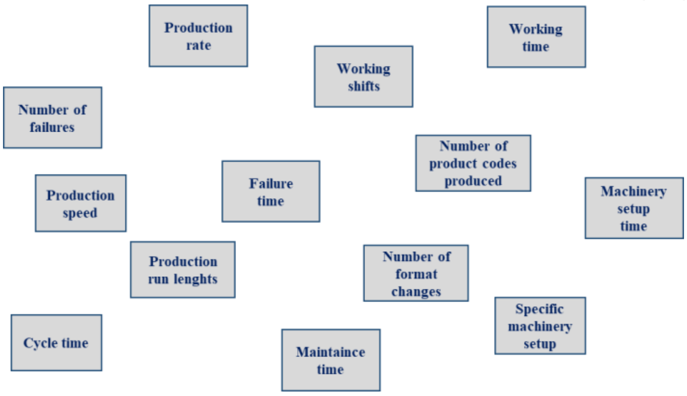


Figure 65 Examples of variables that can influence the process ecoefficiency (Personal elaboration, 2017).

The search for variables may start focusing on aspects commonly used by the organization to schedule the production and after to be extended to other variables. In order to support the process of variables identification, survey with planner responsible, process engineers and maintenance responsible may be supportive.

Once the variables have been identified a correlation analysis must be performed. Correlation between sets of data is a measure of how well they are related. The correlation can be studied with statistical techniques

- Pearson correlation coefficient: assesses linear relationships between two variables (see figure below). It varies between -1 and 1;
- Spearman rank correlation coefficient: assesses monotonic relationships between two variables (see figure below). It varies between -1 and 1;

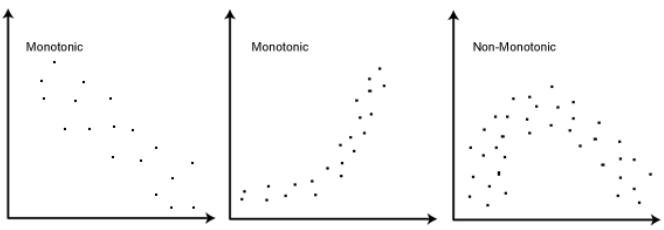


Figure 66 Possible relationships between two variables.

The most common measure of correlation in stats is the Pearson correlation. Typical reference values are:

- High correlation: 0.5 to 1.0 (positive) or -0.5 to -1.0 (negative);

- Medium correlation: 0.3 to 0.5 (positive) or -0.3 to -0.5 (negative);
- Low correlation: 0.1 to 0.3 (positive) or -0.1 to -0.3. (negative).

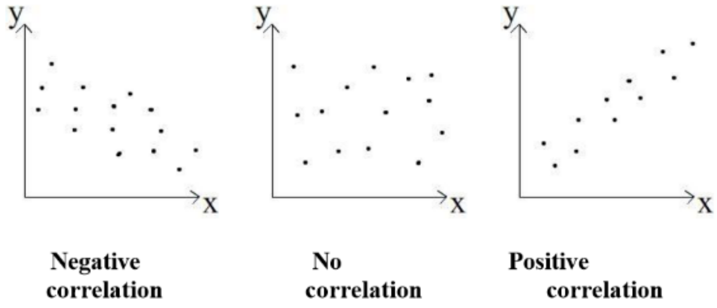


Figure 67 Different degree of linear correlation between two variables.

The results of correlation constitute a symmetric matrix (see as example figure below) where are shown the correlation coefficients for every combination of pairs of variables.

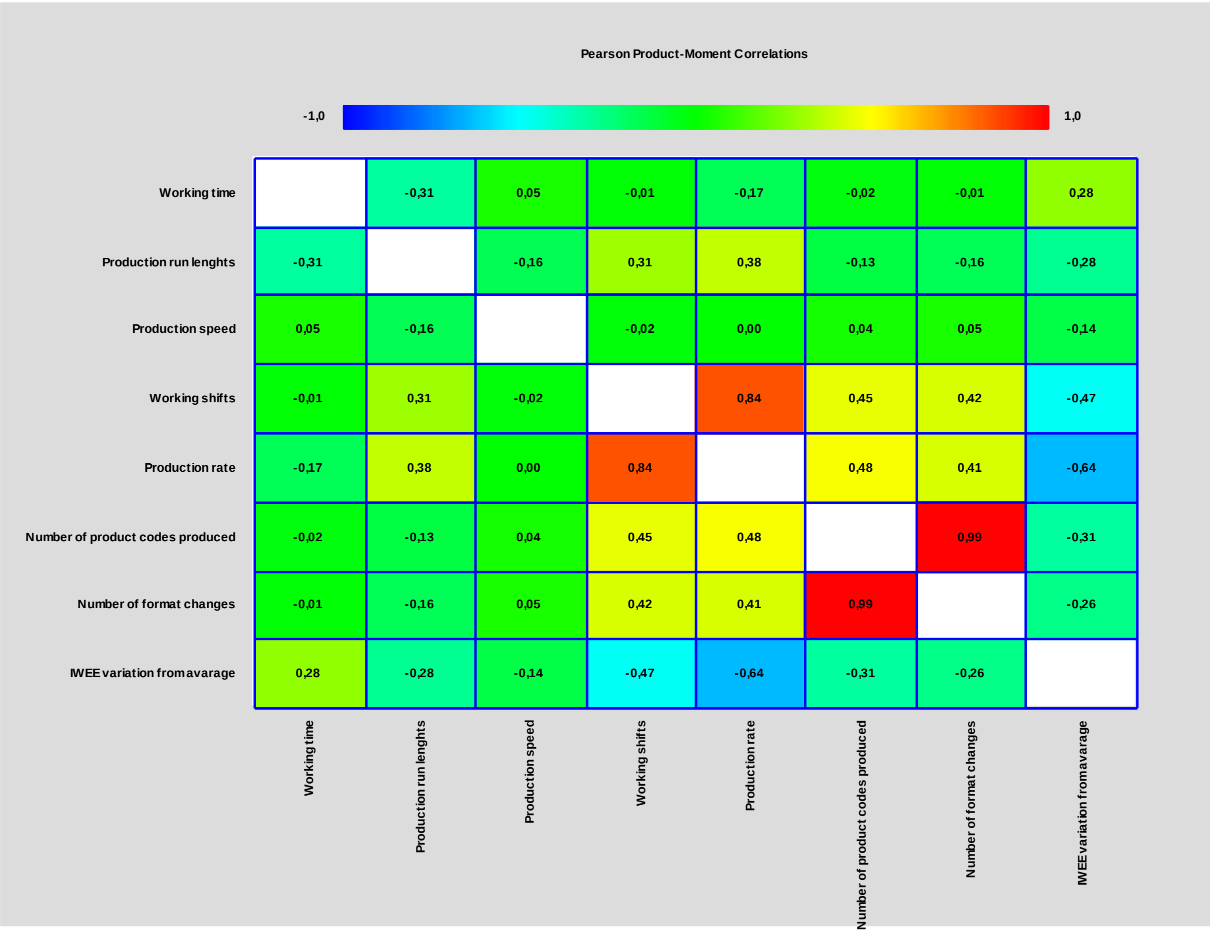


Figure 68 Example of matrix of Pearson correlation coefficients (Personal Elaboration, 2017).

The results of correlation can be obtained use different statistical software or not specific software that implement statistical analysis features. In the case of this PhD thesis the statistical software used is Statgraphics Centurion and it has been briefly descripted in the paragraph 2.2.4.6.2.2 on SEDM module introduce by OES2 specifically to support the use of statistical and mathematical tools and approaches for decision-making through the use of software.

Through the correlation analysis it is possible to identify which variables have a relevant positive or negative influence on IWEE. Only the correlation higher than 0,3 or lower than -0,3 have been considered relevant. The correlation analysis permits also to identify variables that influence indirectly the IWEE influencing some variables that is relevant correlated to IWEE. Therefore, two levels of variables have been distinguished:

- Variables of level 1: these variables show relevant correlations with IWEE;
- Variables of level 2: these variables show relevant correlation with variables of level 1.

An illustrative example of the concept is shown in the following figure.

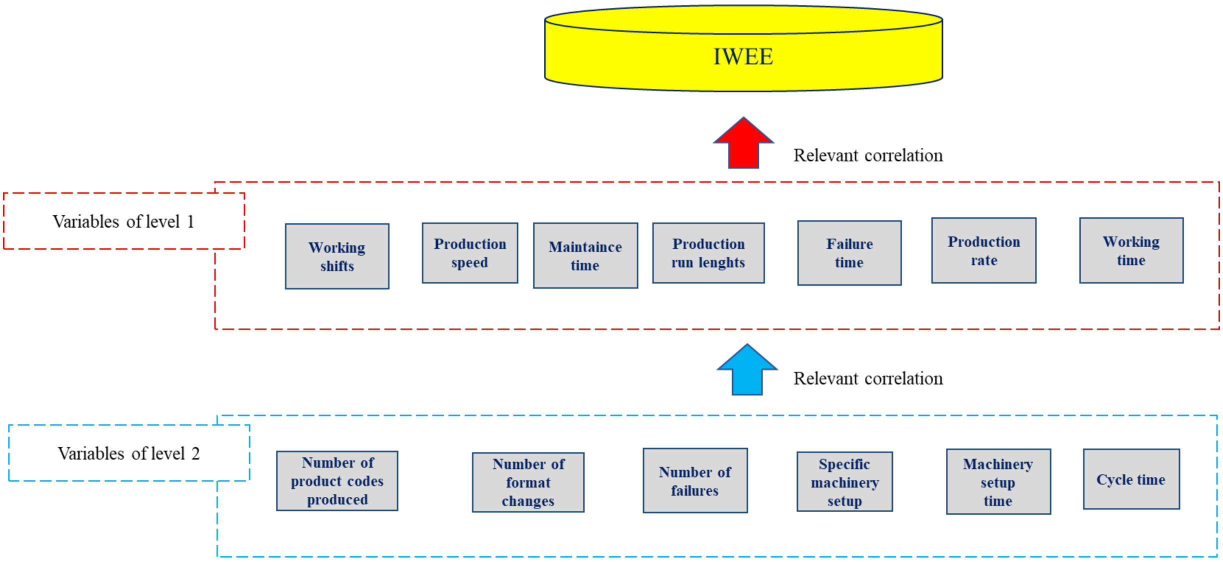


Figure 69 Example of correlation: variables of level 1 and variables of level 2 (Personal Elaboration, 2017).

In order to verify the statistical robustness and validity of correlation analysis traditional test must be performed such as p value-test, outliers analysis, etc. Furthermore, attention must be paid to the data collection processes especially in the case of seasonal processes. In fact, in these cases, you should consider the option to perform correlation analysis dividing in different groups the data of different seasons. Whit the term season, it is intended limited time periods of the years that present from the productive perspective relevant differences (e.g. season of high productivity and season on low productivity).

2.2.4.5.2.2. <u>Development of an index to discriminate productive configurations</u>

Once all correlation analysis have been performed, variables of level 1 and of level 2 are identified. The set of variables of level 1 and level 2 is considered a productive configuration.
In order to study which productive configurations promote better values of IWEE and which productive configurations determine worst values of IWEE the statistical technique of discriminant analysis can be applied. The discriminant analysis permits to classify a set of statistical units in two different groups (e.g. A and B) on the basis of a set of know independent variables as show in the following figure.

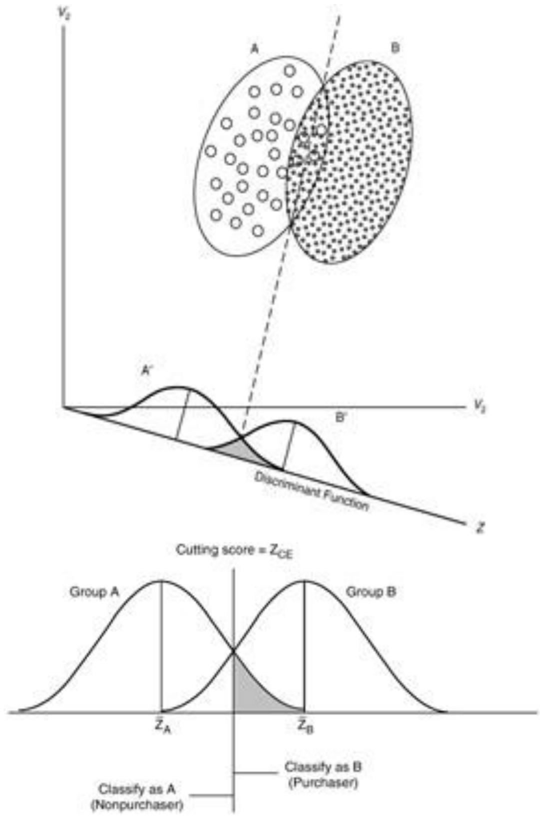


Figure 70 Example of statistic discriminant analysis. In the second figure two thresholds are identifiable.

Therefore, the discriminant analysis permits to obtain a model to forecast the belonging to a group. The model is based on a discriminant function (in the case of two groups) defined on the base of the linear combinations of independent variables that maximize the discrimination between the two groups. The elaboration of the discriminant function has been obtained using multilinear regression mathematical method with a forward stepwise selection of independent variables. The selection of variables is performed with statistical test such as p-value test, F test. The model elaboration is based on a known statistical sample where the group memberships are note. Once the discriminant function can be used to predict the group membership of new statistical units for which the membership is not known (Raudys et al., 2004). In fact, there are two possible objectives in a discriminant analysis:

- finding a predictive equation for classifying new individuals;
- interpreting the predictive equation to better understand the relationships that may exist among the variables.

In order to apply the discriminant analysis technique to IWEE firstly has been defined the variable "IWEE state". Whit the term IWEE states, they are intended the type of variation of IWEE value respect to the average value. Considering only the negative variations smaller than -3% and only the positive variations greater than +3%, to the negative variations have been associated the discriminant state equal to 0 while to the positive variations have been associated the discriminant state equal to 1. The choice to exclude variation included in the range >-3%,<+3% has been done in order to exclude the points related to not significant variations.

Secondly, instead to use as independent classificatory variables the pure variables of level 1 have been elaborate productive indexes as the ratio of each variable for the average value of the variable. These indexes permit to normalize the scale of the different independent variables (e.g. productive run length= 200 minutes/run, production speed=100.000 pieces/hour, number of shifts= 2 shifts/day). The choice to use as reference values the average values of each variable is according to the objective of the application, that is, the identification of which productive configurations promote better values of IWEE and which productive configurations determine worst values of IWEE respect to the average value of IWEE. Once the indexes are elaborated for each variable of level 1 a discriminant analysis algorithm can be applied. This algorithm can be find in statistical software such as Statgraphics Centurion, and exploits a multilinear regression mathematical method in order to calculate the discriminant function. The value assumed by discriminant function has been named IPLE (Index of Potential Loss of Efficiency). The following equation is only an example of the potential result.

$$IPLE_{p,j} = Working\ shifts\ index_{p,j} + Production\ rate\ index_{p,j} - Failure\ time\ index_{p,j} \quad [2.44]$$

Where,
$IPLE_{p,j}$= IPLE value of the *p-esime* process of the *j-esime* site;
$Working\ shifts\ index_{p,j}$= index on working shifts of the *p-esime* process of the *j-esime* site;
$Production\ rate\ index_{p,j}$= index on production rate of the *p-esime* process of the *j-esime* site;
$Failure\ time\ index_{p,j}$= index on failure time of the *p-esime* process of the *j-esime* site.

2.2.4.5.2.3. Classification of productive configuration and variables states

Once the discriminant function and therefore the IPLE value has been obtained for each productive configuration the last step is the set of a classification rule. The classification rule permits in function of the IPLE value to associate to the productive configuration a class that describe its statistical tendency to promote the improve of efficiency or not.
According to figure 70, it is possible to distinguish two threshold IPLE values:

- A lower threshold IPLE value: that is the value of IPLE below which there are only statistical units with IWEE state equal to 0 (with a confidential interval of 95%);
- A upper threshold IPLE value: that is the value of IPLE upper which there are only statistical units with IWEE state equal to 1 (with a confidential interval of 95%).

Therefore, according to figure 70, there is a range between the two thresholds where coexist statistical units with IWEE state equal to 0 with statistical units with IWEE state equal to 1. This range, is common in discriminant analysis and it is considered uncertain because for these IPLE values no predictions are possible. The same concept is proposed in figure 71 in terms of probability curve. With higher values of IPLE the probability to have a good ecoefficiency increase.
Therefore, the classification rule associates to the productive configurations the following classes:

- Class 1: to the IPLE values higher than upper IPLE threshold. The productive configurations in Class 1 statistically promote the improve of IWEE;
- Class 3: to the IPLE values lower than lower IPLE threshold. The productive configurations in Class 3 statistically worse the value of IWEE;
- Class 2: to the IPLE values between the lower and the upper IPLE threshold. The productive configurations in Class 2 statistically are neutral in terms of influence on IWEE value. Sometimes productive configurations in Class 2 may generate an improve of IWEE value and sometimes may generate a worst without a statistical explication if function of considered variables (uncertain range). However, the sum of the IWEE deviations may be equal about 0 confirming the neutrality of the Class 2.

Finally, in order to assess individually, the variables of level 1 and 2, the identification of lower and upper threshold is proposed in order to monitor the state of each variables respect to reference values identify by the organization. Obviously, the set of the two thresholds for each variable of level 1 and 2 is strongly dependent from specific organization requirements and constraints.
The classification of productive configuration supports the optimization of production scheduling according to environmental sustainability objective (IWEE) permitting of assess potential changes of production conditions (e.g. variables of level 1 and 2). This approach can be used also to assess

alternative scenarios in order to calculate the environmental and economic savings generates by different working conditions that increase the number of productive configurations in Class 1 improving IWEE value.

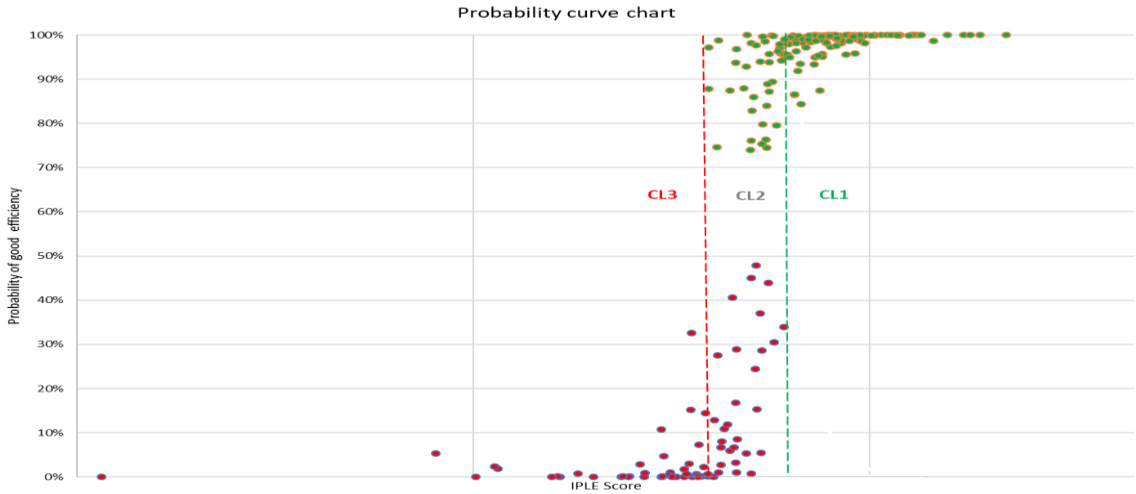


Figure 71 Example of probability curve for IPLE index.

2.2.4.5.3. Development of the software structure

In order to support the operative application of IWEE has been developed also the software structure. It has been developed using programming language of Excel. The software structure has been based on four components:

1. IWEE calculator;
2. IWEE productive configurations data logger;
3. IWEE productive configurations classifier;
4. IWEE process dashboard.

The software structure proposed has been shown in the figure 72. The software component "IWEE calculator" permits the automatic calculation of IWEE sub indexes, IWEE indexes and IWEE. For each of these three steps has been proposed a calculator section. The mathematical logic has been implemented using programming language of excel. All steps are programmed for automatic operation excepted the imputation of reference IOPIs that request the manual data entry by user. As shown in the figure 72, the values of IOPIs has automatically obtained by the STEM named Eco-EKA. In the case of values of IWEE higher than 100%, these values are settled equal to 100%. These situations are possible in function of the reference IOPI selected by user.

The software component "IWEE productive configurations data logger" permits to load data related to productive variables, obtained automatically by EID, and to identify through a correlation analysis of relevant productive variables of level 1 and level 2. The correlation analysis requires the interaction with the STEM named SEDM module, that has the scope to making available the correctly tools for decision making (e.g. statistical software and mathematical optimization software). In fact, in this case, the SEDM module actives the use of statistical software in order to elaborate the correlation analysis. In this case, the statistical software used by SEDM module is Statgraphics Centurion. The results of the correlation analysis, are used in a filter that have the scope to select for the successive elaboration processes only the productive variables of level 1 and level 2. Successively, the productive variables of level 1 were used to elaborate indexes according to the method descripted in the previously paragraph while the productive variables of level 2 are stored in a database with productive variables of level 1.

The software component "IWEE productive configurations classifier" permits to classify the productive configurations in order to support the understanding of IWEE results. The indexes elaborated using productive variables of level 1 were used to elaborate a discriminant function (IPLE) through a

discriminant analysis. The statistical discriminant analysis requires the activation of the SEDM module through the use of the statistical software Statgraphics Centurion in order to sole this statistical problem. In function of thresholds manually defined by user, each productive configuration is assessed through the classification of IPLE, single productive variables of level 1 and 2. For the classification have been used three classes according to the method descripted in the previously paragraph. It is important to underline that the activation of SEDM is realized one time in order to perform the correlation analysis and the discriminant analysis and until the statistical results are considered valid (no relevant changes in production processes) anymore activations are realized.
The last software component "IWEE process dashboard" permits a smart visualization of the IWEE and productive configuration classification. The results are shown in numeric terms and in classes terms. This component permits rapidly to assess the efficiency level of the process and assess if the actual productive configuration promotes or not the process efficiency.

2.2.4.5.4. Test of IWEE in a real case study

The description of the test strategy to verify applicability and effectiveness of OES2 method and its components is available in the paragraph 2.3.

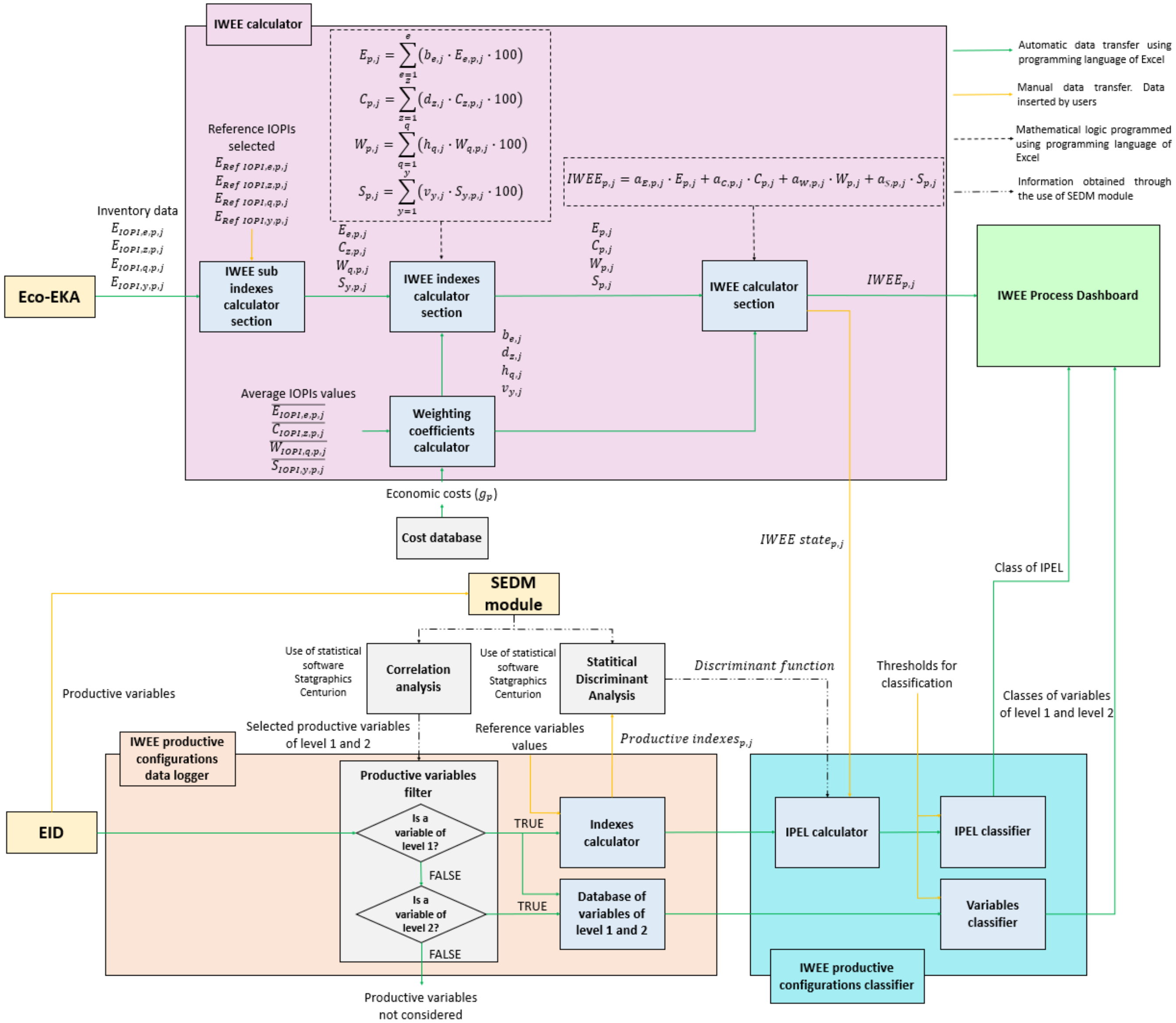


Figure 72 Structure of the Indicator of Work Environmental Efficiency (IWEE) proposed in OES2 (Personal elaboration, 2017).

2.2.4.6. STEM 7: Strategic Environmental Decision Making (SEDM) module

The Indicator of Strategic Environmental Decision Making module (SEDM) have been introduced in OES2 in order to face the gaps related to decision making (see following table).

Life Cycle Management Critical Areas	Identified gaps
Strategic decision making	Lack of use of Decision making Tools (MCDA, optimization, statistical techniques, etc.)

Table 30 Gaps faced by the STEM "Strategic Environmental Decision Making module (SEDM module)".

This gap identified during the scientific literature review constitute relevant EMBs related to the difficulties of organizations to face decision making problems. Many decision making tools have been developed by scientific community in the last decades. However, the lack use of these tools by organizations, do not permit to achieve the optimum performance and the best solutions in the robustness manner. Many authors are according that the combination of EMTs and tools for analytical decision making is essential (Meng et al., 2017; Favi et al., 2017; De Luca et al., 2017; Martin-Gamboa et al., 2017; Docekalova et al., 2017; Aspen et al., 2015; Theodosiou et al., 2015; Validi et al., 2015; Validi et al., 2014; Cinelli et al., 2014; Liu et al., 2012; Herman et al., 2007, Azapagic et al., 1999). In fact, the analytical research of trade-off solutions between environmental performance and economic performance is key perspective to face decision making problems in order to avoid undesirable performance worsening (Jeswani et al., 2010). Generally, decision making tools ranges from optimization through mathematical stochastic methods (e.g. multiobjectives optimization with evolutionary algorithms), fuzzy logic, Multiple Criteria Decision Analysis (MCDA) to statistical methods such as discriminant analysis. These methods are now considered to be valuable tools for environmental decision making.

In this context, the Strategic Environmental Decision Making module (SEDM) proposed whiting OES2 method, has the function to support the use of these tools for strategical decision making problems in order to guarantee the identifications of the best available solutions. SEDM is a flexible module, in fact, the function is to make available decision making tools, based on statistical and mathematical approaches, in order to require the use of these specific tools during strategic decision processes. Today, the use tools are simplified by the use of specific software available on the market. Therefore, the SEDM module is a procedural tool which regulates the use of two software for decision making:

- One to solve mathematical stochastic optimization problems;
- One to solve statistical and MCDA problems.

In the case of this PhD thesis have been chosen the following software:

- ModeFrontier v4.5.4 (64 bit) to solve mathematical stochastic optimization problems;
- Statgraphics Centurion v.17.2.05 (64 bit) to solve statistical and MCDA problems.

The choice has been influenced by two aspects, software license availability and personal knowhow of software. Obviously, different software can be chosen by organization.

A specific procedure has been developed in order to manage the activation of this module inasmuch this module do not work always but only on demand. The OES2 method therefore require the use of decision making tools, pushing the organizations to use these types of tools.

2.2.4.6.1. Definition of a procedure to active the SEDM module

The procedure has been elaborated, according to figure 73, on the base of four steps:

1. Type problem identification;

2. Data, goals and constraints collection;
3. SEDM module application;
4. Solution application to the original problem.

The first step "Type problem identification" permits to assess if there is the presence of a problem that requires the activation of the SEDM module and it permits to assess if the problem is statistical or related to multiobjectives optimization. The problems can be related to three environmental management areas of OES2:

- The area related to EPE and therefore related to decision making issues on management and improvement of environmental performance of the organization and of products portfolio. For example, optimization of environmental performance of supply chain (Azapagic et al., 1999) or optimization of production allocation in the case of a multisite organization (Validi et al., 2015).
- The area related to Ecodesing and therefore related to the identification of best solutions to sustain and improve the decision making issues related to development and assessment new products, new technologies or the acquisition of new productive site.
- The area related to Ecoefficiency and therefore related to decision making issues on optimization and improvement of already existing processes and products (Favi et al., 2017).

The second step of the procedure "Data, goals and constraints collection" requires that for the identified problem are collected all required data and eventual constraints and goals that must be respected (Favi et al., 2017). A large amount of data will be obtained by EID and ERD but a specific data collection processes will be required in order to complete the acquisition inasmuch these types of decision making problems often require to be solved additional information specifically produced by top management and engineers. One of the most important constraints in the environmental decision making is the respect of determined level of costs and economic performance.

The third step of the procedure "SEDM module application" permits the activation of SEDM module. In function of the problem type, the SEDM module active the use of the statistical software or of the optimization software. The first step is the elaboration of the model in the software space. Once the model is elaborated a solver is applied in order to obtain solutions and criteria. A step of MCDA may be required in order to refine the solution and criteria selection in function of compromises and priorities specific of the organization. It is important to underline that generally, the problems faced during the time are different and therefore the elaboration of model must be done every time specifically. Otherwise, if repetitive decision making problems are identified, a standard model can be elaborated in order to simplified the solutions identification.

The final step of the procedure "Solution application to the original problem" requires that the solutions and criteria are applied to the original problem in order to give feedbacks on potential achievable improvements (e.g. elaboration of forecast scenarios) or in order to definitively implement operatively the identified improvement solutions and criteria.

2.2.4.6.2. Test of the SEDM module in a real case study

The description of the test strategy to verify applicability and effectiveness of OES2 method and its components is available in the paragraph 2.3 of the present chapter.

2.2.4.6.2.1. Modefrontier – Statistical software

ModeFrontier is a multi-disciplinary and multi-objective optimisation and design environment developed by ESTECO S.p.A. It is a multidisciplinary and multi-objective software capable of handling complex optimisation problems. The complex algorithms within ModeFrontier can spot the optimal results, even conflicting with each other or belonging to different fields. mode ModeFrontier consists of Design of Experiments (DoE), optimisation algorithms, and robust design tools, capable of blending to

create an efficient strategy to solve complicated multi-disciplinary problems. It is offering a wide range of evolutionary optimisers to manage continuous, discrete, and mixed variable problems. The optimisation technology within ModeFrontier starts a workflow to input the data, connect the components of the models and provide the usage of its solution capabilities. This workflow transfers data from one simulation to the next, updating all parameter values according to the optimization algorithms, thus extracting relevant outputs. ModeFrontier combines opposing objectives and considers user-defined constraints, it helps to manage the complexity. It offers a considerable selection of innovative algorithms and able to tackle discrete or continuous variables to solve single and multi-objective problems. This design environment empowers the user to outline the appropriate robust optimisation strategy according to the design space boundaries. A very strong capability of ModeFrontier is its DoE guided solution approach. DoE connects the optimiser to the optimisation model. It generates the initial population for the optimiser(s) using a variety of distributions and designs. Strong non-linearity, high or low constrained problems, sizable problem dimensions can be addressed by ModeFrontier. Optimisation algorithms cover deterministic, stochastic and heuristic methods for both single and multi-objective problems. The heuristics/meta-heuristics evolutionary algorithms offered by ModeFrontier: MOGA II, NSGA II, MOSA, MOGT, MOPSO, HYBRID, SAmGeA.
Modefrontier v4.6.1 (64 bit)

2.2.4.6.2.2. Statgraphic – Statistical software

Statgraphics Centurion 17 is a comprehensive software for statistical analysis, data visualization and predictive analytics. It contains over 260 procedures covering a wide range of data analysis techniques. Statgraphics 18 features an easy-to-use GUI that does not require learning a complicated command language.
Statgraphics Centurion v.17.2.05 (64 bit)

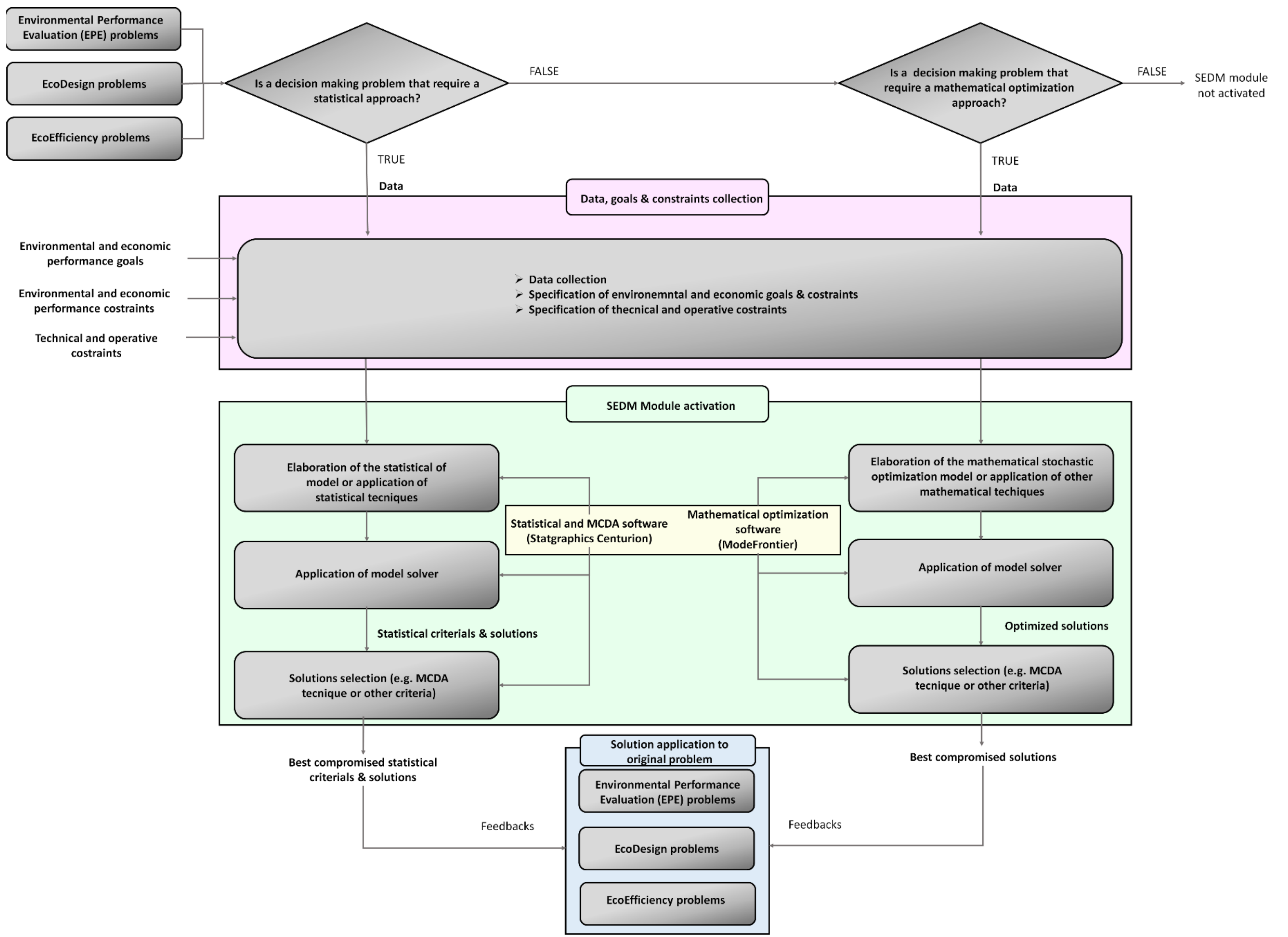


Figure 73 Procedural structure of the SEDM module proposed in OES2 (Personal elaboration, 2017).

2.2.4.7. STEM 8: Environmental Sustainability Strategy Model (ESSM)

The Environmental Sustainability Strategy Model (ESSM) has been introduced in OES2 in order to face the gaps related to the environmental sustainability strategy definition (see following table).

Life Cycle Management Critical Areas	Identified gaps
Strategy & Management criticalities	Unbalanced environmental management strategies
	Divergence between intended and realized environmental management strategy

Table 31 Gaps faced by the STEM "Environmental Sustainability Strategy Model (ESSM)"

These two gaps identified during the scientific literature review constitute two relevant EMBs in strategic planning that are the main reasons because many environmental sustainability strategies elaborated by industrial organization are not able to generate the expected results and benefits. The detailed description of the two gaps is reported in the chapter 1 on scientific literature review. The strategic planning has been recognized, on the base of worldwide criteria, one of the most significant factors, to increase the possibility of success of environmental management strategy established (Guimaraes et al., 2013; Tseng et al., 2009). According to ISO14001:2015 scheme (see figure below) during the planning stage the organization must sets goals and targets to promote the constitutes improvement of environmental performance and give assurance that the environmental management system can achieve these intended outcomes.

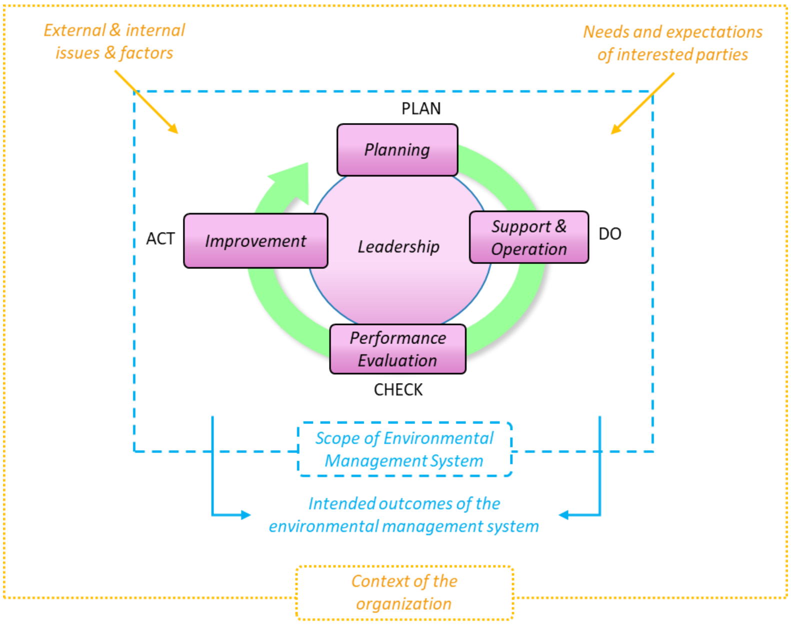


Figure 74 Current approach based on ISO 14001:2015 PDCA Deming Cycle for continuous improvement

However, as emerged from gaps formulation due to scientific literature review, this approach is not able to ensure that the environmental sustainability strategy is balanced and minimize the divergence between the intended goals and targets and the achievable performance. The strategy does not consider environmental performance of products and processes. The scheme where is introduced the ESSM is shown in the following figure.

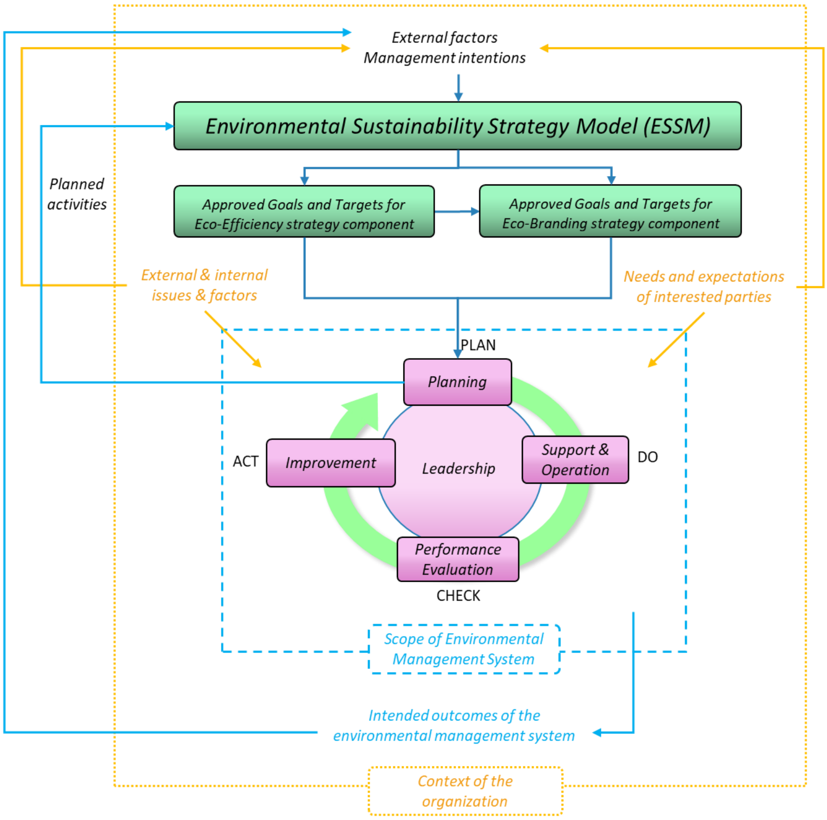


Figure 75 Proposed approach based on ISO 14001:2015 with the introduction of the Environmental Sustainability Strategy Model (ESSM).

In the previously shown scheme Environmental Sustainability Strategy Model (ESSM) is introduced as a STEM in order to support the planning stage of the environmental management system (EMS).

2.2.4.7.1. <u>Features considered to develop the ESSM</u>

The ESSM has been developed in order to improve the managerial process of strategy elaboration and definition. In order to obtain this objective, the ESSM has been developed introducing the following features:

1. *EES structured on two strategical components: the EcoEfficiency Environmental Sustainability Strategy (EcoE-EES) component and the EcoBranding Environmental Sustainability Strategy (EcoB-EES) component* (Jouneault et al. (2016); De Marchi (2012); Orsato et al., 2009).
   The EcoE-EES component is manufacturing oriented and it is related to intents aimed at improving productivity in order to achieve environmental impacts and cost reduction. The EcoB-EES component is marketing oriented and it is related to intents aimed at differentiating firms from competitors in order to improve brand image and increase revenues.
   It is fundamental that these two components are balanced in order to avoid green-washing marketing communications (communications not based effectively on real improvement of environmental performance) and in order to not support with communication and marketing activities the good ecoefficiency activities done. On both these two case the environmental sustainability strategy becomes ineffective in terms of results and benefits for the organization.
2. *Minimization of divergence between intended EES and realized EES.*
   The intended EES is the set of goals and targets desired by organization while the realized EES is the set of performance in terms of goals and targets actually achieved by the organization (Journeault et al., 2016; Mintzberg et al., 1985). This aspect is very important also to ensure the

coherence with environmental policy of the organization that is one of the most important public document to communicate to stakeholders the environmental intensions.

3. *Multiscale definition of goals and targets.*
   As proposed by the environmental impacts assessment also the goals and targets must be identified with a multiscale perspective considering the organizational, site, product and process scales. In fact, the goals and targets established for an organization must be transferred to the smaller scales consistently. In absence of this correlation becomes impossible a correct correlation between the effects of the improvements of environmental performance of products and processes on the trend of environmental performance of the organization. This perspective is according to ISO14001:2015 and it is a very important point in terms of robust establishing of goals on environmental performance and in terms of assessment of improvement plans. Also, the communication activities can be based on multiscale results, in fact, an organization can communicate in the same time for example the performance trend of whole organization and the performance trend of a specific eco-friendly product category.
4. *Increase the importance of ecodesign and ecoefficiency improvement projects.*
   According with the previous bullet point the scales most interested by investments by organization are the product and the process scales. Therefore, the projects of ecodesign and of ecoefficiency improvement are fundamental to improve the environmental performance of single site and of the whole organization (Lewandowska et al., 2014).
5. *Avoiding divergence between EcoB-EES component and EcoE-EES component.*
   It is important to ensure the coherence of marketing communications and the real environmental performance of the organizations and its products. Furthermore, it is important, in terms of brand image management, assess if there is a potential dangerous divergence between the performance of the organization and the performance of sponsored eco-friendly products. The preferable condition is when both sponsored products and whole organization performance are improving.

2.2.4.7.2. The ESSM formulation

The ESSM has been formulated considering the features previously descripted. The figure 76 shown the ESSM proposed. It is possible to distinguish four main stages in the proposed model:

1. **Environment & commitment**: in this stage, the environmental intentions of top management are generated in function of external factors and the commitment of managers;
2. **Competitive strategy**: in this stage, environmental intentions are translated into goals and targets related to EcoE-EES component and EcoB-EES component considering the most recent environmental performance and the most recent communication activities. The goals and targets, in function of specific needs, are established with a multiscale approach for the organization, for products and for processes (according to MLCA model). This stage responds to features requested number 1 and 3;
3. **Manufacturing and communication strategy**: in this stage, the budgeted projects related to ecodesign and ecoefficiency are take into account regarding the manufacturing strategy, while the planned communication activities and LCA studies are take into account regarding the communication strategy. The manufacturing strategy is related to EcoE-EES component while the EcoB-EES component is related to the communication strategy. The communication activities have been distinguished in two groups: the communications on environmental performance and the communications on environmental sustainability brand activities. This stage responds to feature requested number 4;
4. **Consistency analysis**: finally, in this stage, three consistent analysis are performed:
   a. The first consistent analysis verifies the consistency between the EcoE-EES component of the competitive strategy and the manufacturing strategy in order to assess if the goals

and targets sets for the EcoE-EES strategy component are achievable on the base of planned ecoefficiency and eco-design projects;

b. The second consistent analysis verifies the consistency between the EcoB-EES component of the competitive strategy and the communication strategy in order to assess if the goals and targets sets for the EcoB-EES strategy component are achievable on the base of planned communication activities;

c. The third consistent analysis verifies the consistency between EcoB-EES strategy component and between EcoE-EES strategy component in order to avoid potential divergence between communication activities and ecoefficiency activities. In the communication activities are included also the environmental labels the claims and the environmental declarations.

This stage responds to features requested number 2 and 5.

According to Ward et al. (2000) the ESSM is based on the concept that the external context and the management intentions influence the competitive strategy (goals and targets) of the organization which in turn influences the manufacturing strategy (improvement activities planned) of the organization that finally which turn influences the environmental performance of the organization obtained.

2.2.4.7.3. Test of the ESSM in a real case study

The description of the test strategy to verify applicability and effectiveness of OES2 method and its components is available in the paragraph 2.3 of the present chapter.

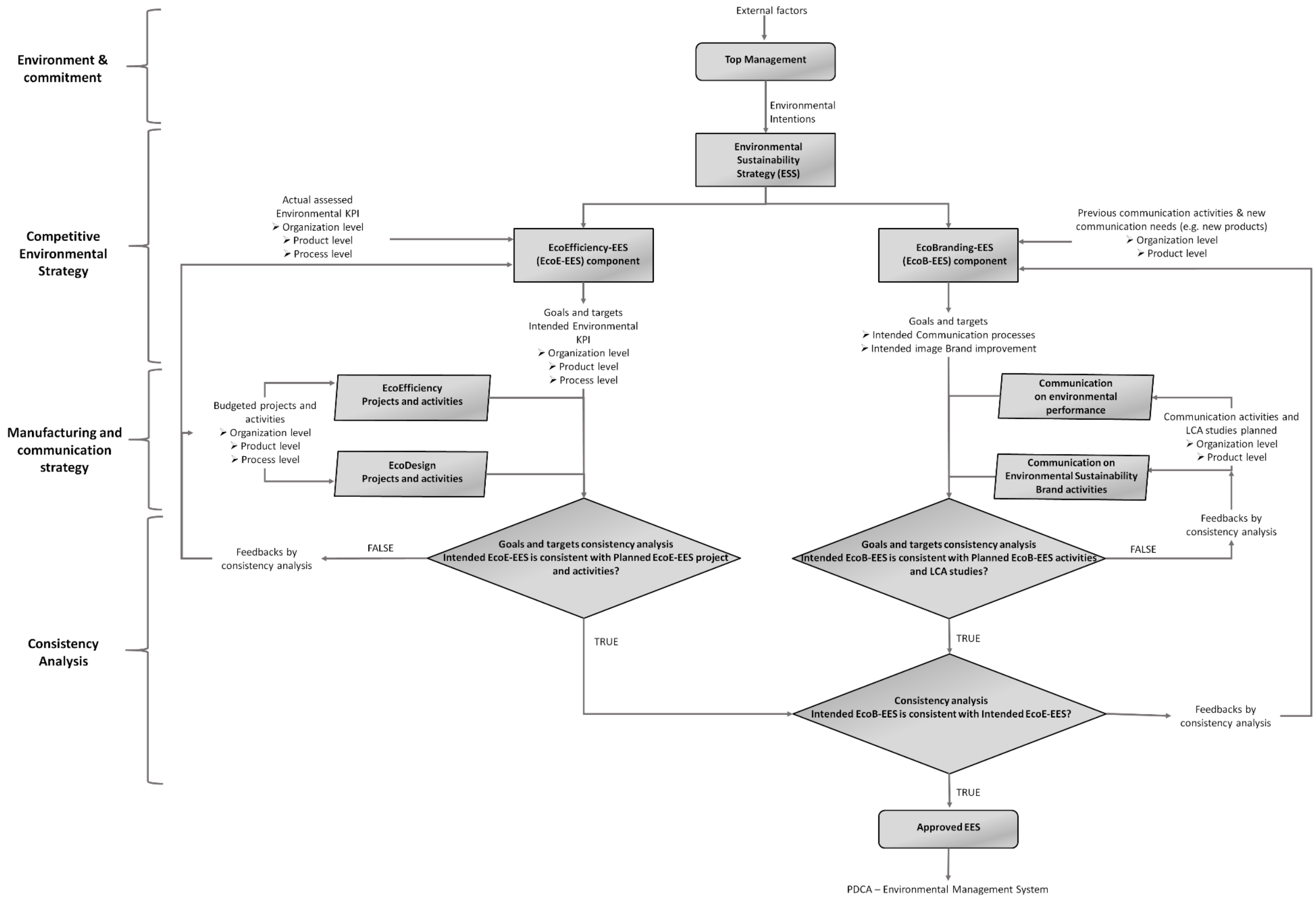


Figure 76 Structure of the Environmental Sustainability Strategy Model (ESSM) proposed in OES2.

2.3. Applicability tests of OES2 method

2.3.1. The importance of packaging industrial sector

The food industry is one of the world's largest industrial sectors and the main energy consumer (Manfredi et al., 2015). Food production, preservation and distribution indeed consume a considerable amount of energy, which causes resource depletion and pollutant emissions (Roy et al., 2009). Packaging is a fundamental element for almost every food product and a vital source of environmental burden and waste. Packaging isolates food from factors affecting loss of quality such as oxygen, moisture and microorganisms, and provides cushioning performance during transportation and storage (Roy et al., 2009). The packaging of food products presents considerable challenges to the food and beverage industry, and minimizing the packaging and modifying both primary and secondary food packaging present an optimizing opportunity for these industries (Henningsson et al., 2004; Hyde et al., 2001). The production stage of the packaging system in fact is reported be the principal cause for the major impacts. Furthermore, the packaging utilization in the food and beverage sector, together to trends of increased consumption of packaged products contributes to a growing volume of packaging waste (WPO, 2008; EUROSTAT, 2010). In order to assess the environmental sustainability and reduce the environmental impacts caused by the food and beverage sector and mainly from the packaging production, EMTs must be applied by organizations at organizational and product level. In this context, the new method developed in this PhD thesis, OES2, has been applied to Acqua Minerale San Benedetto S.p.A. the biggest industry in the beverage sector in Italy and one of the most important in the world.

2.3.2. Case study selection and test setup

The new method developed in this PhD thesis, OES2, has been applied to Acqua Minerale San Benedetto S.p.A. in order to test the applicability and effectiveness of the new method to face scientific gaps identified. The single case study method has been therefore chosen. San Benedetto S.p.A is an Italian company leader in the beverage sector. San Benedetto was the first company in Italy to bottle water in PET containers. Nowadays the company owns eleven sites around the world with a sales network covering about 100 countries on five continents. This organization has been chosen as case study in function of three criteria:

- Relevance of the industrial sector in the field of environmental management;
- High level of complexity in order to stress the applicability of the new method;
- The correspondence between the scientific gaps identified and the environmental management needs perceived by the organization.

In fact, respect to the latter point, the organization had a good background in environmental management. San Benedetto has always considered environmental themes in its business and operations, and sustainability has become important for its long lasting competitive advantage. In line with its environmental policy the company started from 2008 to adopt life cycle thinking approaches to minimize the impacts of its products. However, the organization along its pathway on environmental management has evolved its approach feeling new management needs. These new needs felt by the organization, show a correspondence with the gaps identified in the literature review and makes San Benedetto is a good subject to test all the components of OES2 method.

- Need 1: to extend the life cycle management approach used only for few products to the organizational scale including all productive sites and all products in order to assess the environmental performance of the organization and of all produced products;
- Need 2: the need to compare the environmental performance of all product portfolio in order to identified hotspots and improvement opportunities;
- Need 3: to establish the link between the improvement introduced at level of productive processes and of product through ecodesign initiatives and the performance of the San Benedetto Italian Mineral Water Division and vice versa in order to assess the effects of production delocalization on the organization and od delocalized products;

- Need 4: to introduce criteria on environmental performance in the assessment of innovation projects and support the design stage with tool for the simulation of potential environmental performance for design solution assessed;
- Need 5: to assess the efficiency of productive processes in terms of resources consumptions (e.g. energy, plastic materials, etc.) in order to identify improvement opportunities to reduce environmental impacts and productive economic costs;
- Need 6: to support the strategic decision making related to environmental management with specific tools in order to makes more robust the decision making process and in order to identify optimal solutions;
- Need 7: to introduce a performance tracking of the organization and products performance in order to monitoring the trend of performance and the effects of innovation solutions introduced;
- Need 8: to establish strategies able to permits to assess the requested eco innovation activities to obtain the desired performance and in to align the green communication activities with eco innovation activities;
- Need 9: to develop an integrated data management tool in order to improve the analysis of all data relevant for environmental management and for resource consumptions in order to assess environmental and economic performance.
- Need 10: although the organization has a strategy on the reduction of GHG emission, the organization has interested to assess for internal use other environmental impacts. The organization will assess the possibility in the future to integrate these aspects in the strategy.
- Need 11: the organization has the need to find a solution to communicate to consumers the ecodesign characteristics and the environment performance of their products. The organization have already experiences with EPD but this tool does not cover well this need.

In this context. in order to face these new emerged needs on environmental management, from 2014 the company launched a new project on environmental management that had supported a part of the development of OES2 method and the test stage.

2.3.2.1. Experiences with EMTs of San Benedetto S.p.A.

San Benedetto S.p.A. has a good experience with implementation and use of environmental management tools (EMTs). In fact, the organization has a good knowledge on Life Cycle Assessment methodology, that applies LCA at product level since 2009 (to EcoGreen products), and on Environmental Management Systems. The organization has some Italian site certified ISO 14001 (e.g. Popoli site) and other certified ISO50001 (e.g. Scorzè site). However, the environmental management and energy management approaches are diffused homogenously to all Italian productive sites. This has allowed the organization exploiting internal expertise to develop an environmental management approach practically in accordance with the major part of ISO 14001 requirements in all productive sites. In this context, the organization aims to certify ISO 14001 the site of Scorzè within the beginning of 2019. These element makes San Benedetto S.p.A. a good subject to test OES2 method.

2.3.2.2. Applicability tests setup

In order to test the applicability and effectiveness of the new method to face scientific gaps identified regarding life cycle management at industrial level six tests have been conducted. The results of the tests have been reported in the following chapter

Life Cycle Management Critical Areas	Identified gaps	Organization needs	OES2 test setup
1. Environmental impacts assessment	1. Lack of Environmental Impact Assessment– Product Level	Need 1, Need 2, Need 3	TEST 1
	2. Lack of Environmental Impact Assessment– Organizational Level		
	3. Correlation between product and organizational scale not considered		
	4. Lack of comprehensive impact assessment (Multi-indicators)	Need 10	
	5. Lack of Life Cycle Management approach	Need 1	
	6. Issues on hotspots identification and on burdens shifting	No needs felt	
	7. Impact assessment based on inventory indicators	Need 1	
	8. Technical difficulties in large impact assessment data management	No needs felt	
2. Inventory resources consumptions assessment	9. Technical difficulties in large inventory data management	Need 9	
3. Performance evaluation & performance tracking	10. Lack of OPIs for environmental performance evaluation related to life cycle management at product and organizational level	Need 7	TEST 2
	11. Difficulties in performance tracking and in OPI trends analysis	Need 7	
4. Ecoinnovation	12. Difficulties in implementation of practical ecodesign processes and new eco-friendly alternative solutions comparison	Need 4	TEST 3
	13. Lack of indicators for ecoefficiency assessment	Need 5	TEST 4
5. Strategic decision making	14. Difficulties in the assessment of environmental performance of investments	Need 4	TEST 3
	15. Lack of use of Decision making Tools (MCDA, optimization, statistical techniques, etc.)	Need 6	TEST 5
6. Strategy & Management	16. Unbalanced environmental management strategies	Need 8	TEST 6
	17. Divergence between intended and realized environmental management strategy	Need 8	
7. Market differentiation	18. Difficulty in highlighting the differences in terms of environmental performance of their products respects those of competitors	Need 11	Partially faced by test 1*

Table 32 Specific proposed solutions to overcome identified literature review gaps.

The organization did not perceptive the gaps regarding point 6 and 8 inasmuch:

- • The organization do not know the problems related to burdens shifting. Once the organization has been informed of this potential issue, has shown the need to avoid this issue;
- • This type of issue has been never faced by the organization because has never applied EMTs in large scale (e.g. LCA of a large number of products).

Instead in the case of point 18 (need 11), for reasons related to timing in terms of industrial applicability, has been choice to make the OES2 method compatible with PEF framework. In fact, San Benedetto S.p.A. participates as member of technical secretariat to the scientific group established for the elaboration of the PEF Category Rule for "Packed natural mineral water, spring water and aerated waters, not sweetened nor flavoured". However, on the base of the PEF results, the request to modify PEF some methodological hypotheses (e.g. usage phase with too higher impact) and the difficulties emerged in the data sharing and comparability of results at level of PEF process and Italian process of "Made Green in Italy", San Benedetto, on the base of OES2 method has started to check the possibility in the future to build a specific label to communicate to stakeholders the characteristics of products in terms of ecodesign and ecoefficiency.

According with the objective of this PhD thesis, the tests focus on the assessment of the capabilities of OES2 method regarding life cycle management and on the evaluation on if the new method is able to support the improving of the capacity of the organization on life cycle environmental performance management. Therefore, according with table 33, the following tests have been defined.

OES2 test setup	Details on the test
TEST 1	**Environmental impact & inventory resources consumptions assessment with a multiscale approach (organizational, product, process scales)**: San Benedetto Italian Mineral Water Division (all 5 sites and all 272 products). Data on 2016
TEST 2	**Environmental performance evaluation at organizational scale**: San Benedetto Italian Mineral Water Division (all 5 sites). Data on 2016. **Environmental performance tracking at organizational scale**: San Benedetto Mineral Water Division (Scorzè site) Data from 2013 to 2016 **Environmental performance evaluation and tracking at product level**: San Benedetto EcoGreen Products Line (all sites). Data from 2013 to 2016
TEST 3	**Ecodesing organizational level**: assessment of the acquisition of a new production site and delocalization of the production in the south Italy **Ecodesing product level**: assessment of a lightening project of bottle and cap of mineral water format 0,5L **Ecodesign process level**: assessment of the introduction of a new bottling line
TEST 4	**Ecoefficiency of bottling processes**: assessment of ecoefficiency level, identification of hotspots and improvement opportunities
TEST 5	**Strategic decision making**: identification of PET suppliers mix considering environmental and economic objectives
TEST 6	**Strategy & management actions**: Evaluation of the environmental strategy for the EcoGreen products line and assessment of managerial activities required by OES2

Table 33 Details on tests defined to test applicability and effectiveness of OES2 method.

CHAPTER THREE: APPLICABILITY TEST RESULTS

Highlights:

- **Test 1 results: OES2 method applied to life cycle environmental impact assessment**
- **Test 2 results: OES2 method applied to life cycle performance evaluation**
- **Test 3 results: OES2 method applied to ecodesign**
- **Test 4 results: OES2 method applied to ecoefficiency**
- **Test 5 results: OES2 method applied to strategic decision making**
- **Test 6 results: OES2 method applied to strategy definition & management**

3.1. Introduction to the results

In the present chapter have been presented the results of the tests conducted to assess the applicability and effectiveness of the new method proposed to face identified scientific gaps on environmental management related to life cycle performance management. According to PhD thesis goal and the tests setup the results do not explore other aspects related to environmental management (e.g. legal compliance) that are outside from the objective and are generally well managed by EMTs (e.g. Environmental Management System) used by organizations. Therefore, at level of environmental management system, the test results will have proposed with a perspective on life cycle management excluding not pertinent requirements. In this contest, the results presented focus on the have been structured in 6 paragraphs, one per test:

- Test 1: Application of OES2 method to criticalities on life cycle environmental management areas (1) and (2), related to the assessment of environmental impacts and resource consumptions in life cycle perspective;
- Test 2: Application of OES2 method to criticalities on life cycle environmental management area (3) related to the life cycle performance evaluation;
- Test 3: Application of OES2 method to criticalities on life cycle environmental management areas (4) & (5) – EcoDesing part, related to the application of EcoDesign to develop innovative solutions improving life cycle performance;
- Test 4: Application of OES2 method to criticalities on life cycle environmental management area (4) – Ecoefficiency part, related to the management and the improvement of environmental performance of productive processes;
- Test 5: Application of OES2 method to criticalities on life cycle environmental management area (5) – part Decision Making, related to the use of methods for improve the robustness of strategic decision making processes;
- Test 6: Application of OES2 method to criticalities on life cycle environmental management area (6), related the improvement of aspects related to the environmental strategy and managerial aspects.

The major part of the results, such as OLCA, LCA and EPE results have been certify by third (CSQA Certification Body Accredited by ACCREDIA) trough specific audit activity that is performed every year to verify results returned by the OES2 method. This aspect is a further external verification method applied to ensure the scientific correctly of results obtained and it is fundamental in order to use the results for external communications to stakeholders. The method has passed positively two external audits occurred in June 2016 and May 2017.

3.2. TEST 1: Application of OES2 method to criticalities on environmental management areas (1) and (2)

This test has the objective to assess the capacity of OES2 method to face the gaps on life cycle management related to criticalities on environmental impact assessment and resource consumption assessment.

Life Cycle Management Critical Areas	Identified gaps
1. Environmental impacts assessment	1. Lack of Environmental Impact Assessment– Product Level
	2. Lack of Environmental Impact Assessment– Organizational Level
	3. Correlation between product and organizational scale not considered
	4. Lack of comprehensive impact assessment (Multi-indicators)
	5. Lack of Life Cycle Management approach
	6. Issues on hotspots identification and on burdens shifting
	7. Impact assessment based on inventory indicators
	8. Technical difficulties in large impact assessment data management
2. Resources consumptions assessment	9. Technical difficulties in large inventory data management

Table 34 Identified gaps on environmental impact assessment and inventory resource consumption assessment, faced by OES2 method in the test 1.

In order to face these gaps OES2 method applies:

- Two EMTs: the LCA (ISO 14040, ISO 14044) and OLCA methodologies (ISO/TS 14072);
- Three STEMs: the MLCA model, EID and ERD.

Through the OES2 method the LCA & OLCA methodologies has been applied to the whole Mineral Water San Benedetto Italian Division. According to OES2 method and the theoretical framework descripted in the chapter two, the MLCA model has been applied to guarantee that the model has a multiscale perspective, the EID has been applied to manage all requested inventory data, while the ERD has been applied to manage all results returned by inventory analysis and impact assessment analysis. All requirements of LCA methodology have been considered for the product scale, according to ISO 14040 and ISO14044, while all requirements of OLCA methodology have been considered for the organizational scale, according to ISO/TS 14072. This approach guarantees that the study is in the same time consistence with both methodological approaches. This application has been cited as the first application know to the world of OLCA (UNEP, 2017). The choice to focus the results of San Benedetto Italian Division is methodologically according with the ISO/TS 14072 that allows flexibility in the definition of the reporting unit, admitting different levels of assessment. In this perspective, through the definition of the scope of study, the organization may decide to focus on either the organization as a whole or its portions like business divisions, brands, regions or facilities (UNEP/SETAC, 2015) (see figure below).

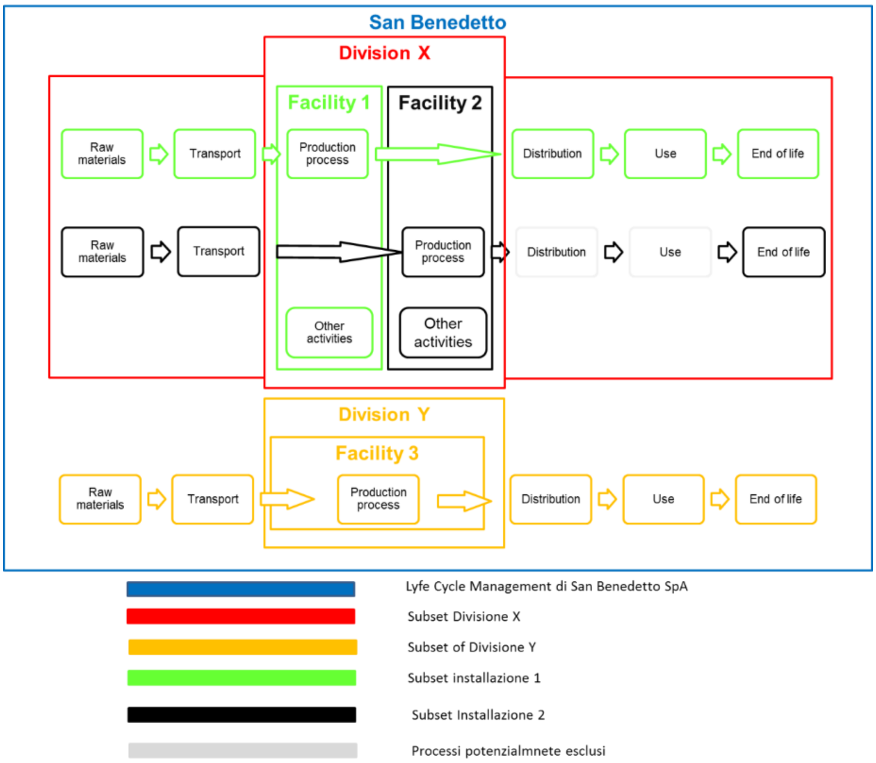


Figure 77 Examples of potential subsets to be assessed (Manzardo et al., 2016)

In fact, although generally, in the same productive site, as in the case of the Scorzè (VE) site, are located different divisions that produce other products such as soft drink (own brand or co-paker) and water of other springs (e.g. water of Guizza spring) in function of specific strategic needs the organization can focuses on results of a specific division.

The application started in the 2015 from the biggest productive site located in the north-est of Italy, Scorzè (VE), for to be extended to all productive site of Italy during the year 2016. Globally the model includes all products and processes related to all sites located in Italy:

- 6 sites (5 bottling sites + 1 site for plastic caps production);
- 37 different bottling lines;
- 57 machineries for bottle production;
- 29 machineries for plastic caps production;
- Almost 1.800 different product codes;
- Almost 40.000 life cycle processes;
- Almost 1,2 millions of data elaborated with EID interfaces to feed the MLCA model.

In this context, the results shown focus on the Mineral Water San Benedetto Italian Division that is the most strategic division of the company. Therefore, the Mineral Water San Benedetto Italian Division refers to all mineral water bottling products produced from all Italian manufacturing sites through the bottling of water extracted by San Benedetto springs located in: Scorzè (Province of Venice (VE)), Popoli (Province of Pescara (PE)), Viggianello (Province of Potenza (PZ)), Donato (Province of Biella (BI)), Atella (Province of Potenza (PZ)). The product portfolio of the Mineral Water San Benedetto Italian Division is shown in table 35 while the detailed description is shown directly in the results (table 46). In the product portfolio has been considered also the division that produce the plastic caps used for the mineral water San Benedetto products, inasmuch the cap production site is property of Acqua Minerale San Benedetto S.p.A.

In the following paragraphs have been descripted all methodological aspects defined to applied LCA and OLCA, the use of MLCA model, EID and ERD and the results obtained. All results have been certified by third party (CSQA Certification Body Accredited by ACCREDIA) trough specific audit activity.

3.2.1.1. Goal & scope definition

The goal of this application was to quantify the environmental impacts related to Mineral Water San Benedetto Italian Division for all the assessment scales: the whole division, single productive sites, single products, single life cycle processes.

The company fully owns the operations and activities located in the division understudy; the consolidation method of the financial and operational control was chosen to determine the organizational boundaries (Martinez-Blanco et al., 2016). According to ISO/TS 14072, all the activities and related life cycle processes of the segment (division) of the organization understudy are therefore considered. Therefore, the scope includes: the extraction and transformation and transport of raw and ancillary material from different suppliers, the processes that directly take place in the company, the distribution of finished products, the use stage and the end of life operations.

In the division understudy, PET bottles are produced, and water is bottled in different format of PET and Glass containers. The company directly operates the process of PET container production and glass container recycling (Manzardo et al., 2015).

3.2.1.1.1. Function of the System

The function of the understudy system consists in the production and delivery of all products of Mineral Water San Benedetto Italian Division, with a life cycle perspective, starting from the extraction of raw materials to the end of life disposal.

3.2.1.1.2. Reporting unit and functional units

According to the goal of the study the reporting unit considered is the overall volume of water (1.412.034.408 litres/year) withdrawn by San Benedetto springs and bottled in PET and Glass containers in the year 2016. According to the guideline from UNEP-SETAC on OLCA, table 35 reports the product portfolio produced in the reference period. This practice will improve the capability of interpretation of results and of results performance tracking. In the case of the assessment of the impacts of single sites, the reporting unit is rescaled to the total volume of water drawn by San Benedetto spring of the specific site. Instead, in the case of the assessment of single products the methodological elements defined is the functional unit that is defined equal to 1 bottle of the specific product under study. The coexistence of methodological elements of OLCA and LCA is due to the fact that OES2 through the introduction of MLCA model is able in the same time to apply the two methodologies.

Productive site	Water product line	Format	Number of product references	Production in bottles 2016	Production in litres 2016
		litre/bottle	n°	bottles/year	litres/year
Scorzè (VE)	PET	0,25	4	1.495.536	373.884
		0,33	6	3.063.384	1.010.917
		0,4	8	1.598.292	639.317
		0,5	62	666.399.468	333.199.734
		0,75	7	7.703.334	5.777.501
		1	12	51.167.100	51.167.100
		1,5	47	191.875.716	287.813.574
		2	9	108.483.336	216.966.672
	PET aseptic	0,25	2	16.130.232	4.032.558
		0,5	2	26.295.576	13.147.788
		0,75	1	5.800.464	4.350.348
	Glass One Way (OW)	0,25	12	5.084.856	1.271.214
		0,5	18	6.195.940	3.097.970
		0,75	17	7.239.528	5.429.646
		1	14	5.660.964	5.660.964
	Glass Reusable	0,25	2	770.544	192.636
		0,5	4	12.548.440	6.274.220
		0,75	5	20.455.656	15.341.742
		1	5	23.018.736	23.018.736
	TOTAL		**237**	**1.160.987.102**	**978.766.521**
Popoli (PE)	PET	0,5	7	204.915.456	102.457.728
		1	2	915.240	915.240
		1,5	4	26.525.028	39.787.542
		2	2	29.046.966	58.093.932
	TOTAL		**15**	**261.402.690**	**201.254.442**
Viggianello (PZ)	PET	0,5	1	20.600.400	10.300.200
		1	1	160.134	160.134
		1,5	1	8.709.816	13.064.724
		2	6	72.261.456	144.522.912
	TOTAL		**9**	**101.731.806**	**168.047.970**
Donato (BI)	PET	0,5	2	84.967.656	42.483.828
		1,5	2	5.678.944	8.518.491
		2	1	1.927.176	3.854.352
	TOTAL		**5**	**92.573.776**	**54.856.671**
Atella (PZ)	PET	1	2	3.327.828	3.327.828
	Glass Reusable	0,75	2	1.550.304	1.162.728
		1	2	4.618.248	4.618.248
	TOTAL		**6**	**9.496.380**	**9.108.804**
TOTALE LINEA ACQUA SAN BENEDETTO			**272**	**1.626.191.754**	**1.412.034.408**

Table 35 Product portfolio of the Mineral Water San Benedetto Italian Division

3.2.1.1.3. Organizational boundaries and system boundaries

The system boundary is defined considering a process-based approach and the additional operations of the organization. The figure 78 reports the life cycle processes representation of a generic PET bottled water and generic Glass bottled water.

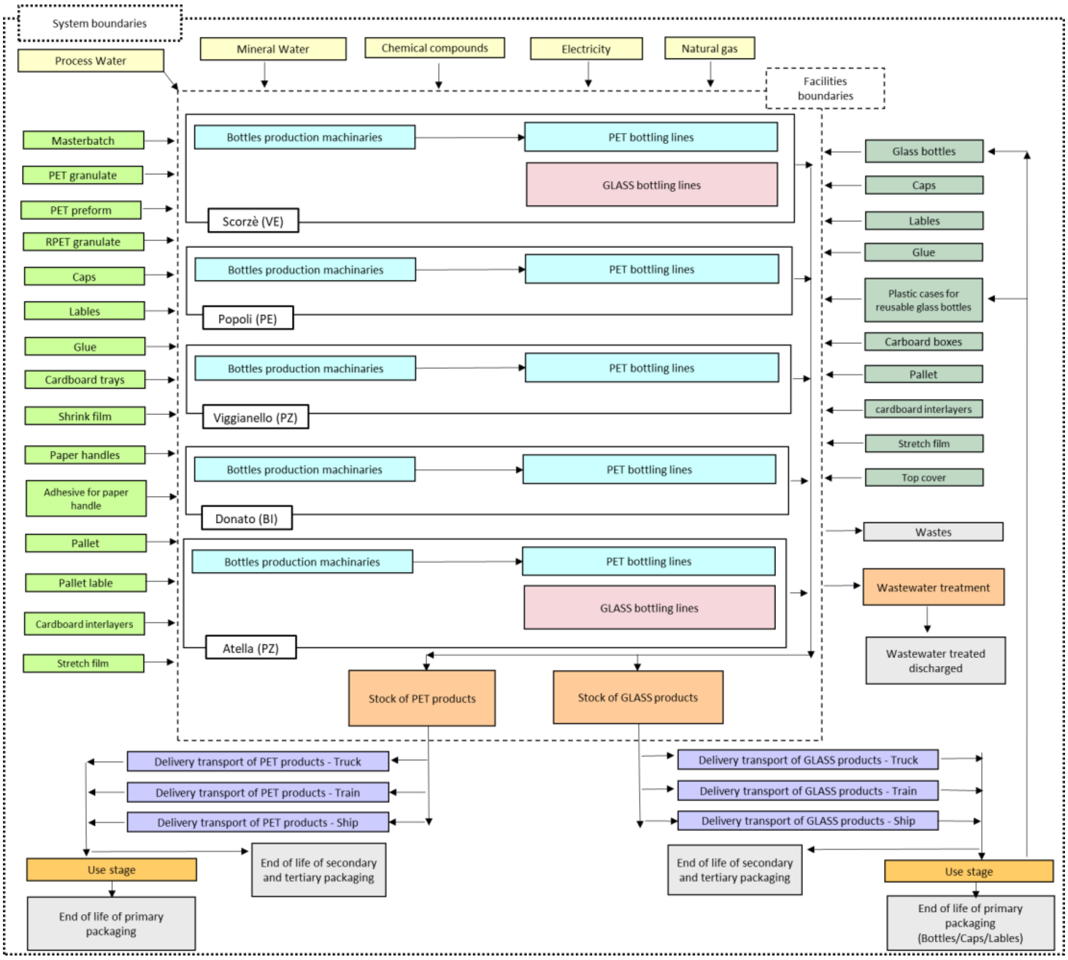


Figure 78 Life cycle processes of the division under study.

The organizational boundary has been defined including all processes related to the production of products of the Mineral Water San Benedetto Italian Division that mainly refers to:

- Production and transport of raw materials (e.g. PET granulate, RPET granulate (recycled PET), dye master, plastic preform);
- Production and transport of all primary packaging components (e.g. bottles, caps, labels);
- Production and transport of all secondary packaging components (e.g. shrink film, paper handles, plastic baskets, carton trays, carton boxes, etc.);
- Production and transport of all tertiary packaging components (e.g. stretch film, pallets, top cover sheet);
- Production of energy vectors used by the organization for the production processes (e.g. electricity, natural gas, etc.)
- Production and transport of chemicals compounds and auxiliary materials;
- Disposal processes of wastes generate by production sites;
- Delivery processes conduced with truck, train and ship;
- Energy consumption during delivery processes (electricity consumption for product cooling at store point);
- Disposal processes of wastes generate by product unpacking (e.g. secondary and tertiary packaging components);

- Energy consumption during usage phase (electricity consumption for product cooling at domestic fridge) and car transport by consumer;
- End of life processes to disposal primary packaging components of products (bottle, cap, label).

3.2.1.1.4. Environmental impact assessment methodology

The impact categories shown in the following table, were considered to be relevant for the impact assessment.

Impact assessment categories	Impact assessment methods collections used
Climate change	IPCC 2013 GWP 100a v 1.00 (IPCC, 2016)
Ozone depletion	ReCiPe 2008, Europe Midpoint (H) (Goedkoop et al., 2013)
Terrestrial acidification	ReCiPe 2008, Europe Midpoint (H) (Goedkoop et al., 2013)
Terrestrial ecotoxicity	ReCiPe 2008, Europe Midpoint (H) (Goedkoop et al., 2013)
Water scarcity.	Water footprint scarcity (Boulay et al., 2011)
Aquatic eutrophication	IMPACT 2002+ (Joliet et al., 2005)
Aquatic ecotoxicity	IMPACT 2002+ (Joliet et al., 2005)
Aquatic acidification	IMPACT 2002+ (Joliet et al., 2005)
Human toxicity	ReCiPe 2008, Europe Midpoint (H) (Goedkoop et al., 2013)
Land occupation	IMPACT 2002+ (Joliet et al., 2005)
Metal depletion	ReCiPe 2008, Europe Midpoint (H) (Goedkoop et al., 2013)
Fossil depletion	ReCiPe 2008, Europe Midpoint (H) (Goedkoop et al., 2013)

Table 36 Environmental impact assessment methods used to quantify environmental impacts at midpoint level.

The choice of integrating different methods collections methods is related to the will to have a more comprehensive analysis impact categories profile. The descriptions of the methods have been provided in the chapter 2.

3.2.1.1.5. Cut-off criterion

The cut-off criterion has been set equal to 1% in terms of environmental relevance. In this way, a material flow/energy flow/process may be excluded if generates a contribution to the total environmental impact smaller than the 1% of the total environmental impact. The cut-off criterion has been applied only to flows and processes for which no data were not available.

3.2.1.1.6. Data sources and selection criteria

The inventory build has been required the use of types of data and different data sources:

- Primary data: data directly collected by the organization. All data on raw material consumption, energy consumptions, chemical compounds consumptions, production processes under control of the organization, aspects that characterize the packaging components (primary, secondary e tertiary), and the delivery data are primary.
- Secondary data: data obtained through the use of international LCA database (Ecoinvent v3.1). These data are used to build the inventory related to processes out the control of the organization for which no primary data were available. The organization had try to ask some primary data to suppliers but with poor results. The detail of database selected has been shown in the inventory analysis paragraph. Some other secondary data have been obtained from international LCA peer reviewed scientific papers and from national recognized reports (e.g. Annual report of ISPRA on waste disposal scenarios).
- Tertiary data: data related to estimation. No data from estimation have been used for the present application.

The data collection process has been conducted according to the principles shown in the following table:

Topic	Criteria adopted
Time period coverage	Primary data for all the processes under control of the organization. For Scorzè site from 2013 to 2016; for Viggianello site from 2015 to 2016, for other sites from 2016. Other life cycle processes modelled with Ecoinvent database using the most recent (v.3)
Geographical coverage	Primary data re site specific for each production site. In the case of secondary data, average production from the country of origin is considered where available.
Technology coverage	Primary and secondary data always refers to the technology in use if not differently specified.
Precision and uncertainly	Most of the data collected are primary with limited uncertainty. The use of EID has permit a very detailed data collection reducing approximations. In the selection of secondary data, it was preferred to use Ecoinvent data sets that also present uncertainty information and data. The data have undergone two audits by third-party for the certification.
Completeness, Representativeness	All primary data have been collected. The use of EID permits a collection of very detailed data (about 1,2 million) for each category in a unit process under control by organization. Actual manufacturing data for the product life cycles were collected,
Consistency	Consistency considers how uniformly the study methodology is applied to the various components of the analysis. The consistency is total and verified by two audits by third-party for certification of results.
Reproducibility	The study has been performed and described such that another LCA practitioner could reproduce this study

Table 37 Data quality criteria

3.2.1.1.7. Assessment tools

In order to perform the environmental impact assessment has been used the following tools:

- LCA software: SimaPro v8.0 in order to develop the **SimaPro MLCA model (STEM of OES2)**;
- Data management tool: **EID interfaces (STEM of OES2)** in order to automatically collect all inventory data required and to feed data to SimaPro model;
- Results management tool: **ERD interfaces (STEM of OES2)** in order to automatically manage all results returned by SimaPro model related to the inventory analysis and to the impact assessment analysis.

3.2.1.2. Life cycle inventory analysis

In this paragraph, all the data acquired, and calculations performed are reported. The paragraph is divided in four parts:

- In the first part has been performed a description of the life cycle production processes and of the products in order to permit a better understanding of the processes involved and therefore of the data required;
- In the second part has been shown example of application of the EID interfaces used in OES2 to automatize the data collection process and the data feed process to SimaPro model;
- In the third part has been detailly descripted for each different life cycle processes the Ecoinvent database used to model the process;
- Finally, in the fourth part have been shown example of inventory results managed by ERD interface.

3.2.1.2.1. Productive processes description

In the present paragraph a briefly description of productive processes has been provided. With reference to the products of the San Benedetto PET Mineral Water Sub Division the process started by the production of the PET bottle. This process can be performed with three different technological solutions:

- Bottle production starts from PET/RPET granulate and is performed with mono-stage machineries;
- Bottle production starts with the production of a preform with press machineries by San Benedetto and after, the bottle production has been performed with blow moulding machineries. This is the bi-stage technology.
- The third case is equal to the second one but the preform is bought from suppliers.

The raw materials are PET and Recycled-PET (RPET). The second one is used only in specific products (e.g. products line EcoGreen). The use of RPET is increasing over the time. The PET is bought from different suppliers potentially located all over the world (mainly Asia). The RPET mainly is bought in Europe. The PET and RPET arrive at the San Benedetto productive site mainly in big bags on wooden pallet. All specific transport processes have been characterized in function of the specific supplier (with EID interfaces shown in the next paragraphs).

The second process is the bottling process. The mineral water is withdrawn by underground springs and bottled by different bottling lines that packed many different products. The bottling lines permit also the process of pack of the products applying primary, secondary and tertiary packaging components. The types of packaging components used have been reported in the next table. The pallet of finished products obtained at the end of the bottling line is ready to the storage in specific warehouse or ready for the direct delivery process. For every packaging components have been considered the specific production process and the transport process in the case of all suppliers. All energy (electricity and thermal), chemical and auxiliary materials consumptions, used for the productive processes have been considered. At level of machineries for bottle production and of bottling machines, many technological and technical differences could exist. They have been considered using data specific for every machinery and bottling line linking these data with the production of specific products. For example, exist bottling lines with aseptic technology that are very different from the standard bottling lines. In the case of the products in glass bottle the bottling process is different and the packaging components are reported in the following table. Two family of glass products can be distinguished: the One-Way glass products and the Reusable Glass products.

3.2.1.2.2. General products description

In the following table has been shown the primary, secondary and tertiary packaging components that can characterize the San Benedetto products bottled in PET and glass bottles. In the case of PET products, the following formats exists: 0,25 L, 0,33 L, 0,40 L, 0,5 L, 0,75 L, 1,0 L, 1,5 L e 2,0 L. While in the case of glass bottled products exist the following formats: 0,25 L, 0,5 L, 0,75 L e 1,0 L.

Packaging type	Packaging components - PET products	Packaging components - GLASS products
Primary packaging components	PET bottle in different formats	Glass bottle in different formats
	PET bottle with %RPET in different formats	Aluminium crown caps
	Flat HDPE caps in different formats	Front labels in PET
	Push & pull caps in HDPE and PP	Retro labels in PET
	Labels in OPP	Labels glue
	Labels in PE	
	Labels in packaging paper	
	Labels in aluminized paper	
	Labels glue	
	Shrinking film in LPE	Cardboard boxes in different formats
	Paper handles	Plastic cases

Packaging type	Packaging components - PET products	Packaging components - GLASS products
Secondary packaging components	Adhesive for paper handles	Tray glue
	Tray glue	
	Cardboard tray in different formats	
Tertiary packaging components	Wooden pallet	Wooden pallet
	Mini wooden pallet	F Stretch film in LLPE
	Stretch film in LLPE	Cardboard interlayer
	Cardboard interlayer	Top cover
	Strap	Pallet labels
	Top cover	Pallet labels glue
	Pallet labels	
	Pallet labels glue	
	Strap	

Table 38 General list of primary, secondary and tertiary packaging components

3.2.1.2.3. Primary data collection – The application of EID interfaces

Primary data were collected separately for each product and process under control of the organization in the case of each production site. Material inputs are related to different aspects: primary, secondary and tertiary packaging materials, chemical compounds using for the sanitization and cleaning of the installations, chemical compound using for wastewater treatment. Energy inputs are related to electricity and methane gas consumptions. Other information collected at product level are related to the distances for the distribution of every product in function of the different means of transport (truck, train and ship) and the transports related to suppliers for raw materials acquisition (truck, train and ship). The enormous amount of data (almost 1,2 milions of data) and the high level of detail have required the application of the Environmental Inventory Database (EID) in order to simplify and efficiently support the extensive data collection. Following the methodological approach developed in the chapter 2, seven different data collection interfaces have been programmed in excel programming language in order to automatize the data collection process and the SimaPro MCLA model feed process (Zvezdov et al., 2016).

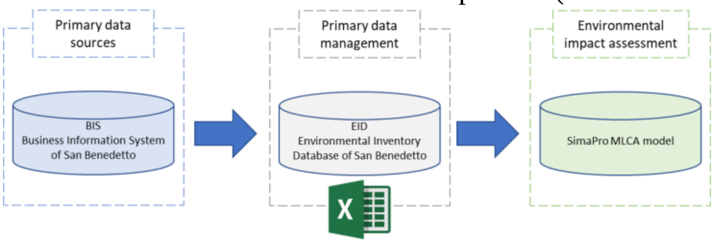


Figure 79 EID interfaces for automatic data collection from BIS sources and automatic SimaPro MLCA model feed.

The Environmental Inventory Database (EID) of San Benedetto has been structured as follow:

1. EID_SB_Upstram_distance_mapping:
2. EID_SB_Products_mapping;
3. EID_SB_Production_mapping;
4. EID_SB_Energy_mapping;
5. EID_SB_Chemicals_mapping;
6. EID_SB_EnvironmentalServices_mapping;
7. EID_SB_Downstream_mapping;

All these interfaces have been implemented separately to each production site. It is necessary because different production site can have different BISs (Business Information Systems) and therefore changes to the programming code of the interfaces can be required in order to adjust the iteration between BIS and EID interfaces. The interfaces divide the database consistently with different life cycle stages and processes. The EID permits to collect every year all the data and to save historical data to support performance tracking performed in OES2. In the following paragraphs have been descripted the interfaces that constitute the Environmental Inventory Database (EID) of San Benedetto.

3.2.1.2.3.1. Inventory data collection – EID_SB_Upstream_distance_mapping

This EID interface permits to identify the transport distances travelled by truck, train and ship to transport every item from every supplier to every production site of San Benedetto. The items considered are every packaging component (primary, secondary and tertiary) and every auxiliary material (e.g. chemical compounds) that are required for the production of San Benedetto products and for the maintenance of the production processes. This interface maps thousands of items. It has required the built of a distance database that permits to maps all the distances between the suppliers and San Benedetto production sites. In function of the quantity provides by each supplier the interface calculates for every item automatically the weighted average distance by truck, train and ship. The extraction of data requires specific query to BISs.

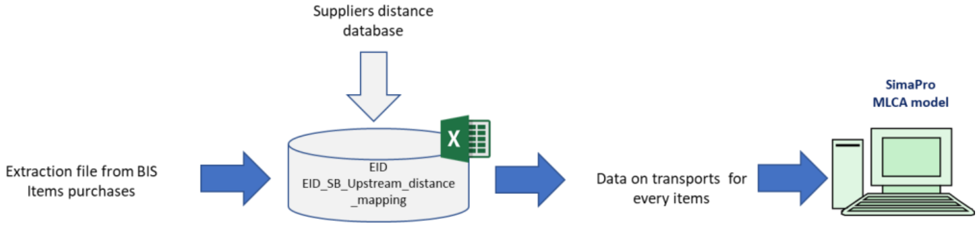


Figure 80 Simplified flowchart of EID_SB_Upstream_distance_mapping

The association between specific items and supplier is guaranteed by the SAP identification code that is specific for every item. Starting from a SAP extraction of every items purchases the interface loads and elaborates automatically the data providing immediately the results. The interface permits to feed to SimaPro MLCA model this type of data for every modelled item and permits to users to have access to the data. In the following figures have been shown the EID_SB_Upstream_distance_mapping interface.

F3 =SE.ERRORE(CERCA.VERT($C3;'E:\Copia\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Acqua_e_Bibite\SB_Upstream_Distance_Mapping\[Database_distanze_MP_Scorze.xlsx]Fornitori_Packaging'!$A$2:$E$2987;2;FALSO);0)

	A	B	C	D	F	G	H	I	J	N	O	P
1			Supplier							Average weighted distances		
2	Item	Description	Identification code	Quantity	Supplier location	Truck [km]	Train[km]	Ship [km]	% supplier contribution on total provided	Truck [km]	Train[km]	Ship [km]
3	10024099	ET.ACQ.N.0,5L FB 220X55 38MY 16/2	0020000885 - ETAPAK BASKI AMBALAJ SANAYI VE TICA	260.970.294,00	Izmir - Turchia	57	0	1447	0,94	60,35	0,00	1359,44
4	10024099	ET.ACQ.N.0,5L FB 220X55 38MY 16/2	0010000012 - GPS S.P.A.	15.399.169,00	Schio (VI) -Italia	100	0	0	0,06	60,35	0,00	1359,44
5	10024099	ET.ACQ.N.0,5L FB 220X55 38MY 16/2	0010007825 - PLASTYLENIA S.P.A.	1.409.007,00	Campi Bisenzio (FI) - Italia	248	0	0	0,01	60,35	0,00	1359,44
6	10023500	ET.ACQ. NATURALE 0,5L SB 220X55 38MY C15	0020000885 - ETAPAK BASKI AMBALAJ SANAYI VE TICA	47.309.497,00	Izmir - Turchia	57	0	1447	0,99	68,40	0,00	1434,30
7	10023500	ET.ACQ. NATURALE 0,5L SB 220X55 38MY C15	0010005264 - ROTOCALCO MEDITERRANEA S.R.L.	420.866,00	Siracusa (SR) - Italia	1350	0	6,5	0,01	68,40	0,00	1434,30
8	10023503	ET.ACQUA FRIZZ.0,5L SB 220X55 30MY C15	0010000055 - IRPLAST S.P.A.	24.881.116,00	Empoli (FI) - Italia	274	0	0	1,00	274,00	0,00	0,00
9	10024138	ET.ACQUA FRIZZ.0,5L FB 220X55 30MY 16/2	0010000055 - IRPLAST S.P.A.	142.771.722,00	Empoli (FI) - Italia	274	0	0	1,00	274,00	0,00	0,00
10	10023756	ET.ACQ. NATURALE 0,5L FB 220X55 38MY 16	0020000885 - ETAPAK BASKI AMBALAJ SANAYI VE TICA	69.977.134,00	Izmir - Turchia	57	0	1447	1,00	57,00	0,00	1447,00
11	10023759	ET.ACQUA FRIZZ.0,5L FB 220X55 30MY 16	0010000055 - IRPLAST S.P.A.	31.386.535,00	Empoli (FI) - Italia	274	0	0	1,00	274,00	0,00	0,00
12	10024136	ET.ACQ.N.0,5L FB ECO.220X55 38MY 16/2	0020000885 - ETAPAK BASKI AMBALAJ SANAYI VE TICA	4.125.588,00	Izmir - Turchia	57	0	1447	1,00	57,00	0,00	1447,00
13	10023784	ET.ACQ.NAT.0,5L FB ECO.220X55 38MY 16	0020000885 - ETAPAK BASKI AMBALAJ SANAYI VE TICA	2.911.336,00	Izmir - Turchia	57	0	1447	1,00	57,00	0,00	1447,00
14	10023757	ET.A.N.0,5L FB 220X55 38MY OLD WILD W.16	0020000885 - ETAPAK BASKI AMBALAJ SANAYI VE TICA	2.153.740,00	Izmir - Turchia	57	0	1447	1,00	57,00	0,00	1447,00
15	10025543	ET.ACQ.N.0,5L FB ECO.220X55 38MY 16/3	0020000885 - ETAPAK BASKI AMBALAJ SANAYI VE TICA	6.975.899,00	Izmir - Turchia	57	0	1447	0,88	62,12	0,00	1274,86
16	10025543	ET.ACQ.N.0,5L FB ECO.220X55 38MY 16/3	0010000012 - GPS S.P.A.	941.936,00	Schio (VI) -Italia	100	0	0	0,12	62,12	0,00	1274,86
17	10024134	ET.A.N.0,5L FB 220X55 38MY OLD W.W.16/2	0020000885 - ETAPAK BASKI AMBALAJ SANAYI VE TICA	866.176,00	Izmir - Turchia	57	0	1447	1,00	57,00	0,00	1447,00
18	10021636	ET.ACQ.N.1L FB EASY ECO.288X55 38MY 16/2	0020000885 - ETAPAK BASKI AMBALAJ SANAYI VE TICA	13.807.050,00	Izmir - Turchia	57	0	1447	1,00	57,00	0,00	1447,00
19	10023451	ET.ACQ.NAT.0,5L SB ECO.220X55 38MY C15	0020000885 - ETAPAK BASKI AMBALAJ SANAYI VE TICA	1.213.989,00	Izmir - Turchia	57	0	1447	1,00	57,00	0,00	1447,00
20	10021648	ET.ACQ.N.1L FB EASY ECO.288X55 38MY 16/3	0020000885 - ETAPAK BASKI AMBALAJ SANAYI VE TICA	14.227.120,00	Izmir - Turchia	57	0	1447	1,00	57,00	0,00	1447,00
21	10023248	ET.ACQ.NAT.6X0,5L GU 220X55 38MY R14	0020000885 - ETAPAK BASKI AMBALAJ SANAYI VE TICA	10.419.479,00	Izmir - Turchia	57	0	1447	1,00	57,00	0,00	1447,00
22	10021501	ET.ACQ.N.1L SB EASY ECO.288X55 38MY C15	0020000885 - ETAPAK BASKI AMBALAJ SANAYI VE TICA	5.801.621,00	Izmir - Turchia	57	0	1447	1,00	57,00	0,00	1447,00
23	10021579	ET.ACQ.N.1L FB EASY ECO.288X55 38MY 16	0020000885 - ETAPAK BASKI AMBALAJ SANAYI VE TICA	4.993.286,00	Izmir - Turchia	57	0	1447	1,00	57,00	0,00	1447,00
24	10023249	ET.ACQ.FRIZ.6X0,5L GU 220X55 38MY R14	0020000885 - ETAPAK BASKI AMBALAJ SANAYI VE TICA	5.013.529,00	Izmir - Turchia	57	0	1447	1,00	57,00	0,00	1447,00
25	10026087	ET.TONICA 0,180L SCHWEPPES R14	0010000068 - LA PRENSA ETICHETTE ITALIA S.R.L.	3.037.000,00	San Giuliano Milanese (MI) - Italia	271	0	0	1,00	271,00	0,00	0,00
26	10026088	ET.LIMONE 0,180L SCHWEPPES R14	0010000068 - LA PRENSA ETICHETTE ITALIA S.R.L.	29.088.000,00	San Giuliano Milanese (MI) - Italia	271	0	0	1,00	271,00	0,00	0,00
27	10020013	ET.ACQ.NAT.1,5L GU 288X55 38MY I57 R14/2	0020000885 - ETAPAK BASKI AMBALAJ SANAYI VE TICA	23.009.286,00	Izmir - Turchia	57	0	1447	1,00	57,00	0,00	1447,00
28	10022035	ET.ACQ.NAT.0,5L FB 220X55 30MY EURO 16	0010000055 - IRPLAST S.P.A.	9.838.863,00	Empoli (FI) - Italia	274	0	0	1,00	274,00	0,00	0,00
29	10026117	ET.TONICA 0,180L SCHWEPPES 15	0010000068 - LA PRENSA ETICHETTE ITALIA S.R.L.	40.317.000,00	San Giuliano Milanese (MI) - Italia	271	0	0	1,00	271,00	0,00	0,00
30	10022036	ET.ACQ.FRI.0,5L FB 220X55 30MY EURO 16	0010000055 - IRPLAST S.P.A.	3.339.666,00	Empoli (FI) - Italia	274	0	0	1,00	274,00	0,00	0,00
31	10023425	ET.A.N.0,5L SB 220X55 30MY PASSOV.ISR.15	0010000055 - IRPLAST S.P.A.	3.023.933,00	Empoli (FI) - Italia	274	0	0	1,00	274,00	0,00	0,00
32	10023495	ET.ACQ.NAT.0,5 SB 220X55 30MY EURO C15	0010000055 - IRPLAST S.P.A.	1.139.985,00	Empoli (FI) - Italia	274	0	0	1,00	274,00	0,00	0,00
33	10023504	ET.ACQUA LEG/FRI.0,5L SB 220X55 30MY C15	0010000055 - IRPLAST S.P.A.	579.530,00	Empoli (FI) - Italia	274	0	0	1,00	274,00	0,00	0,00
34	10024139	ET.ACQ.L/F.0,5L FB 220X55 30MY 16/2	0010000055 - IRPLAST S.P.A.	4.007.421,00	Empoli (FI) - Italia	274	0	0	1,00	274,00	0,00	0,00
35	10022051	ET.ACQ.NAT.0,5L FB 220X55 30MY ISRAE.16	0010000055 - IRPLAST S.P.A.	14.097.854,00	Empoli (FI) - Italia	274	0	0	1,00	274,00	0,00	0,00
36	10023246	ET.ACQ.NA.0,5L SB 220X55 30MY ISRAE.14/2	0010000055 - IRPLAST S.P.A.	308.623,00	Empoli (FI) - Italia	274	0	0	1,00	274,00	0,00	0,00
37	10025524	ET.ENERGADE ARANCIA 0,5L 220X70 38MY 16	0010000055 - IRPLAST S.P.A.	2.019.385,00	Empoli (FI) - Italia	274	0	0	1,00	274,00	0,00	0,00
38	10023655	ET.ENERGADE ARANCIA 0,5L 220X70 38MY 15	0010000055 - IRPLAST S.P.A.	4.040.600,00	Empoli (FI) - Italia	274	0	0	1,00	274,00	0,00	0,00
39	10025523	ET.ENERGADE LIMONE 0,5L 220x70 38MY 16	0010000055 - IRPLAST S.P.A.	2.263.570,00	Empoli (FI) - Italia	274	0	0	1,00	274,00	0,00	0,00
40	10023654	ET.ENERGADE LIMONE 0,5L 220x70 38MY 15	0010000055 - IRPLAST S.P.A.	5.081.533,00	Empoli (FI) - Italia	274	0	0	1,00	274,00	0,00	0,00
41	10023505	ET.AC.N.SB 0,5 220X55 38MY O.WILD. W.C15	0010000012 - GPS S.P.A.	1.113.147,00	Schio (VI) -Italia	100	0	0	1,00	100,00	0,00	0,00
42	10023343	ET.THE LIMONE BLUES 0,5L 220X70 38MY 15	0010000055 - IRPLAST S.P.A.	2.531.411,00	Empoli (FI) - Italia	274	0	0	0,93	293,94	0,00	0,00
43	10023343	ET.THE LIMONE BLUES 0,5L 220X70 38MY 15	Z120 - GRAN GUIZZA S.P.A.	193.339,00	Popoli (PE) - Italia	555	0	0	0,07	293,94	0,00	0,00

Purchases - 2016 | Preforme | Ingredienti_cotte

Figure 81 EID_SB_Upstream_distance_mapping interface.

3.2.1.2.3.2. Inventory data collection – EID_SB_Products_mapping

This EID interface permits to map for every product realized in every production site all packaging components (primary, secondary and tertiary) required. Following the flowchart shown below, the interface acquires product bills extracted from SAP (figure 83) and specifications on weight and material for every packaging component from a database. The interface maps all products produced.

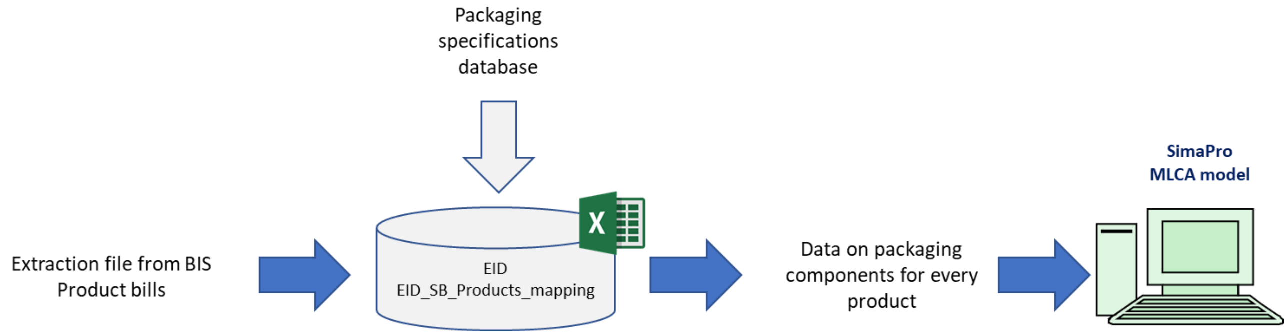
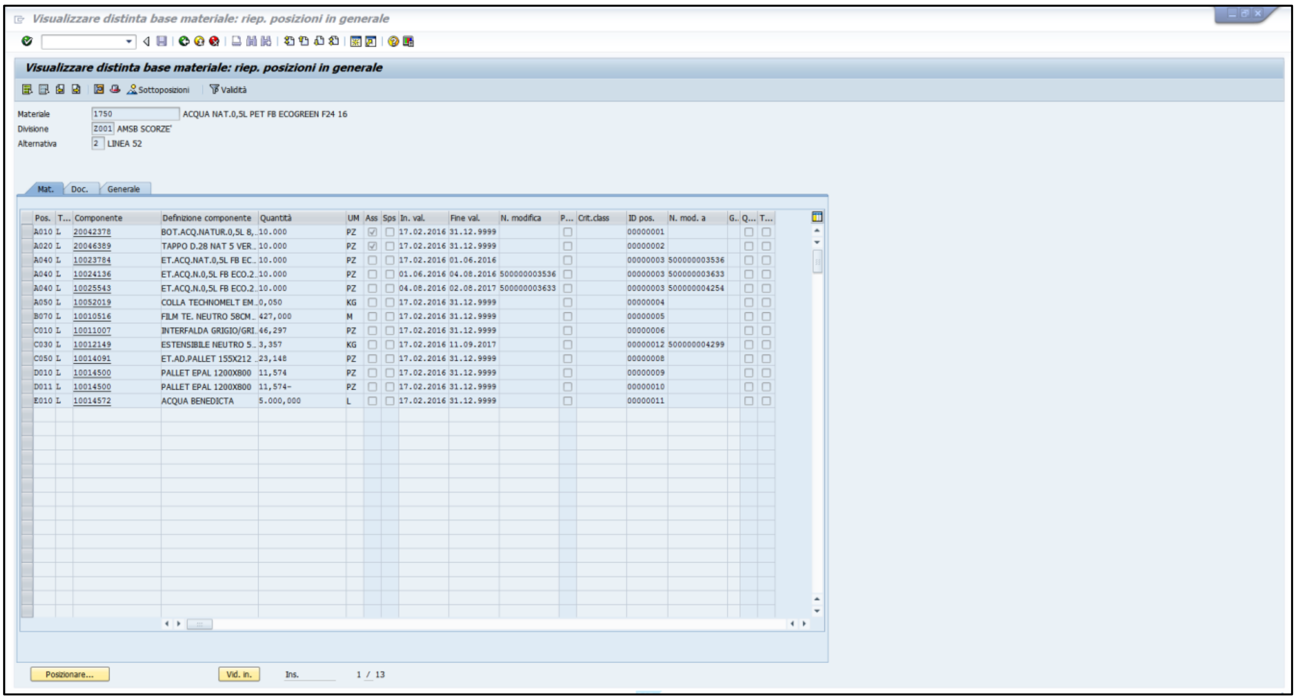


Figure 82 Simplified flowchart of EID_SB_Products_mapping



Visualizzare distinta base materiale: riep. posizioni in generale

Materiale 1750 ACQUA NAT.0,5L PET FB ECOGREEN F24 16
Divisione Z001 AMSB SCORZE'
Alternativa 2 LINEA 52

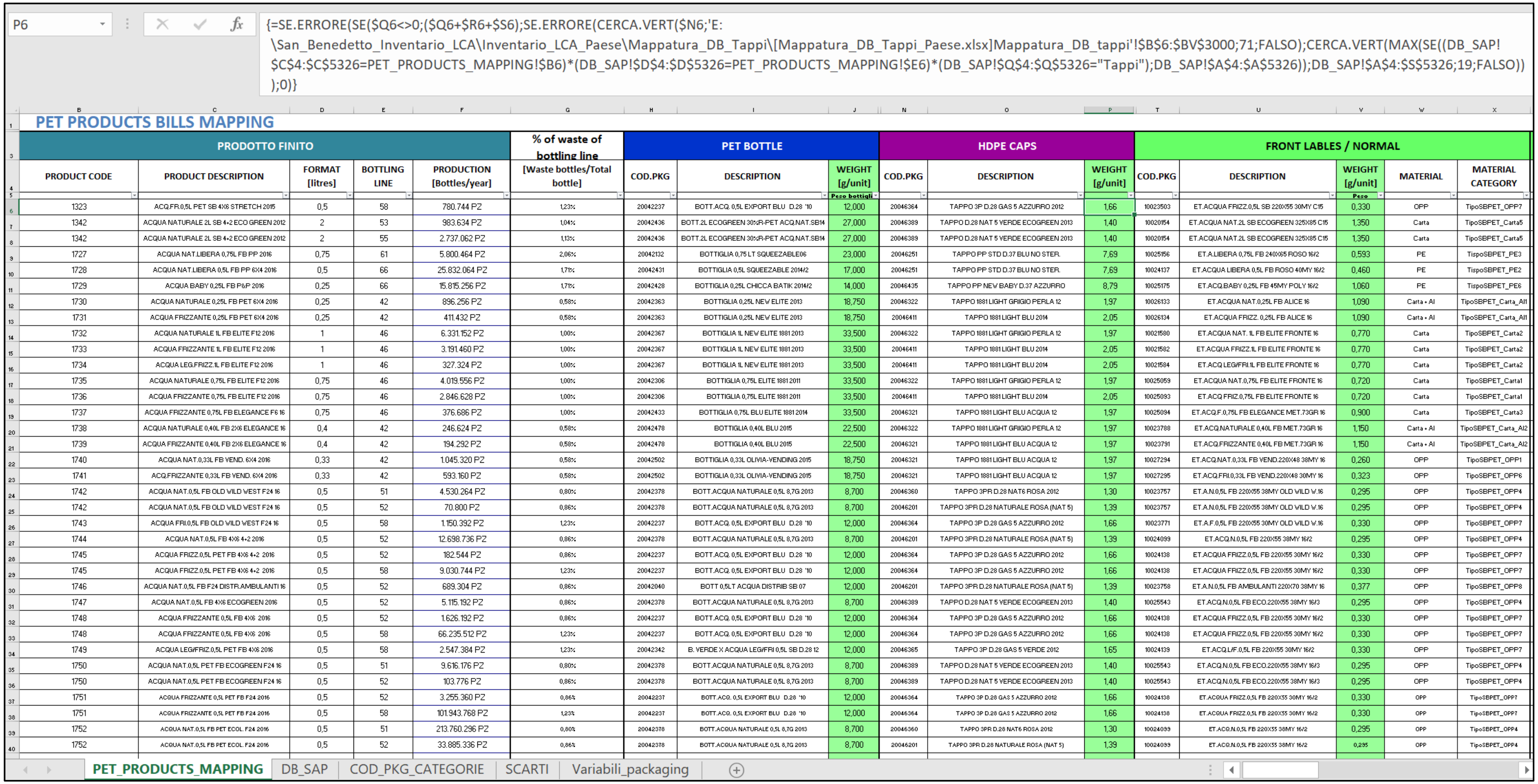
Mat. Doc. Generale

Pos.	T...	Componente	Definizione componente	Quantità	UM	Ass	Sps	In. val.	Fine val.	N. modifica	P...	Crit.class	ID pos.	N. mod. a	G..	Q...	T...
A010	L	20042378	BOT.ACQ.NATUR.0,5L 8,..	10.000	PZ	✓		17.02.2016	31.12.9999				00000001				
A020	L	20046389	TAPPO D.28 NAT 5 VER...	10.000	PZ	✓		17.02.2016	31.12.9999				00000002				
A040	L	10023784	ET.ACQ.NAT.0,5L FB EC...	10.000	PZ			17.02.2016	01.06.2016				00000003	500000003536			
A040	L	10024136	ET.ACQ.N.0,5L FB ECO.2..	10.000	PZ			01.06.2016	04.08.2016	500000003536			00000003	500000003633			
A040	L	10025543	ET.ACQ.N.0,5L FB ECO.2..	10.000	PZ			04.08.2016	02.08.2017	500000003633			00000003	500000004254			
A050	L	10052019	COLLA TECHNOMELT EM...	0,050	KG			17.02.2016	31.12.9999				00000004				
B070	L	10010516	FILM TE. NEUTRO 58CM...	427,000	M			17.02.2016	31.12.9999				00000005				
C010	L	10011007	INTERFALDA GRIGIO/GRI..	46,297	PZ			17.02.2016	31.12.9999				00000006				
C030	L	10012149	ESTENSIBILE NEUTRO 5...	3,357	KG			17.02.2016	11.09.2017				00000012	500000004299			
C050	L	10014091	ET.AD.PALLET 155X212 ...	23,148	PZ			17.02.2016	31.12.9999				00000008				
D010	L	10014500	PALLET EPAL 1200X800	11,574	PZ			17.02.2016	31.12.9999				00000009				
D011	L	10014500	PALLET EPAL 1200X800	11,574-	PZ			17.02.2016	31.12.9999				00000010				
E010	L	10014572	ACQUA BENEDICTA	5.000,000	L			17.02.2016	31.12.9999				00000011				

Posizionare... Vid. in. Ins. 1 / 13

Figure 83 Example of product bill from SAP.

In the following figures have been shown the EID_SB_Products_mapping interface. Every row is a different product while the columns show information on different packaging components (SAP code, weight, material, etc.).



PRODOTTO FINITO					% of waste of bottling line	PET BOTTLE			HDPE CAPS			FRONT LABLES / NORMAL				
PRODUCT CODE	PRODUCT DESCRIPTION	FORMAT [litres]	BOTTLING LINE	PRODUCTION [Bottles/year]	[Waste bottles/Total bottle]	COD.PKG	DESCRIPTION	WEIGHT [g/unit]	COD.PKG	DESCRIPTION	WEIGHT [g/unit]	COD.PKG	DESCRIPTION	WEIGHT [g/unit]	MATERIAL	MATERIAL CATEGORY
1323	ACQ.FR.0,5L PET SB 4X6 STRETCH 2015	0,5	58	780.744 PZ	1,23%	20042237	BOTT.ACQ. 0,5L EXPORT BLU D.28 '10	12,000	20046364	TAPPO 3P D.28 GAS 5 AZZURRO 2012	1,66	10023503	ET.ACQUA FRIZZ.0,5L SB 220X55 30MY C15	0,330	OPP	TipoSBPET_OPP7
1342	ACQUA NATURALE 2L SB 4+2 ECO GREEN 2012	2	53	983.634 PZ	1,04%	20042436	BOTT.2L ECOGREEN 30%R-PET ACQ.NAT.SB14	27,000	20046389	TAPPO D.28 NAT 5 VERDE ECOGREEN 2013	1,40	10020154	ET.ACQUA NAT.2L SB ECOGREEN 325X85 C15	1,350	Carta	TipoSBPET_Carta5
1342	ACQUA NATURALE 2L SB 4+2 ECO GREEN 2012	2	55	2.737.062 PZ	1,13%	20042436	BOTT.2L ECOGREEN 30%R-PET ACQ.NAT.SB14	27,000	20046389	TAPPO D.28 NAT 5 VERDE ECOGREEN 2013	1,40	10020154	ET.ACQUA NAT.2L SB ECOGREEN 325X85 C15	1,350	Carta	TipoSBPET_Carta5
1727	ACQUA NAT.LIBERA 0,75L FB PP 2016	0,75	61	5.800.464 PZ	2,06%	20042132	BOTTIGLIA 0,75 LT SQUEEZABLE06	23,000	20046251	TAPPO PP STD D.37 BLU NO STER.	7,69	10025156	ET.A.LIBERA 0,75L FB 240X65 ROSO 16/2	0,593	PE	TispoSBPET_PE3
1728	ACQUA NAT.LIBERA 0,5L FB PP 6X4 2016	0,5	66	25.832.064 PZ	1,71%	20042431	BOTTIGLIA 0,5L SQUEEZABLE 2014/2	17,000	20046251	TAPPO PP STD D.37 BLU NO STER.	7,69	10024137	ET.ACQUA LIBERA 0,5L FB ROSO 40MY 16/2	0,460	PE	TispoSBPET_PE2
1729	ACQUA BABY 0,25L FB P&P 2016	0,25	66	15.815.256 PZ	1,71%	20042428	BOTTIGLIA 0,25L CHICCA BATIK 2014/2	14,000	20046435	TAPPO PP NEW BABY D.37 AZZURRO	8,79	10025175	ET.ACQ.BABY 0,25L FB 45MY POLY 16/2	1,060	PE	TispoSBPET_PE6
1730	ACQUA NATURALE 0,25L FB PET 6X4 2016	0,25	42	896.256 PZ	0,58%	20042363	BOTTIGLIA 0,25L NEW ELITE 2013	18,750	20046322	TAPPO 1881 LIGHT GRIGIO PERLA 12	1,97	10026133	ET.ACQUA NAT.0,25L FB ALICE 16	1,090	Carta + Al	TipoSBPET_Carta_Al1
1731	ACQUA FRIZZANTE 0,25L FB PET 6X4 2016	0,25	42	411.432 PZ	0,58%	20042363	BOTTIGLIA 0,25L NEW ELITE 2013	18,750	20046411	TAPPO 1881 LIGHT BLU 2014	2,05	10026134	ET.ACQUA FRIZZ. 0,25L FB ALICE 16	1,090	Carta + Al	TipoSBPET_Carta_Al1
1732	ACQUA NATURALE 1L FB ELITE F12 2016	1	46	6.331.152 PZ	1,00%	20042367	BOTTIGLIA 1L NEW ELITE 1881 2013	33,500	20046322	TAPPO 1881 LIGHT GRIGIO PERLA 12	1,97	10021580	ET.ACQUA NAT. 1L FB ELITE FRONTE 16	0,770	Carta	TipoSBPET_Carta2
1733	ACQUA FRIZZANTE 1L FB ELITE F12 2016	1	46	3.191.460 PZ	1,00%	20042367	BOTTIGLIA 1L NEW ELITE 1881 2013	33,500	20046411	TAPPO 1881 LIGHT BLU 2014	2,05	10021582	ET.ACQUA FRIZZ.1L FB ELITE FRONTE 16	0,770	Carta	TipoSBPET_Carta2
1734	ACQUA LEG.FRIZZ.1L FB ELITE F12 2016	1	46	327.324 PZ	1,00%	20042367	BOTTIGLIA 1L NEW ELITE 1881 2013	33,500	20046411	TAPPO 1881 LIGHT BLU 2014	2,05	10021584	ET.ACQ LEG/FRI.1L FB ELITE FRONTE 16	0,770	Carta	TipoSBPET_Carta2
1735	ACQUA NATURALE 0,75L FB ELITE F12 2016	0,75	46	4.019.556 PZ	1,00%	20042306	BOTTIGLIA 0,75L ELITE 1881 2011	33,500	20046322	TAPPO 1881 LIGHT GRIGIO PERLA 12	1,97	10025059	ET.ACQUA NAT.0,75L FB ELITE FRONTE 16	0,720	Carta	TipoSBPET_Carta1
1736	ACQUA FRIZZANTE 0,75L FB ELITE F12 2016	0,75	46	2.846.628 PZ	1,00%	20042306	BOTTIGLIA 0,75L ELITE 1881 2011	33,500	20046411	TAPPO 1881 LIGHT BLU 2014	2,05	10025093	ET.ACQ FRIZ.0,75L FB ELITE FRONTE 16	0,720	Carta	TipoSBPET_Carta1
1737	ACQUA FRIZZANTE 0,75L FB ELEGANCE F6 16	0,75	46	376.686 PZ	1,00%	20042433	BOTTIGLIA 0,75L BLU ELITE 1881 2014	33,500	20046321	TAPPO 1881 LIGHT BLU ACQUA 12	1,97	10025094	ET.ACQ.F.0,75L FB ELEGANCE MET.73GR 16	0,900	Carta	TipoSBPET_Carta3
1738	ACQUA NATURALE 0,40L FB 2X6 ELEGANCE 16	0,4	42	246.624 PZ	0,58%	20042478	BOTTIGLIA 0,40L BLU 2015	22,500	20046322	TAPPO 1881 LIGHT GRIGIO PERLA 12	1,97	10023788	ET.ACQ.NATURALE 0,40L FB MET.73GR 16	1,150	Carta + Al	TipoSBPET_Carta_Al2
1739	ACQUA FRIZZANTE 0,40L FB 2X6 ELEGANCE 16	0,4	42	194.292 PZ	0,58%	20042478	BOTTIGLIA 0,40L BLU 2015	22,500	20046321	TAPPO 1881 LIGHT BLU ACQUA 12	1,97	10023791	ET.ACQ.FRIZZANTE 0,40L FB MET.73GR 16	1,150	Carta + Al	TipoSBPET_Carta_Al2
1740	ACQUA NAT.0,33L FB VEND. 6X4 2016	0,33	42	1.045.320 PZ	0,58%	20042502	BOTTIGLIA 0,33L OLIVIA-VENDING 2015	18,750	20046321	TAPPO 1881 LIGHT BLU ACQUA 12	1,97	10027294	ET.ACQ.NAT.0,33L FB VEND.220X48 38MY 16	0,260	OPP	TipoSBPET_OPP1
1741	ACQ.FRIZZANTE 0,33L FB VEND. 6X4 2016	0,33	42	593.160 PZ	0,58%	20042502	BOTTIGLIA 0,33L OLIVIA-VENDING 2015	18,750	20046321	TAPPO 1881 LIGHT BLU ACQUA 12	1,97	10027295	ET.ACQ.FRI.0,33L FB VEND.220X48 30MY 16	0,323	OPP	TipoSBPET_OPP6
1742	ACQUA NAT.0,5L FB OLD WILD WEST F24 16	0,5	51	4.530.264 PZ	0,80%	20042378	BOTT.ACQUA NATURALE 0,5L 8,7G 2013	8,700	20046360	TAPPO 3PR D.28 NAT6 ROSA 2012	1,30	10023757	ET.A.N.0,5L FB 220X55 38MY OLD WILD W.16	0,295	OPP	TipoSBPET_OPP4
1742	ACQUA NAT.0,5L FB OLD WILD WEST F24 16	0,5	52	70.800 PZ	0,86%	20042378	BOTT.ACQUA NATURALE 0,5L 8,7G 2013	8,700	20046201	TAPPO 3PR D.28 NATURALE ROSA (NAT 5)	1,39	10023757	ET.A.N.0,5L FB 220X55 38MY OLD WILD W.16	0,295	OPP	TipoSBPET_OPP4
1743	ACQUA FRI.0,5L FB OLD WILD WEST F24 16	0,5	58	1.150.392 PZ	1,23%	20042237	BOTT.ACQ. 0,5L EXPORT BLU D.28 '10	12,000	20046364	TAPPO 3P D.28 GAS 5 AZZURRO 2012	1,66	10023771	ET.A.F.0,5L FB 220X55 30MY OLD WILD W.16	0,330	OPP	TipoSBPET_OPP7
1744	ACQUA NAT.0,5L FB 4X6 4+2 2016	0,5	52	12.698.736 PZ	0,86%	20042378	BOTT.ACQUA NATURALE 0,5L 8,7G 2013	8,700	20046201	TAPPO 3PR D.28 NATURALE ROSA (NAT 5)	1,39	10024099	ET.ACQ.N.0,5L FB 220X55 38MY 16/2	0,295	OPP	TipoSBPET_OPP4
1745	ACQUA FRIZZ.0,5L PET FB 4X6 4+2 2016	0,5	52	182.544 PZ	0,86%	20042237	BOTT.ACQ. 0,5L EXPORT BLU D.28 '10	12,000	20046364	TAPPO 3P D.28 GAS 5 AZZURRO 2012	1,66	10024138	ET.ACQUA FRIZZ.0,5L FB 220X55 30MY 16/2	0,330	OPP	TipoSBPET_OPP7
1745	ACQUA FRIZZ.0,5L PET FB 4X6 4+2 2016	0,5	58	9.030.744 PZ	1,23%	20042237	BOTT.ACQ. 0,5L EXPORT BLU D.28 '10	12,000	20046364	TAPPO 3P D.28 GAS 5 AZZURRO 2012	1,66	10024138	ET.ACQUA FRIZZ.0,5L FB 220X55 30MY 16/2	0,330	OPP	TipoSBPET_OPP7
1746	ACQUA NAT.0,5L FB F24 DISTR.AMBULANTI 16	0,5	52	689.304 PZ	0,86%	20042040	BOTT 0,5LT ACQUA DISTRIB SB 07	12,000	20046201	TAPPO 3PR D.28 NATURALE ROSA (NAT 5)	1,39	10023758	ET.A.N.0,5L FB AMBULANTI 220X70 38MY 16	0,377	OPP	TipoSBPET_OPP8
1747	ACQUA NAT.0,5L FB 4X6 ECOGREEN 2016	0,5	52	5.115.192 PZ	0,86%	20042378	BOTT.ACQUA NATURALE 0,5L 8,7G 2013	8,700	20046389	TAPPO D.28 NAT 5 VERDE ECOGREEN 2013	1,40	10025543	ET.ACQ.N.0,5L FB ECO.220X55 38MY 16/3	0,295	OPP	TipoSBPET_OPP4
1748	ACQUA FRIZZANTE 0,5L FB 4X6 2016	0,5	52	1.626.192 PZ	0,86%	20042237	BOTT.ACQ. 0,5L EXPORT BLU D.28 '10	12,000	20046364	TAPPO 3P D.28 GAS 5 AZZURRO 2012	1,66	10024138	ET.ACQUA FRIZZ.0,5L FB 220X55 30MY 16/2	0,330	OPP	TipoSBPET_OPP7
1748	ACQUA FRIZZANTE 0,5L FB 4X6 2016	0,5	58	66.235.512 PZ	1,23%	20042237	BOTT.ACQ. 0,5L EXPORT BLU D.28 '10	12,000	20046364	TAPPO 3P D.28 GAS 5 AZZURRO 2012	1,66	10024138	ET.ACQUA FRIZZ.0,5L FB 220X55 30MY 16/2	0,330	OPP	TipoSBPET_OPP7
1749	ACQUA LEG/FRIZ.0,5L PET FB 4X6 2016	0,5	58	2.547.384 PZ	1,23%	20042342	B. VERDE X ACQUA LEG/FRI 0,5L SB D.28 12	12,000	20046365	TAPPO 3P D.28 GAS 5 VERDE 2012	1,65	10024139	ET.ACQ.L/F.0,5L FB 220X55 30MY 16/2	0,330	OPP	TipoSBPET_OPP7
1750	ACQUA NAT.0,5L PET FB ECOGREEN F24 16	0,5	51	9.616.176 PZ	0,80%	20042378	BOTT.ACQUA NATURALE 0,5L 8,7G 2013	8,700	20046389	TAPPO D.28 NAT 5 VERDE ECOGREEN 2013	1,40	10025543	ET.ACQ.N.0,5L FB ECO.220X55 38MY 16/3	0,295	OPP	TipoSBPET_OPP4
1750	ACQUA NAT.0,5L PET FB ECOGREEN F24 16	0,5	52	103.776 PZ	0,86%	20042378	BOTT.ACQUA NATURALE 0,5L 8,7G 2013	8,700	20046389	TAPPO D.28 NAT 5 VERDE ECOGREEN 2013	1,40	10025543	ET.ACQ.N.0,5L FB ECO.220X55 38MY 16/3	0,295	OPP	TipoSBPET_OPP4
1751	ACQUA FRIZZANTE 0,5L PET FB F24 2016	0,5	52	3.255.360 PZ	0,86%	20042237	BOTT.ACQ. 0,5L EXPORT BLU D.28 '10	12,000	20046364	TAPPO 3P D.28 GAS 5 AZZURRO 2012	1,66	10024138	ET.ACQUA FRIZZ.0,5L FB 220X55 30MY 16/2	0,330	OPP	TipoSBPET_OPP7
1751	ACQUA FRIZZANTE 0,5L PET FB F24 2016	0,5	58	101.943.768 PZ	1,23%	20042237	BOTT.ACQ. 0,5L EXPORT BLU D.28 '10	12,000	20046364	TAPPO 3P D.28 GAS 5 AZZURRO 2012	1,66	10024138	ET.ACQUA FRIZZ.0,5L FB 220X55 30MY 16/2	0,330	OPP	TipoSBPET_OPP7
1752	ACQUA NAT.0,5L FB PET ECOL. F24 2016	0,5	51	213.760.296 PZ	0,80%	20042378	BOTT.ACQUA NATURALE 0,5L 8,7G 2013	8,700	20046360	TAPPO 3PR D.28 NAT6 ROSA 2012	1,30	10024099	ET.ACQ.N.0,5L FB 220X55 38MY 16/2	0,295	OPP	TipoSBPET_OPP4
1752	ACQUA NAT.0,5L FB PET ECOL. F24 2016	0,5	52	33.885.336 PZ	0,86%	20042378	BOTT.ACQUA NATURALE 0,5L 8,7G 2013	8,700	20046201	TAPPO 3PR D.28 NATURALE ROSA (NAT 5)	1,39	10024099	ET.ACQ.N.0,5L FB 220X55 38MY 16/2	0,295	OPP	TipoSBPET_OPP4

Figure 84 EID_SB_Products_mapping interface (example 1)

BC7

{=SE.ERRORE(CERCA.VERT(MAX(SE((DB_SAP!$C$4:$C$5326=PET_PRODUCTS_MAPPING!$B7)*(DB_SAP!$D$4:$D$5326=PET_PRODUCTS_MAPPING!$E7)*(DB_SAP!$Q$4:$Q$5326="Carta maniglie"); DB_SAP!$A$4:$A$5326));DB_SAP!$A$4:$S$5326;5;FALSO);0)}

SHRINK FILM NEUTRAL					SHRINK FILM NOKOL					PAPER HANDLE			ADHESIVE PAPER HANDLE		
COD.PKG	DESCRIPTION	WEIGHT [g/unit] Peso Film	MATERIAL	MATERIAL CATEGORY	COD.PKG	DESCRIPTION	WEIGHT [g/unit] Peso Film	MATERIAL	MATERIAL CATEGORY	COD.PKG	DESCRIPTION	WEIGHT [g/unit] Peso carta	COD.PKG	DESCRIPTION	WEIGHT [g/unit] Peso nastro
10010767	F.ACQUA FRIZZANTE 6X0,5L SB 60X45MY 14/2	1,528		TipoSB_9	0	0	0,000			0	0	0,000	0	0	0,000
10010581	F.ACQ.NA.2 SB COOP.4+2 ECO.78X60M 30% 14	3,858		TipoSB_26	0	0	0,000			10011304	CARTA MAN.AC.N.2L SB COOP.4+2 ECOG.13/2	0,067	10011039	NAST.AD.X MAN.2LT PRE 25MMx75MYx800MT	0,176
10010581	F.ACQ.NA.2 SB COOP.4+2 ECO.78X60M 30% 14	3,858		TipoSB_26	0	0	0,000			10011304	CARTA MAN.AC.N.2L SB COOP.4+2 ECOG.13/2	0,067	10011066	NAST.ADXMAN.1,5L POST 25MMx73MYx6500MT	0,117
10010089	F.NEUTRO 40CMX55MY I.50+60+61(EX12008	1,720		TipoSB_13	0	0	0,000			0	0	0,000	0	0	0,000
10010954	F.ACQUA LIBERA 4X0,5L FB 63X50MY 16	1,788		TipoSB_14	10010813	F.NEUTRO NOKOL 60CMX45MY 2015	1,066			0	0	0,000	0	0	0,000
10010955	F.ACQUA BABY 4X0,25L FB 53X50MY 16	1,239		TipoSB_2	10010762	F.NEUTRO NOKOL 45CMX45MY 2014	0,667			0	0	0,000	0	0	0,000
10010926	F.ACQ.N.ALICE 4X0,25L SB 50X40MY I42 15	0,935		TipoSB_27	10010626	F.NOKOL+EAN X A.N.0,25L ALICE 45X45MY 14	0,699			0	0	0,000	0	0	0,000
10010927	F.ACQUA FRIZ.ALICE 4X0,25L FB 50X40MY 16	0,935		TipoSB_27	10010627	F.NOKOL+EAN X A.F.0,25L ALICE 45X45MY 14	0,699			0	0	0,000	0	0	0,000
10010950	F.ACQ.NAT.ELITE 12X1L FB+ EAN 92X60MY 16	2,412		TipoSB_17	0	0	0,000			0	0	0,000	0	0	0,000
10010951	F.ACQ.FRI.12X1L FB+ EAN ELITE 92X60MY 16	2,412		TipoSB_17	0	0	0,000			0	0	0,000	0	0	0,000
10010952	F.A.LE/FR.12X1L FB+ EAN ELITE 92X60MY 16	2,412		TipoSB_17	0	0	0,000			0	0	0,000	0	0	0,000
10010322	F.NEUTRO F12 I46 X ACQ.ELITE 92X60MY 12	2,412		TipoSB_17	0	0	0,000			0	0	0,000	0	0	0,000
10010322	F.NEUTRO F12 I46 X ACQ.ELITE 92X60MY 12	2,412		TipoSB_17	0	0	0,000			0	0	0,000	0	0	0,000
10010953	F.ACQ.FRI.6X0,75L FB ELEGANCE 69X60MY 16	2,761		TipoSB_19	0	0	0,000			0	0	0,000	0	0	0,000
10010932	F.NEUTRO 6X0,40L 60X40MY 2015/2	1,197		TipoSB_28	10010822	F.NOKOL NEUTRO 0,40L SB 40X45MY 2015	1,118			0	0	0,000	0	0	0,000
10010932	F.NEUTRO 6X0,40L 60X40MY 2015/2	1,197		TipoSB_28	10010822	F.NOKOL NEUTRO 0,40L SB 40X45MY 2015	1,118			0	0	0,000	0	0	0,000
10010853	F.NEUTRO 65X40MY X VEND. 0,33L SB+SCH 15	1,296		TipoSB_29	10010813	F.NEUTRO NOKOL 60CMX45MY 2015	1,004			0	0	0,000	0	0	0,000
10010853	F.NEUTRO 65X40MY X VEND. 0,33L SB+SCH 15	1,296		TipoSB_29	10010813	F.NEUTRO NOKOL 60CMX45MY 2015	1,004			0	0	0,000	0	0	0,000
10010516	FILM TE. NEUTRO 58CMX55MY 0,5L '14	1,281		TipoSB_4	0	0	0,000			0	0	0,000	0	0	0,000
10010516	FILM TE. NEUTRO 58CMX55MY 0,5L '14	1,281		TipoSB_4	0	0	0,000			0	0	0,000	0	0	0,000
10010516	FILM TE. NEUTRO 58CMX55MY 0,5L '14	1,281		TipoSB_4	0	0	0,000			0	0	0,000	0	0	0,000
10010936	F.ACQ.NAT. 6X0,5L FB 60X45MY 4+2 COOP 16	1,528		TipoSB_9	10010762	F.NEUTRO NOKOL 45CMX45MY 2014	1,010			0	0	0,000	0	0	0,000
10010938	F.ACQ.FRIZ.6X0,5L FB COOP 4+2 60X45MY 16	1,528		TipoSB_9	10010762	F.NEUTRO NOKOL 45CMX45MY 2014	1,010			0	0	0,000	0	0	0,000
10010938	F.ACQ.FRIZ.6X0,5L FB COOP 4+2 60X45MY 16	1,528		TipoSB_9	10010762	F.NEUTRO NOKOL 45CMX45MY 2014	1,010			0	0	0,000	0	0	0,000
10010516	FILM TE. NEUTRO 58CMX55MY 0,5L '14	1,281		TipoSB_4	0	0	0,000			0	0	0,000	0	0	0,000
10010949	F.ACQ.NAT.6X0,5L FB ECO.60X45MY 30% 16	1,528		TipoSB_9	10010762	F.NEUTRO NOKOL 45CMX45MY 2014	1,010			0	0	0,000	0	0	0,000
10010937	F.ACQUA FRIZZANTE 6X0,5L FB 60X45MY 16	1,528		TipoSB_9	10010762	F.NEUTRO NOKOL 45CMX45MY 2014	1,010			0	0	0,000	0	0	0,000
10010937	F.ACQUA FRIZZANTE 6X0,5L FB 60X45MY 16	1,528		TipoSB_9	10010762	F.NEUTRO NOKOL 45CMX45MY 2014	1,010			0	0	0,000	0	0	0,000
10010939	F.ACQUA LEG/FRIZ 6X0,5L FB 60X45MY 16	1,528		TipoSB_9	10010762	F.NEUTRO NOKOL 45CMX45MY 2014	1,010			0	0	0,000	0	0	0,000
10010516	FILM TE. NEUTRO 58CMX55MY 0,5L '14	1,281		TipoSB_4	0	0	0,000			0	0	0,000	0	0	0,000
10010516	FILM TE. NEUTRO 58CMX55MY 0,5L '14	1,281		TipoSB_4	0	0	0,000			0	0	0,000	0	0	0,000
10010516	FILM TE. NEUTRO 58CMX55MY 0,5L '14	1,281		TipoSB_4	0	0	0,000			0	0	0,000	0	0	0,000
10010516	FILM TE. NEUTRO 58CMX55MY 0,5L '14	1,281		TipoSB_4	0	0	0,000			0	0	0,000	0	0	0,000
10010516	FILM TE. NEUTRO 58CMX55MY 0,5L '14	1,281		TipoSB_4	0	0	0,000			0	0	0,000	0	0	0,000
10010516	FILM TE. NEUTRO 58CMX55MY 0,5L '14	1,281		TipoSB_4	0	0	0,000			0	0	0,000	0	0	0,000

PET_PRODUCTS_MAPPING | DB_SAP | COD_PKG_CATEGORIE | SCARTI | Variabili_packaging

Figure 85 EID_SB_Products_mapping interface (example 2)

3.2.1.2.3.3. Inventory data collection – EID_SB_Production_mapping

This EID interface permits to map all the productions related to different product codes and different bottle codes at level respectively of each bottling line and machinery for bottle production. The EID interface is split in two different components, on for the bottling lines and one for the machineries for bottles production. Following the flowchart shown below, the interface for bottling processes acquires data on volumes bottled in the different periods of the year for each product code from reports automatically extracted from SAP with a specific query (example of SAP query: ZAMSB_MMIC_003). The product code is the element that permits to link the specific production occurred in a bottling line with its product bill.

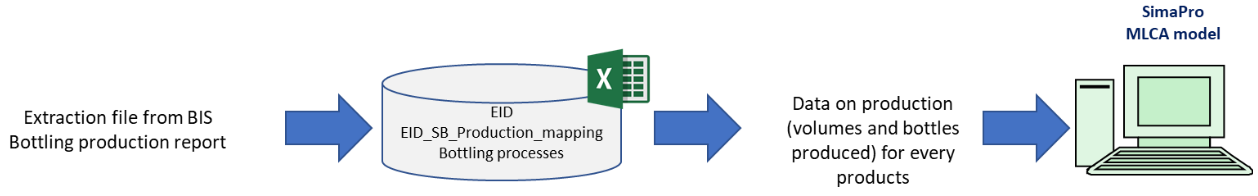


Figure 86 Simplified flowchart of EID_SB_Production_mapping, bottling processes part

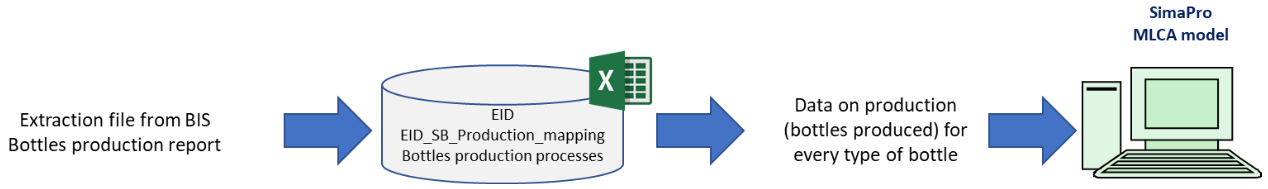
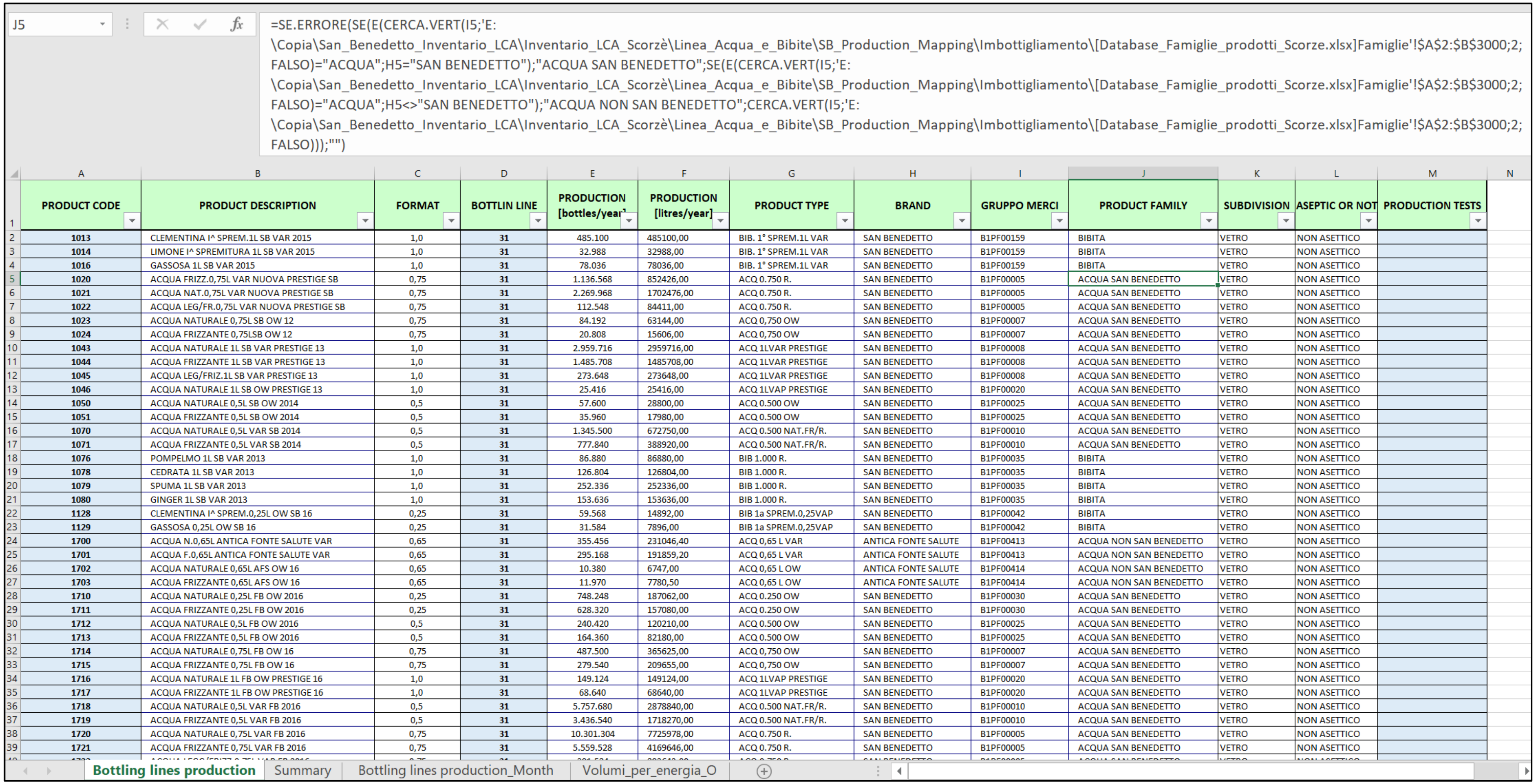


Figure 87 Simplified flowchart of EID_SB_Production_mapping, bottle production processes part

In the case of the interface for bottle production processes, it acquires data on specific production of bottles occurred during the year by reports extracted by the software used to register the productive activity of the bottle production department. The data acquired permits to assess the different specifications of the bottles (e.g. weight, % RPET, etc.) and the contribution of the different machineries (in terms of bottle produced) to the production of a specific bottle. This high detail permits to assess the difference of production of the same bottle with machineries with different performance.



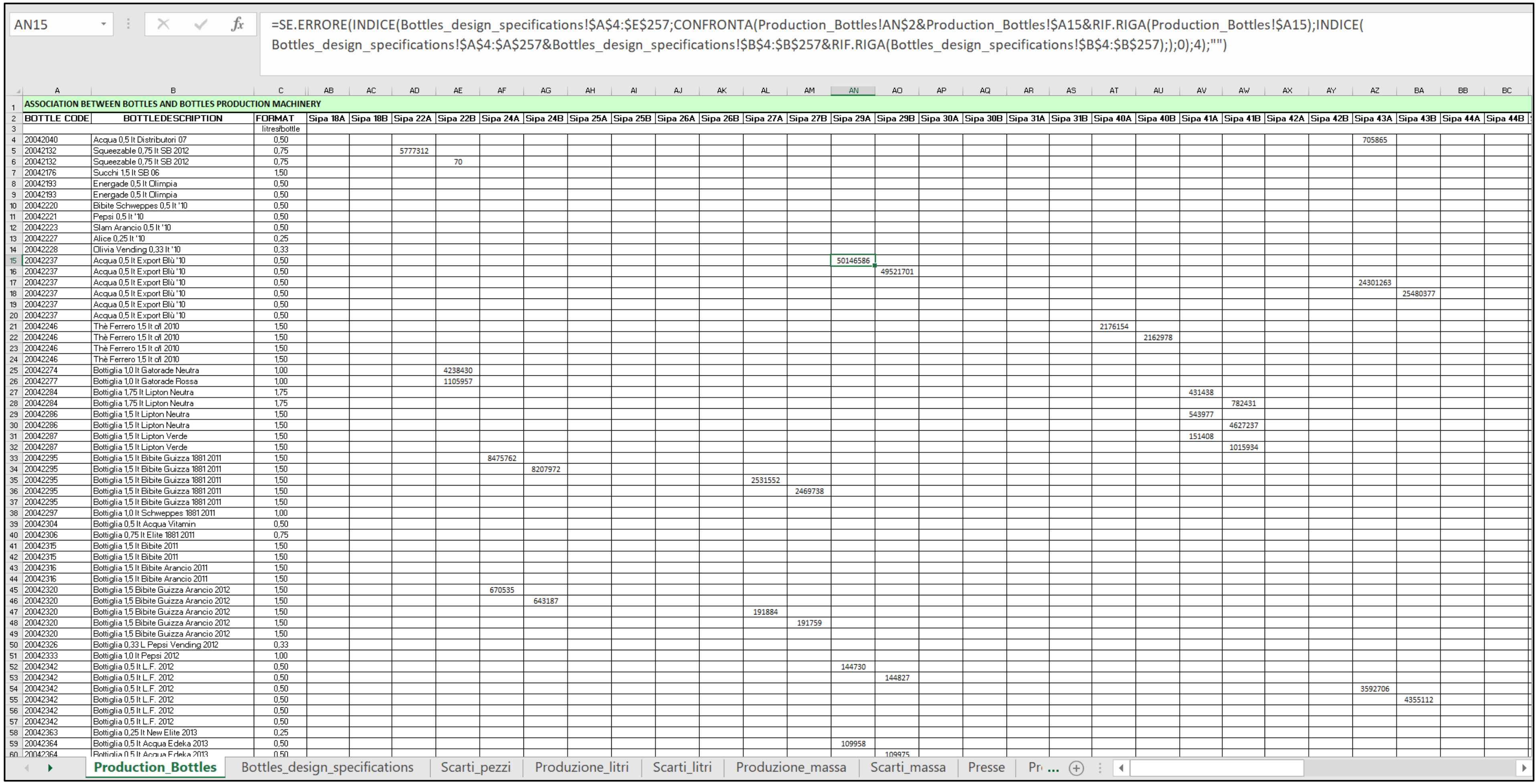
J5

=SE.ERRORE(SE(E(CERCA.VERT(I5;'E:\Copia\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Acqua_e_Bibite\SB_Production_Mapping\Imbottigliamento\[Database_Famiglie_prodotti_Scorze.xlsx]Famiglie'!$A$2:$B$3000;2;FALSO)="ACQUA";H5="SAN BENEDETTO");"ACQUA SAN BENEDETTO";SE(E(CERCA.VERT(I5;'E:\Copia\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Acqua_e_Bibite\SB_Production_Mapping\Imbottigliamento\[Database_Famiglie_prodotti_Scorze.xlsx]Famiglie'!$A$2:$B$3000;2;FALSO)="ACQUA";H5<>"SAN BENEDETTO");"ACQUA NON SAN BENEDETTO";CERCA.VERT(I5;'E:\Copia\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Acqua_e_Bibite\SB_Production_Mapping\Imbottigliamento\[Database_Famiglie_prodotti_Scorze.xlsx]Famiglie'!$A$2:$B$3000;2;FALSO)));"")

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	PRODUCT CODE	PRODUCT DESCRIPTION	FORMAT	BOTTLIN LINE	PRODUCTION [bottles/year]	PRODUCTION [litres/year]	PRODUCT TYPE	BRAND	GRUPPO MERCI	PRODUCT FAMILY	SUBDIVISION	ASEPTIC OR NOT	PRODUCTION TESTS
2	1013	CLEMENTINA I^ SPREM.1L SB VAR 2015	1,0	31	485.100	485100,00	BIB. 1° SPREM.1L VAR	SAN BENEDETTO	B1PF00159	BIBITA	VETRO	NON ASETTICO	
3	1014	LIMONE I^ SPREMITURA 1L SB VAR 2015	1,0	31	32.988	32988,00	BIB. 1° SPREM.1L VAR	SAN BENEDETTO	B1PF00159	BIBITA	VETRO	NON ASETTICO	
4	1016	GASSOSA 1L SB VAR 2015	1,0	31	78.036	78036,00	BIB. 1° SPREM.1L VAR	SAN BENEDETTO	B1PF00159	BIBITA	VETRO	NON ASETTICO	
5	1020	ACQUA FRIZZ.0,75L VAR NUOVA PRESTIGE SB	0,75	31	1.136.568	852426,00	ACQ 0.750 R.	SAN BENEDETTO	B1PF00005	ACQUA SAN BENEDETTO	VETRO	NON ASETTICO	
6	1021	ACQUA NAT.0,75L VAR NUOVA PRESTIGE SB	0,75	31	2.269.968	1702476,00	ACQ 0.750 R.	SAN BENEDETTO	B1PF00005	ACQUA SAN BENEDETTO	VETRO	NON ASETTICO	
7	1022	ACQUA LEG/FR.0,75L VAR NUOVA PRESTIGE SB	0,75	31	112.548	84411,00	ACQ 0.750 R.	SAN BENEDETTO	B1PF00005	ACQUA SAN BENEDETTO	VETRO	NON ASETTICO	
8	1023	ACQUA NATURALE 0,75L SB OW 12	0,75	31	84.192	63144,00	ACQ 0,750 OW	SAN BENEDETTO	B1PF00007	ACQUA SAN BENEDETTO	VETRO	NON ASETTICO	
9	1024	ACQUA FRIZZANTE 0,75LSB OW 12	0,75	31	20.808	15606,00	ACQ 0,750 OW	SAN BENEDETTO	B1PF00007	ACQUA SAN BENEDETTO	VETRO	NON ASETTICO	
10	1043	ACQUA NATURALE 1L SB VAR PRESTIGE 13	1,0	31	2.959.716	2959716,00	ACQ 1LVAR PRESTIGE	SAN BENEDETTO	B1PF00008	ACQUA SAN BENEDETTO	VETRO	NON ASETTICO	
11	1044	ACQUA FRIZZANTE 1L SB VAR PRESTIGE 13	1,0	31	1.485.708	1485708,00	ACQ 1LVAR PRESTIGE	SAN BENEDETTO	B1PF00008	ACQUA SAN BENEDETTO	VETRO	NON ASETTICO	
12	1045	ACQUA LEG/FRIZ.1L SB VAR PRESTIGE 13	1,0	31	273.648	273648,00	ACQ 1LVAR PRESTIGE	SAN BENEDETTO	B1PF00008	ACQUA SAN BENEDETTO	VETRO	NON ASETTICO	
13	1046	ACQUA NATURALE 1L SB OW PRESTIGE 13	1,0	31	25.416	25416,00	ACQ 1LVAP PRESTIGE	SAN BENEDETTO	B1PF00020	ACQUA SAN BENEDETTO	VETRO	NON ASETTICO	
14	1050	ACQUA NATURALE 0,5L SB OW 2014	0,5	31	57.600	28800,00	ACQ 0.500 OW	SAN BENEDETTO	B1PF00025	ACQUA SAN BENEDETTO	VETRO	NON ASETTICO	
15	1051	ACQUA FRIZZANTE 0,5L SB OW 2014	0,5	31	35.960	17980,00	ACQ 0.500 OW	SAN BENEDETTO	B1PF00025	ACQUA SAN BENEDETTO	VETRO	NON ASETTICO	
16	1070	ACQUA NATURALE 0,5L VAR SB 2014	0,5	31	1.345.500	672750,00	ACQ 0.500 NAT.FR/R.	SAN BENEDETTO	B1PF00010	ACQUA SAN BENEDETTO	VETRO	NON ASETTICO	
17	1071	ACQUA FRIZZANTE 0,5L VAR SB 2014	0,5	31	777.840	388920,00	ACQ 0.500 NAT.FR/R.	SAN BENEDETTO	B1PF00010	ACQUA SAN BENEDETTO	VETRO	NON ASETTICO	
18	1076	POMPELMO 1L SB VAR 2013	1,0	31	86.880	86880,00	BIB 1.000 R.	SAN BENEDETTO	B1PF00035	BIBITA	VETRO	NON ASETTICO	
19	1078	CEDRATA 1L SB VAR 2013	1,0	31	126.804	126804,00	BIB 1.000 R.	SAN BENEDETTO	B1PF00035	BIBITA	VETRO	NON ASETTICO	
20	1079	SPUMA 1L SB VAR 2013	1,0	31	252.336	252336,00	BIB 1.000 R.	SAN BENEDETTO	B1PF00035	BIBITA	VETRO	NON ASETTICO	
21	1080	GINGER 1L SB VAR 2013	1,0	31	153.636	153636,00	BIB 1.000 R.	SAN BENEDETTO	B1PF00035	BIBITA	VETRO	NON ASETTICO	
22	1128	CLEMENTINA I^ SPREM.0,25L OW SB 16	0,25	31	59.568	14892,00	BIB 1a SPREM.0,25VAP	SAN BENEDETTO	B1PF00042	BIBITA	VETRO	NON ASETTICO	
23	1129	GASSOSA 0,25L OW SB 16	0,25	31	31.584	7896,00	BIB 1a SPREM.0,25VAP	SAN BENEDETTO	B1PF00042	BIBITA	VETRO	NON ASETTICO	
24	1700	ACQUA N.0,65L ANTICA FONTE SALUTE VAR	0,65	31	355.456	231046,40	ACQ 0,65 L VAR	ANTICA FONTE SALUTE	B1PF00413	ACQUA NON SAN BENEDETTO	VETRO	NON ASETTICO	
25	1701	ACQUA F.0,65L ANTICA FONTE SALUTE VAR	0,65	31	295.168	191859,20	ACQ 0,65 L VAR	ANTICA FONTE SALUTE	B1PF00413	ACQUA NON SAN BENEDETTO	VETRO	NON ASETTICO	
26	1702	ACQUA NATURALE 0,65L AFS OW 16	0,65	31	10.380	6747,00	ACQ 0,65 L OW	ANTICA FONTE SALUTE	B1PF00414	ACQUA NON SAN BENEDETTO	VETRO	NON ASETTICO	
27	1703	ACQUA FRIZZANTE 0,65L AFS OW 16	0,65	31	11.970	7780,50	ACQ 0,65 L OW	ANTICA FONTE SALUTE	B1PF00414	ACQUA NON SAN BENEDETTO	VETRO	NON ASETTICO	
28	1710	ACQUA NATURALE 0,25L FB OW 2016	0,25	31	748.248	187062,00	ACQ 0.250 OW	SAN BENEDETTO	B1PF00030	ACQUA SAN BENEDETTO	VETRO	NON ASETTICO	
29	1711	ACQUA FRIZZANTE 0,25L FB OW 2016	0,25	31	628.320	157080,00	ACQ 0.250 OW	SAN BENEDETTO	B1PF00030	ACQUA SAN BENEDETTO	VETRO	NON ASETTICO	
30	1712	ACQUA NATURALE 0,5L FB OW 2016	0,5	31	240.420	120210,00	ACQ 0.500 OW	SAN BENEDETTO	B1PF00025	ACQUA SAN BENEDETTO	VETRO	NON ASETTICO	
31	1713	ACQUA FRIZZANTE 0,5L FB OW 2016	0,5	31	164.360	82180,00	ACQ 0.500 OW	SAN BENEDETTO	B1PF00025	ACQUA SAN BENEDETTO	VETRO	NON ASETTICO	
32	1714	ACQUA NATURALE 0,75L FB OW 16	0,75	31	487.500	365625,00	ACQ 0,750 OW	SAN BENEDETTO	B1PF00007	ACQUA SAN BENEDETTO	VETRO	NON ASETTICO	
33	1715	ACQUA FRIZZANTE 0,75L FB OW 16	0,75	31	279.540	209655,00	ACQ 0,750 OW	SAN BENEDETTO	B1PF00007	ACQUA SAN BENEDETTO	VETRO	NON ASETTICO	
34	1716	ACQUA NATURALE 1L FB OW PRESTIGE 16	1,0	31	149.124	149124,00	ACQ 1LVAP PRESTIGE	SAN BENEDETTO	B1PF00020	ACQUA SAN BENEDETTO	VETRO	NON ASETTICO	
35	1717	ACQUA FRIZZANTE 1L FB OW PRESTIGE 16	1,0	31	68.640	68640,00	ACQ 1LVAP PRESTIGE	SAN BENEDETTO	B1PF00020	ACQUA SAN BENEDETTO	VETRO	NON ASETTICO	
36	1718	ACQUA NATURALE 0,5L VAR FB 2016	0,5	31	5.757.680	2878840,00	ACQ 0.500 NAT.FR/R.	SAN BENEDETTO	B1PF00010	ACQUA SAN BENEDETTO	VETRO	NON ASETTICO	
37	1719	ACQUA FRIZZANTE 0,5L VAR FB 2016	0,5	31	3.436.540	1718270,00	ACQ 0.500 NAT.FR/R.	SAN BENEDETTO	B1PF00010	ACQUA SAN BENEDETTO	VETRO	NON ASETTICO	
38	1720	ACQUA NATURALE 0,75L VAR FB 2016	0,75	31	10.301.304	7725978,00	ACQ 0.750 R.	SAN BENEDETTO	B1PF00005	ACQUA SAN BENEDETTO	VETRO	NON ASETTICO	
39	1721	ACQUA FRIZZANTE 0,75L VAR FB 2016	0,75	31	5.559.528	4169646,00	ACQ 0.750 R.	SAN BENEDETTO	B1PF00005	ACQUA SAN BENEDETTO	VETRO	NON ASETTICO	

Bottling lines production | Summary | Bottling lines production_Month | Volumi_per_energia_O

Figure 88 EID_SB_Production_mapping interface (Bottling Lines)



AN15

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=SE.ERRORE(INDICE(Bottles_design_specifications!$A$4:$E$257;CONFRONTA(Production_Bottles!AN$2&Production_Bottles!$A15&RIF.RIGA(Production_Bottles!$A15);INDICE(
Bottles_design_specifications!$A$4:$A$257&Bottles_design_specifications!$B$4:$B$257&RIF.RIGA(Bottles_design_specifications!$B$4:$B$257););0);4);"")
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	A	B	C	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP	AQ	AR	AS	AT	AU	AV	AW	AX	AY	AZ	BA	BB	BC
1	ASSOCIATION BETWEEN BOTTLES AND BOTTLES PRODUCTION MACHINERY																														
2	BOTTLE CODE	BOTTLEDESCRIPTION	FORMAT	Sipa 18A	Sipa 18B	Sipa 22A	Sipa 22B	Sipa 24A	Sipa 24B	Sipa 25A	Sipa 25B	Sipa 26A	Sipa 26B	Sipa 27A	Sipa 27B	Sipa 29A	Sipa 29B	Sipa 30A	Sipa 30B	Sipa 31A	Sipa 31B	Sipa 40A	Sipa 40B	Sipa 41A	Sipa 41B	Sipa 42A	Sipa 42B	Sipa 43A	Sipa 43B	Sipa 44A	Sipa 44B
3			litres/bottle																												
4	20042040	Acqua 0,5 lt Distributori 07	0,50																									705865			
5	20042132	Squeezable 0,75 lt SB 2012	0,75			5777312																									
6	20042132	Squeezable 0,75 lt SB 2012	0,75				70																								
7	20042176	Succhi 1,5 lt SB 06	1,50																												
8	20042193	Energade 0,5 lt Olimpia	0,50																												
9	20042193	Energade 0,5 lt Olimpia	0,50																												
10	20042220	Bibite Schweppes 0,5 lt '10	0,50																												
11	20042221	Pepsi 0,5 lt '10	0,50																												
12	20042223	Slam Arancio 0,5 lt '10	0,50																												
13	20042227	Alice 0,25 lt '10	0,25																												
14	20042228	Olivia Vending 0,33 lt '10	0,33																												
15	20042237	Acqua 0,5 lt Export Blù '10	0,50													50146586															
16	20042237	Acqua 0,5 lt Export Blù '10	0,50														49521701														
17	20042237	Acqua 0,5 lt Export Blù '10	0,50																									24301263			
18	20042237	Acqua 0,5 lt Export Blù '10	0,50																										25480377		
19	20042237	Acqua 0,5 lt Export Blù '10	0,50																												
20	20042237	Acqua 0,5 lt Export Blù '10	0,50																												
21	20042246	Thè Ferrero 1,5 lt c/l 2010	1,50																			2176154									
22	20042246	Thè Ferrero 1,5 lt c/l 2010	1,50																				2162978								
23	20042246	Thè Ferrero 1,5 lt c/l 2010	1,50																												
24	20042246	Thè Ferrero 1,5 lt c/l 2010	1,50																												
25	20042274	Bottiglia 1,0 lt Gatorade Neutra	1,00				4238430																								
26	20042277	Bottiglia 1,0 lt Gatorade Rossa	1,00				1105957																								
27	20042284	Bottiglia 1,75 lt Lipton Neutra	1,75																					431438							
28	20042284	Bottiglia 1,75 lt Lipton Neutra	1,75																						782431						
29	20042286	Bottiglia 1,5 lt Lipton Neutra	1,50																					543977							
30	20042286	Bottiglia 1,5 lt Lipton Neutra	1,50																						4627237						
31	20042287	Bottiglia 1,5 lt Lipton Verde	1,50																					151408							
32	20042287	Bottiglia 1,5 lt Lipton Verde	1,50																						1015934						
33	20042295	Bottiglia 1,5 lt Bibite Guizza 1881 2011	1,50					8475762																							
34	20042295	Bottiglia 1,5 lt Bibite Guizza 1881 2011	1,50						8207972																						
35	20042295	Bottiglia 1,5 lt Bibite Guizza 1881 2011	1,50											2531552																	
36	20042295	Bottiglia 1,5 lt Bibite Guizza 1881 2011	1,50												2469738																
37	20042295	Bottiglia 1,5 lt Bibite Guizza 1881 2011	1,50																												
38	20042297	Bottiglia 1,0 lt Schweppes 1881 2011	1,00																												
39	20042304	Bottiglia 0,5 lt Acqua Vitamin	0,50																												
40	20042306	Bottiglia 0,75 lt Elite 1881 2011	0,75																												
41	20042315	Bottiglia 1,5 lt Bibite 2011	1,50																												
42	20042315	Bottiglia 1,5 lt Bibite 2011	1,50																												
43	20042316	Bottiglia 1,5 lt Bibite Arancio 2011	1,50																												
44	20042316	Bottiglia 1,5 lt Bibite Arancio 2011	1,50																												
45	20042320	Bottiglia 1,5 Bibite Guizza Arancio 2012	1,50					670535																							
46	20042320	Bottiglia 1,5 Bibite Guizza Arancio 2012	1,50						643187																						
47	20042320	Bottiglia 1,5 Bibite Guizza Arancio 2012	1,50											191884																	
48	20042320	Bottiglia 1,5 Bibite Guizza Arancio 2012	1,50												191759																
49	20042320	Bottiglia 1,5 Bibite Guizza Arancio 2012	1,50																												
50	20042326	Bottiglia 0,33 L Pepsi Vending 2012	0,33																												
51	20042333	Bottiglia 1,0 lt Pepsi 2012	1,00																												
52	20042342	Bottiglia 0,5 lt L.F. 2012	0,50													144730															
53	20042342	Bottiglia 0,5 lt L.F. 2012	0,50														144827														
54	20042342	Bottiglia 0,5 lt L.F. 2012	0,50																									3592706			
55	20042342	Bottiglia 0,5 lt L.F. 2012	0,50																										4355112		
56	20042342	Bottiglia 0,5 lt L.F. 2012	0,50																												
57	20042342	Bottiglia 0,5 lt L.F. 2012	0,50																												
58	20042363	Bottiglia 0,25 lt New Elite 2013	0,25																												
59	20042364	Bottiglia 0,5 lt Acqua Edeka 2013	0,50													109958															
60	20042364	Bottiglia 0,5 lt Acqua Edeka 2013	0,50														109975														

Production_Bottles | Bottles_design_specifications | Scarti_pezzi | Produzione_litri | Scarti_litri | Produzione_massa | Scarti_massa | Presse | Pr ...

Figure 89 EID_SB_Production_mapping interface (Bottles production machineries – Part 1)

G4

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=SE.ERRORE(INDICE('E:
\Copia\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Acqua_e_Bibite\SB_Production_Mapping\Produzione_bottiglie_PET\[Sorgente_dati_pesi_e_composizione_produzione_bottiglie_
PET_Scorze.xlsx]Input'!$A$4:$AM$70003;CONFRONTA($A4&$B4;INDICE('E:
\Copia\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Acqua_e_Bibite\SB_Production_Mapping\Produzione_bottiglie_PET\[Sorgente_dati_pesi_e_composizione_produzione_bottiglie_
PET_Scorze.xlsx]Input'!$C$4:$C$70003&'E:
\Copia\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Acqua_e_Bibite\SB_Production_Mapping\Produzione_bottiglie_PET\[Sorgente_dati_pesi_e_composizione_produzione_bottiglie_
PET_Scorze.xlsx]Input'!$A$4:$A$70003;);0);6);0)
```

	A	B	C	F	G	H	I	J	K
1–2	BOTTLE PRODUCTION MACHINERY	BOTTLE CODE	BOTTLE DESCRIPTION	FORMAT	PET weight per bottle	RPET weight per bottle	Masterbatch weight per bottle	TOTAL BOTTLE WEIGHT	CONTRIBUTION OF THE MACHINERY TO THE TOTAL BOTTLE PRODUCTION
3									
4	Sipa 43A	20042040	Acqua 0,5 lt Distributori 07	0,50	12,00	0,00	0,00	12,00	1,00
5	Sipa 22A	20042132	Squeezable 0,75 lt SB 2012	0,75	23,00	0,00	0,00	23,00	1,00
6	Sipa 22B	20042132	Squeezable 0,75 lt SB 2012	0,75	23,00	0,00	0,00	23,00	0,00
7	Sipa 10B	20042176	Succhi 1,5 lt SB 06	1,50	40,00	0,00	0,00	40,00	1,00
8	Sipa 8A	20042193	Energade 0,5 lt Olimpia	0,50	14,10	0,00	0,00	14,10	0,81
9	Sipa 17B	20042193	Energade 0,5 lt Olimpia	0,50	15,60	0,00	0,00	15,60	0,19
10	Soffiatrice L42	20042220	Bibite Schweppes 0,5 lt '10	0,50	26,25	0,00	0,00	26,25	1,00
11	Soffiatrice L42	20042221	Pepsi 0,5 lt '10	0,50	20,50	0,00	0,00	20,50	1,00
12	Soffiatrice L42	20042223	Slam Arancio 0,5 lt '10	0,50	20,50	0,00	0,00	20,50	1,00
13	Soffiatrice L42	20042227	Alice 0,25 lt '10	0,25	22,50	0,00	0,00	22,50	1,00
14	Soffiatrice L42	20042228	Olivia Vending 0,33 lt '10	0,33	22,50	0,00	0,00	22,50	1,00
15	Sipa 29A	20042237	Acqua 0,5 lt Export Blù '10	0,50	11,98	0,00	0,02	12,00	0,19
16	Sipa 29B	20042237	Acqua 0,5 lt Export Blù '10	0,50	11,98	0,00	0,02	12,00	0,19
17	Sipa 43A	20042237	Acqua 0,5 lt Export Blù '10	0,50	11,98	0,00	0,03	12,00	0,09
18	Sipa 43B	20042237	Acqua 0,5 lt Export Blù '10	0,50	11,98	0,00	0,03	12,00	0,10
19	Sipa 50A	20042237	Acqua 0,5 lt Export Blù '10	0,50	11,98	0,00	0,02	12,00	0,21
20	Sipa 50B	20042237	Acqua 0,5 lt Export Blù '10	0,50	11,98	0,00	0,02	12,00	0,22
21	Sipa 40A	20042246	Thè Ferrero 1,5 lt c/l 2010	1,50	37,70	0,00	0,00	37,70	0,12
22	Sipa 40B	20042246	Thè Ferrero 1,5 lt c/l 2010	1,50	37,70	0,00	0,00	37,70	0,12
23	Sipa 47A	20042246	Thè Ferrero 1,5 lt c/l 2010	1,50	37,70	0,00	0,00	37,70	0,38
24	Sipa 47B	20042246	Thè Ferrero 1,5 lt c/l 2010	1,50	37,70	0,00	0,00	37,70	0,38
25	Sipa 22B	20042274	Bottiglia 1,0 lt Gatorade Neutra	1,00	26,00	0,00	0,00	26,00	1,00
26	Sipa 22B	20042277	Bottiglia 1,0 lt Gatorade Rossa	1,00	25,84	0,00	0,16	26,00	1,00
27	Sipa 41A	20042284	Bottiglia 1,75 lt Lipton Neutra	1,75	34,00	0,00	0,00	34,00	0,36
28	Sipa 41B	20042284	Bottiglia 1,75 lt Lipton Neutra	1,75	34,00	0,00	0,00	34,00	0,64
29	Sipa 41A	20042286	Bottiglia 1,5 lt Lipton Neutra	1,50	34,00	0,00	0,00	34,00	0,11
30	Sipa 41B	20042286	Bottiglia 1,5 lt Lipton Neutra	1,50	34,00	0,00	0,00	34,00	0,89
31	Sipa 41A	20042287	Bottiglia 1,5 lt Lipton Verde	1,50	33,98	0,00	0,02	34,00	0,13
32	Sipa 41B	20042287	Bottiglia 1,5 lt Lipton Verde	1,50	33,98	0,00	0,02	34,00	0,87
33	Sipa 24A	20042295	Bottiglia 1,5 lt Bibite Guizza 1881 2011	1,50	31,20	0,00	0,00	31,20	0,34
34	Sipa 24B	20042295	Bottiglia 1,5 lt Bibite Guizza 1881 2011	1,50	31,20	0,00	0,00	31,20	0,33
35	Sipa 27A	20042295	Bottiglia 1,5 lt Bibite Guizza 1881 2011	1,50	31,20	0,00	0,00	31,20	0,10
36	Sipa 27B	20042295	Bottiglia 1,5 lt Bibite Guizza 1881 2011	1,50	31,20	0,00	0,00	31,20	0,10
37	Soffiatrice 2	20042295	Bottiglia 1,5 lt Bibite Guizza 1881 2011	1,50	31,20	0,00	0,00	31,20	0,14
38	Soffiatrice 2	20042297	Bottiglia 1,0 lt Schweppes 1881 2011	1,00	40,00	0,00	0,00	40,00	1,00
39	Sipa 10A	20042304	Bottiglia 0,5 lt Acqua Vitamin	0,50	16,66	0,00	0,34	17,00	1,00
40	Soffiatrice 2	20042306	Bottiglia 0,75 lt Elite 1881 2011	0,75	33,50	0,00	0,00	33,50	1,00
41	Sipa 16A	20042315	Bottiglia 1,5 lt Bibite 2011	1,50	33,40	0,00	0,00	33,40	0,50
42	Sipa 16B	20042315	Bottiglia 1,5 lt Bibite 2011	1,50	33,40	0,00	0,00	33,40	0,50
43	Sipa 16A	20042316	Bottiglia 1,5 lt Bibite Arancio 2011	1,50	33,37	0,00	0,03	33,40	0,51
44	Sipa 16B	20042316	Bottiglia 1,5 lt Bibite Arancio 2011	1,50	33,37	0,00	0,03	33,40	0,49
45	Sipa 24A	20042320	Bottiglia 1,5 Bibite Guizza Arancio 2012	1,50	31,17	0,00	0,03	31,20	0,35
46	Sipa 24B	20042320	Bottiglia 1,5 Bibite Guizza Arancio 2012	1,50	31,17	0,00	0,03	31,20	0,33
47	Sipa 27A	20042320	Bottiglia 1,5 Bibite Guizza Arancio 2012	1,50	31,17	0,00	0,03	31,20	0,10
48	Sipa 27B	20042320	Bottiglia 1,5 Bibite Guizza Arancio 2012	1,50	31,17	0,00	0,03	31,20	0,10

Production_Bottles | **Bottles_design_specifications** | Scarti_pezzi | Produzione_litri | Scarti_litri | Produzione_massa | Scarti_massa | Presse | Pr ...

Figure 90 EID_SB_Production_mapping interface (Bottles production machineries – Part 2)

3.2.1.2.3.4. Inventory data collection – EID_SB_Energy_mapping

This EID interface permits to map all the energy consumptions for every process that occurred in the productive site and every product realized. All relevant energy vectors are assessed such as electricity, natural gas, etc. The energy consumptions have been divided in direct energy consumptions, when the consumption is directly measured at level of a bottling line or of a bottle production machinery, and in indirect energy consumptions, when the consumptions occur at level of equipment that carry out auxiliary services (e.g. air compressors, chillers, etc.). The interface maps every energy consumption type according to the detail level of the measures. The energy mapping at product and process level is usually a challenge because the indirect energy consumptions must be allocated to different products and processes. The allocation has often based on physical relationships. Normally these physical relationships are related to quantitative allocation in function of considerations on mass or on number of units produced according to ISO14044. However, this method shows limits because the allocation procedure results too simplified. Considering as example the electricity consumed by the chillers (7°C), the value is measured by an energy monitor software. This energy is consumed in the site for different processes such as: bottling processes, bottles and preforms production processes. A classic allocation, according to ISO14040, based on considerations on mass or number of units cannot allocate the correct consumptions to the different processes. In fact, the consumptions of the processes are intrinsically different and with a classic allocation, relevant errors of allocation of resource consumptions can be made between different processes and different products (Manzardo et al., 2015). For this reason, according to the method shown in chapter 2, regarding the development of EID, specific transfer rules have been developed to cross this allocation issue emerged.

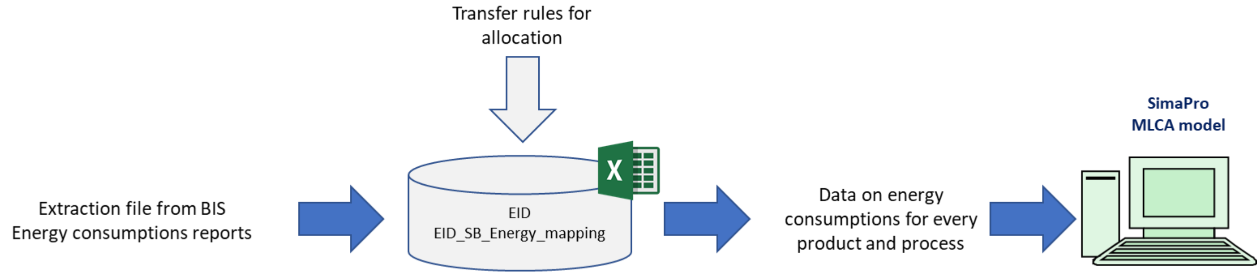


Figure 91 Simplified flowchart of EID_SB_Energy_mapping

<u>Example of transfer rule – indirect electricity allocation for preforms production:</u>

A big challenge during site data collection was related to the processes and machineries shared with products under the responsibility of the other two divisions located in the site understudy (Martinez-Blanco et al., 2016). In fact, especially in the case of indirect electricity consumption of utilities that serve a large quantity of different productive processes, no measures of specific consumption of the different machineries are available. In this context generally, the procedure of allocation is applied according to ISO14040-44 on the base of physical relationship between the outputs. Often this relationship provides the simply relationship on the base of the physical mass. Considering the case of the preforms production, the press consumes indirect electricity due to the consumptions of compressed air and of cold water (7°C) for cooling the molds. These types of consumptions are shared with bottle production processes in the same department. In this case in general the simply allocation on the base of the mass worked by machineries is used. However, this approach can conduct to significant estimation errors, overestimating or underestimating the indirect energy consumptions for the production of preforms. In this context, the transfer rules have been introduced in order to improve the allocation procedure. The transfer rules are structured mathematical relationships that on the base of technical and technological considerations permit to transfer a consumption to a specific process, machinery or product. This approach responds to the suggestion of Martinez-Blanco et al. (2016) of to build “engineering models” to avoid allocation. The technical considerations can be based on considerations provides by person skilled on the specific process understudy, while the technologic considerations can derive from technical specifications from the machinery manufactured. In the present case information provided by the company that have manufactured the press have been used to develop specific transfer rules for the two press machineries present in the productive site of Scorzè regarding the consumption of cold water (7°C) and the consumption of compressed air (10 bar).

Preform press	Specification on compressed air (10 bar) consumption (α)	Cooling requiremen (c)t	Machinery productive mass speed (v)
	Nm3/h	kWht/h	kg/h
Press 75 (PPS300)	80	203	255
Press 74 (XFORM)	100	305	782

Table 39 List of technical specification of the two press for the preforms production

Considering the primary data on the electricity consumption for the production of 1 Nm3 of air compressed (10 bar) of 0,169 kWh/Nm3 ($E_{Air\ 10\ bar\ spec}$) and the EER value (4,0 for 2016) the following transfer rules have been defined:

$$E_{Air\ 10bar\ press} = E_{Air\ 10\ bar\ spec} \cdot \alpha \cdot \frac{1}{v} \quad [3.1]$$

$$E_{Cool\ 7°C\ press} = \frac{1}{EER_{Chillers\ 7°C}} \cdot c \cdot \frac{1}{v} \quad [3.2]$$

These are two example of transfer rules implemented in the EID interfaces in order to improve the data allocation and the application of the best available and detailed information on processes and technologies. The results shown in the table below summarize the different between the traditional allocation method and the method proposed based on transfer rules.

Preform press	Indirect electricity consumptions Traditional allocation method	Indirect electricity consumptions Transfer rules	Delta %
	kWh/1000 preforms	kWh/1000 preforms	
Press 75 (PPS300)	16,7	10,2	-39%
Press 74 (XFORM)	16,7	7,5	-55%

Table 40 Comparison between traditional allocation of indirect electricity consumptions and the results applied transfer rules.

As it is possible to notice by the results provided by the previously table, the traditional allocation generated a great overestimation of the consumptions. Therefore, the developed and implementation of the transfer rules have improved the precision and the electricity consumption attribution.

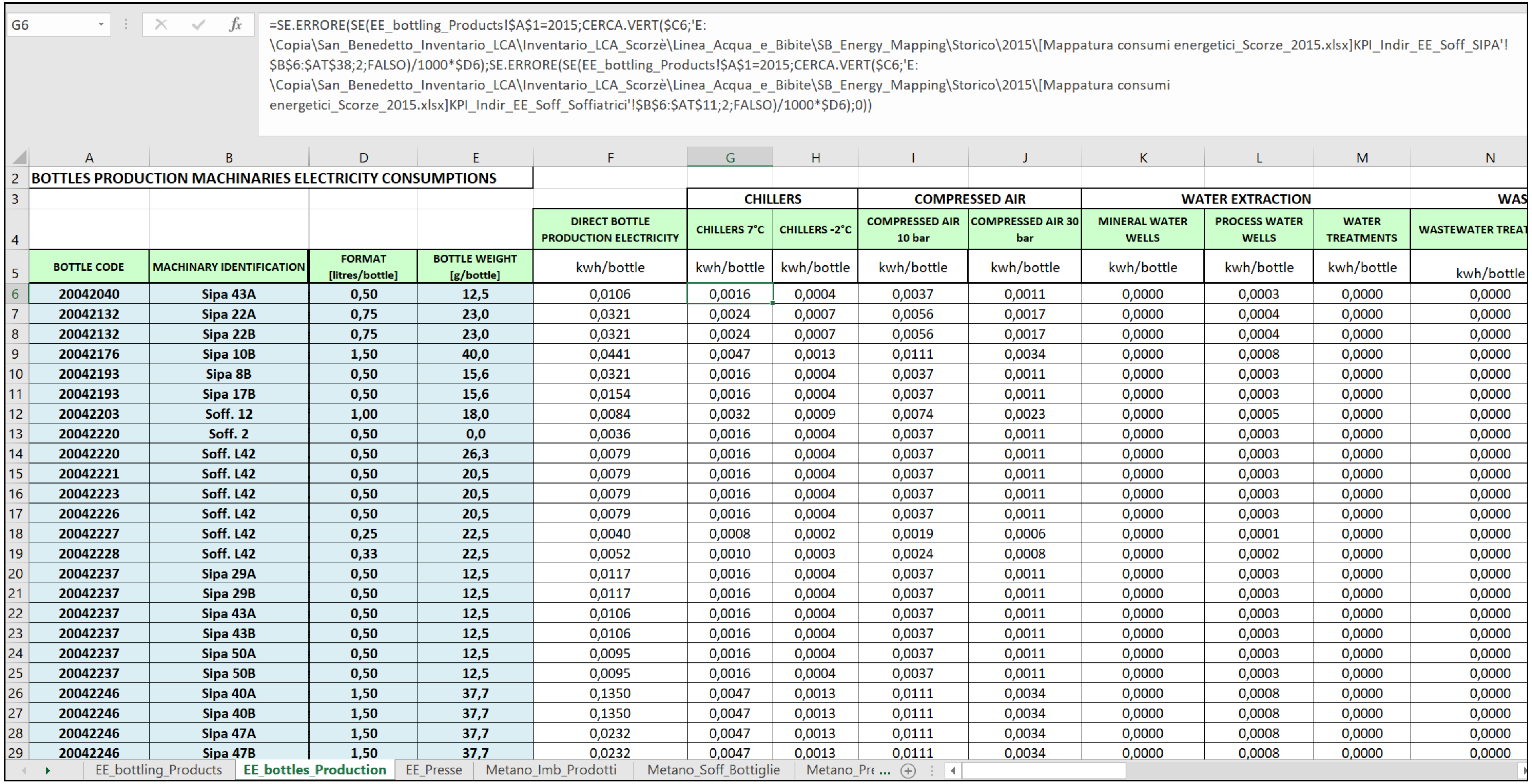
F6 =SE.ERRORE(SE(E($A$1=2015;SINISTRA($D6;2)="AC";F$4="Trattamenti acqua");0;SE(E($A$1=2015;SINISTRA($D6;2)="AC";F$4="Sala sciroppi, zuccheri e infusione");0;SE($A$1=2015;CERCA.VERT($B6;'E:\Copia\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Acqua_e_Bibite\SB_Energy_Mapping\Storico\2015\[Mappatura consumi energetici_Scorze_2015.xlsx]KPI_Indir_EE_Imb_Linee'!$A$6:$W$28;2;FALSO)/1000*$C6)));0)

BOTTLING LINES ELECTRICITY CONSUMPTIONS

					CHILLERS		COMPRESSED AIR		WATER EXTRACTION			WASTE MANAGEMENT	HOT UTILITIES	LIGHTING AND CON
				DIRECT BOTTLING LINE ELECTRICITY	CHILLERS 7°C	CHILLERS -2°C	COMPRESSED AIR 10 bar	COMPRESSED AIR 30 bar	MINERAL WATER WELLS	PROCESS WATER WELLS	WATER TREATMENTS	WASTEWATER TREATMENT	THERMAL POWER UNITS	LIGHTING AND CONDITIONING
PRODUCT	BOTTLING LINE	FORMAT	Tipologia prodotto	kwh/bottle	kwh/bottle	kwh/bottle	kwh/bottle	kwh/bottle	kwh/bottle	kwh/bottle	kwh/bottle	kwh/bottle	kwh/bottle	kwh / pezzo
1013	31	1	BIBITA	0,0146	0,0054	0,0015	0,0019	0,0000	0,0007	0,0003	0,0005	0,0060	0,0024	0,0016
1014	31	1	BIBITA	0,0146	0,0054	0,0015	0,0019	0,0000	0,0007	0,0003	0,0005	0,0060	0,0024	0,0016
1015	31	1	BIBITA	0,0146	0,0054	0,0015	0,0019	0,0000	0,0007	0,0003	0,0005	0,0060	0,0024	0,0016
1016	31	1	BIBITA	0,0146	0,0054	0,0015	0,0019	0,0000	0,0007	0,0003	0,0005	0,0060	0,0024	0,0016
1020	31	0,75	ACQUA SAN BENEDETTO	0,0109	0,0040	0,0011	0,0015	0,0000	0,0006	0,0002	0,0000	0,0045	0,0018	0,0012
1021	31	0,75	ACQUA SAN BENEDETTO	0,0109	0,0040	0,0011	0,0015	0,0000	0,0006	0,0002	0,0000	0,0045	0,0018	0,0012
1022	31	0,75	ACQUA SAN BENEDETTO	0,0109	0,0040	0,0011	0,0015	0,0000	0,0006	0,0002	0,0000	0,0045	0,0018	0,0012
1023	31	0,75	ACQUA SAN BENEDETTO	0,0109	0,0040	0,0011	0,0015	0,0000	0,0006	0,0002	0,0000	0,0045	0,0018	0,0012
1024	31	0,75	ACQUA SAN BENEDETTO	0,0109	0,0040	0,0011	0,0015	0,0000	0,0006	0,0002	0,0000	0,0045	0,0018	0,0012
1043	31	1	ACQUA SAN BENEDETTO	0,0146	0,0054	0,0015	0,0019	0,0000	0,0007	0,0003	0,0000	0,0060	0,0024	0,0016
1044	31	1	ACQUA SAN BENEDETTO	0,0146	0,0054	0,0015	0,0019	0,0000	0,0007	0,0003	0,0000	0,0060	0,0024	0,0016
1045	31	1	ACQUA SAN BENEDETTO	0,0146	0,0054	0,0015	0,0019	0,0000	0,0007	0,0003	0,0000	0,0060	0,0024	0,0016
1046	31	1	ACQUA SAN BENEDETTO	0,0146	0,0054	0,0015	0,0019	0,0000	0,0007	0,0003	0,0000	0,0060	0,0024	0,0016
1047	31	1	ACQUA SAN BENEDETTO	0,0146	0,0054	0,0015	0,0019	0,0000	0,0007	0,0003	0,0000	0,0060	0,0024	0,0016
1050	31	0,5	ACQUA SAN BENEDETTO	0,0073	0,0027	0,0008	0,0010	0,0000	0,0004	0,0002	0,0000	0,0030	0,0012	0,0008
1051	31	0,5	ACQUA SAN BENEDETTO	0,0073	0,0027	0,0008	0,0010	0,0000	0,0004	0,0002	0,0000	0,0030	0,0012	0,0008
1070	31	0,5	ACQUA SAN BENEDETTO	0,0073	0,0027	0,0008	0,0010	0,0000	0,0004	0,0002	0,0000	0,0030	0,0012	0,0008
1071	31	0,5	ACQUA SAN BENEDETTO	0,0073	0,0027	0,0008	0,0010	0,0000	0,0004	0,0002	0,0000	0,0030	0,0012	0,0008
1074	31	1	BIBITA	0,0146	0,0054	0,0015	0,0019	0,0000	0,0007	0,0003	0,0005	0,0060	0,0024	0,0016
1076	31	1	BIBITA	0,0146	0,0054	0,0015	0,0019	0,0000	0,0007	0,0003	0,0005	0,0060	0,0024	0,0016
1077	31	1	BIBITA	0,0146	0,0054	0,0015	0,0019	0,0000	0,0007	0,0003	0,0005	0,0060	0,0024	0,0016
1078	31	1	BIBITA	0,0146	0,0054	0,0015	0,0019	0,0000	0,0007	0,0003	0,0005	0,0060	0,0024	0,0016
1079	31	1	BIBITA	0,0146	0,0054	0,0015	0,0019	0,0000	0,0007	0,0003	0,0005	0,0060	0,0024	0,0016
1080	31	1	BIBITA	0,0146	0,0054	0,0015	0,0019	0,0000	0,0007	0,0003	0,0005	0,0060	0,0024	0,0016
1187	31	0,25	BIBITA	0,0036	0,0013	0,0004	0,0005	0,0000	0,0002	0,0001	0,0001	0,0015	0,0006	0,0004
1188	31	0,25	BIBITA	0,0036	0,0013	0,0004	0,0005	0,0000	0,0002	0,0001	0,0001	0,0015	0,0006	0,0004
1189	31	0,25	BIBITA	0,0036	0,0013	0,0004	0,0005	0,0000	0,0002	0,0001	0,0001	0,0015	0,0006	0,0004
1190	31	0,25	BIBITA	0,0036	0,0013	0,0004	0,0005	0,0000	0,0002	0,0001	0,0001	0,0015	0,0006	0,0004
1981	31	0,25	ACQUA SAN BENEDETTO	0,0036	0,0013	0,0004	0,0005	0,0000	0,0002	0,0001	0,0000	0,0015	0,0006	0,0004
1982	31	0,25	ACQUA SAN BENEDETTO	0,0036	0,0013	0,0004	0,0005	0,0000	0,0002	0,0001	0,0000	0,0015	0,0006	0,0004
5122	31	1	BIBITA	0,0146	0,0054	0,0015	0,0019	0,0000	0,0007	0,0003	0,0005	0,0060	0,0024	0,0016
7027	31	0,25	ACQUA SAN BENEDETTO	0,0036	0,0013	0,0004	0,0005	0,0000	0,0002	0,0001	0,0000	0,0015	0,0006	0,0004
7028	31	0,5	ACQUA SAN BENEDETTO	0,0073	0,0027	0,0008	0,0010	0,0000	0,0004	0,0002	0,0000	0,0030	0,0012	0,0008
7029	31	0,5	ACQUA SAN BENEDETTO	0,0073	0,0027	0,0008	0,0010	0,0000	0,0004	0,0002	0,0000	0,0030	0,0012	0,0008

EE_bottling_Products | EE_bottles_Production | EE_Presse | Metano_Imb_Prodotti | Metano_Soff_Bottiglie | Metano_Pr ...

Figure 92 EID_SB_Energy_mapping interface (Bottles production machineries – Part 1)



G6 =SE.ERRORE(SE(EE_bottling_Products!$A$1=2015;CERCA.VERT($C6;'E:\Copia\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Acqua_e_Bibite\SB_Energy_Mapping\Storico\2015\[Mappatura consumi energetici_Scorze_2015.xlsx]KPI_Indir_EE_Soff_SIPA'!$B$6:$AT$38;2;FALSO)/1000*$D6);SE.ERRORE(SE(EE_bottling_Products!$A$1=2015;CERCA.VERT($C6;'E:\Copia\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Acqua_e_Bibite\SB_Energy_Mapping\Storico\2015\[Mappatura consumi energetici_Scorze_2015.xlsx]KPI_Indir_EE_Soff_Soffiatrici'!$B$6:$AT$11;2;FALSO)/1000*$D6);0))

BOTTLES PRODUCTION MACHINARIES ELECTRICITY CONSUMPTIONS

					CHILLERS		COMPRESSED AIR		WATER EXTRACTION			WAS
				DIRECT BOTTLE PRODUCTION ELECTRICITY	CHILLERS 7°C	CHILLERS -2°C	COMPRESSED AIR 10 bar	COMPRESSED AIR 30 bar	MINERAL WATER WELLS	PROCESS WATER WELLS	WATER TREATMENTS	WASTEWATER TREAT
BOTTLE CODE	MACHINARY IDENTIFICATION	FORMAT [litres/bottle]	BOTTLE WEIGHT [g/bottle]	kwh/bottle	kwh/bottle	kwh/bottle	kwh/bottle	kwh/bottle	kwh/bottle	kwh/bottle	kwh/bottle	kwh/bottle
20042040	Sipa 43A	0,50	12,5	0,0106	0,0016	0,0004	0,0037	0,0011	0,0000	0,0003	0,0000	0,0000
20042132	Sipa 22A	0,75	23,0	0,0321	0,0024	0,0007	0,0056	0,0017	0,0000	0,0004	0,0000	0,0000
20042132	Sipa 22B	0,75	23,0	0,0321	0,0024	0,0007	0,0056	0,0017	0,0000	0,0004	0,0000	0,0000
20042176	Sipa 10B	1,50	40,0	0,0441	0,0047	0,0013	0,0111	0,0034	0,0000	0,0008	0,0000	0,0000
20042193	Sipa 8B	0,50	15,6	0,0321	0,0016	0,0004	0,0037	0,0011	0,0000	0,0003	0,0000	0,0000
20042193	Sipa 17B	0,50	15,6	0,0154	0,0016	0,0004	0,0037	0,0011	0,0000	0,0003	0,0000	0,0000
20042203	Soff. 12	1,00	18,0	0,0084	0,0032	0,0009	0,0074	0,0023	0,0000	0,0005	0,0000	0,0000
20042220	Soff. 2	0,50	0,0	0,0036	0,0016	0,0004	0,0037	0,0011	0,0000	0,0003	0,0000	0,0000
20042220	Soff. L42	0,50	26,3	0,0079	0,0016	0,0004	0,0037	0,0011	0,0000	0,0003	0,0000	0,0000
20042221	Soff. L42	0,50	20,5	0,0079	0,0016	0,0004	0,0037	0,0011	0,0000	0,0003	0,0000	0,0000
20042223	Soff. L42	0,50	20,5	0,0079	0,0016	0,0004	0,0037	0,0011	0,0000	0,0003	0,0000	0,0000
20042226	Soff. L42	0,50	20,5	0,0079	0,0016	0,0004	0,0037	0,0011	0,0000	0,0003	0,0000	0,0000
20042227	Soff. L42	0,25	22,5	0,0040	0,0008	0,0002	0,0019	0,0006	0,0000	0,0001	0,0000	0,0000
20042228	Soff. L42	0,33	22,5	0,0052	0,0010	0,0003	0,0024	0,0008	0,0000	0,0002	0,0000	0,0000
20042237	Sipa 29A	0,50	12,5	0,0117	0,0016	0,0004	0,0037	0,0011	0,0000	0,0003	0,0000	0,0000
20042237	Sipa 29B	0,50	12,5	0,0117	0,0016	0,0004	0,0037	0,0011	0,0000	0,0003	0,0000	0,0000
20042237	Sipa 43A	0,50	12,5	0,0106	0,0016	0,0004	0,0037	0,0011	0,0000	0,0003	0,0000	0,0000
20042237	Sipa 43B	0,50	12,5	0,0106	0,0016	0,0004	0,0037	0,0011	0,0000	0,0003	0,0000	0,0000
20042237	Sipa 50A	0,50	12,5	0,0095	0,0016	0,0004	0,0037	0,0011	0,0000	0,0003	0,0000	0,0000
20042237	Sipa 50B	0,50	12,5	0,0095	0,0016	0,0004	0,0037	0,0011	0,0000	0,0003	0,0000	0,0000
20042246	Sipa 40A	1,50	37,7	0,1350	0,0047	0,0013	0,0111	0,0034	0,0000	0,0008	0,0000	0,0000
20042246	Sipa 40B	1,50	37,7	0,1350	0,0047	0,0013	0,0111	0,0034	0,0000	0,0008	0,0000	0,0000
20042246	Sipa 47A	1,50	37,7	0,0232	0,0047	0,0013	0,0111	0,0034	0,0000	0,0008	0,0000	0,0000
20042246	Sipa 47B	1,50	37,7	0,0232	0,0047	0,0013	0,0111	0,0034	0,0000	0,0008	0,0000	0,0000

EE_bottling_Products | EE_bottles_Production | EE_Presse | Metano_Imb_Prodotti | Metano_Soff_Bottiglie | Metano_Pr ...

Figure 93 EID_SB_Energy_mapping interface (Bottles production machineries – Part 2)

3.2.1.2.3.5. Inventory data collection – EID_SB_Environmental_service_mapping

This EID interface permits to map all the wastes generated by the productive sites. The interface acquires data from MUD electronic report. Every waste is distinguished in function of the CER code and in function of specific destination. The destination has been assessed in order to evaluate the transport distance travelled and the disposal scenario. For many wastes the disposal scenario is known and reported in the MUD report but for a part of wastes the disposal scenario is unknown and in this case statistical data on disposal scenarios have been used in function of the destination (e.g ISPRA disposal scenarios differentiated for every Italian region).

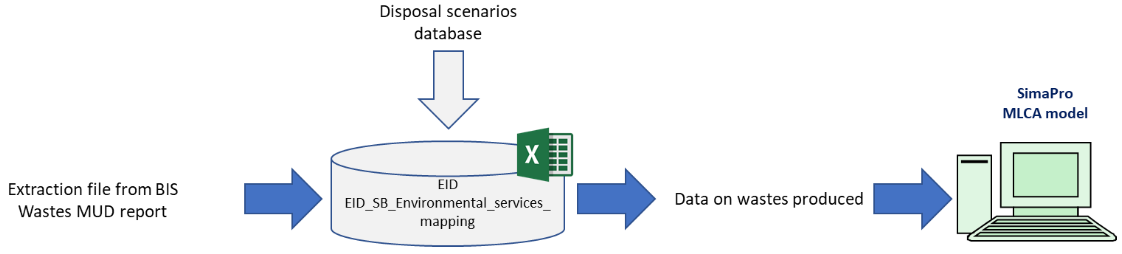


Figure 94 Simplified flowchart of EID_SB_Environmental_services_mapping

In this case, no transfer rules have been defined and the traditional allocation has been applied. The allocation of wastes masses on products has been conducted considering the volume bottled for every product. This interface maps also the wastewater flows in input to wastewater treatment plant and the volume of treated wastewater discharged.

3.2.1.2.3.6. Inventory data collection – EID_SB_Chemicals_mapping

This EID interface permits to map all the chemical consumptions and to associate the consumptions to specific processes and therefore to specific products. The interface acquires data of consumptions by the informatic database where are registered all the stock variations. In this case a specific transfer rule has been introduced according with the method descripted in the chapter 2. The transfer rule is based in a Boolean matrix that define if a specific bottling line consume or not the specific chemical compounds. In order to establish the Boolean matrix has been performed an association analysis of every chemical compound with every bottling process. Once defined the Boolean matrix considering all chemical compounds, traditional allocation rules, on the base of the total volume bottled from each bottling line, have been applied in order to identify the chemical consumption for each product. In this way, different products realized in the same bottling line obtain the same consumption in have the same format.

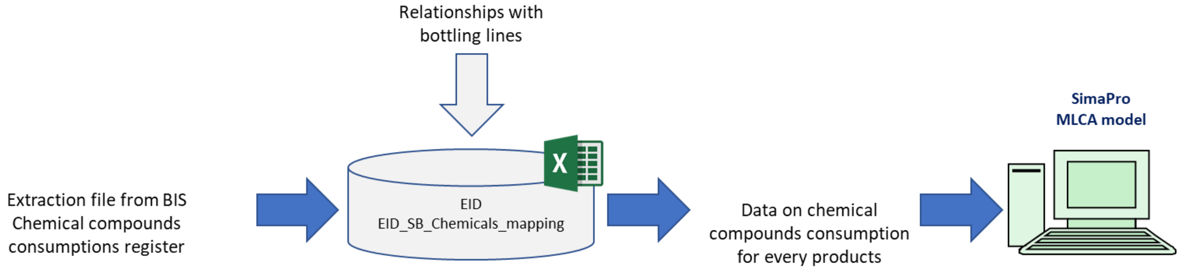
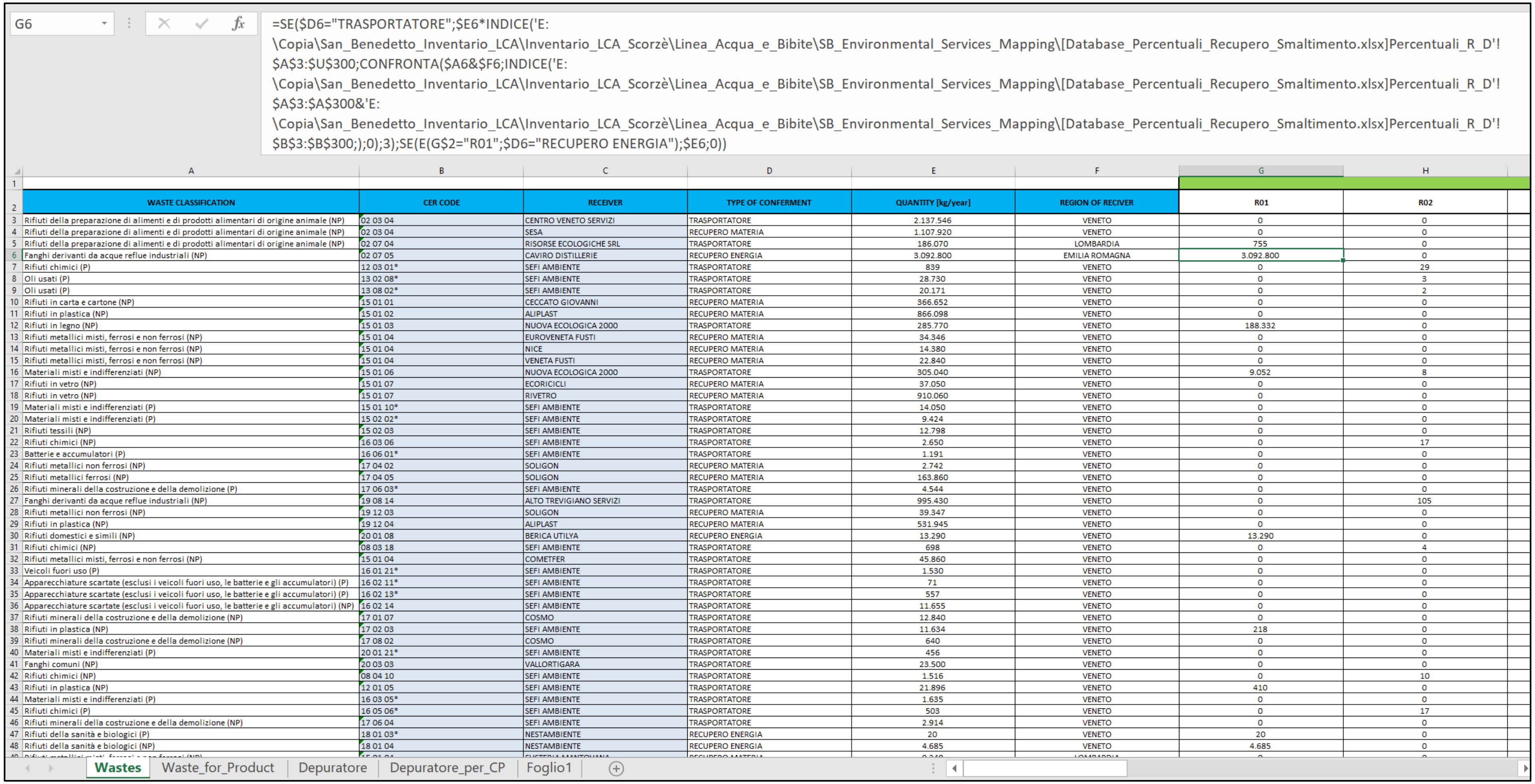


Figure 95 Simplified flowchart of EID_SB_Chemicals_mapping



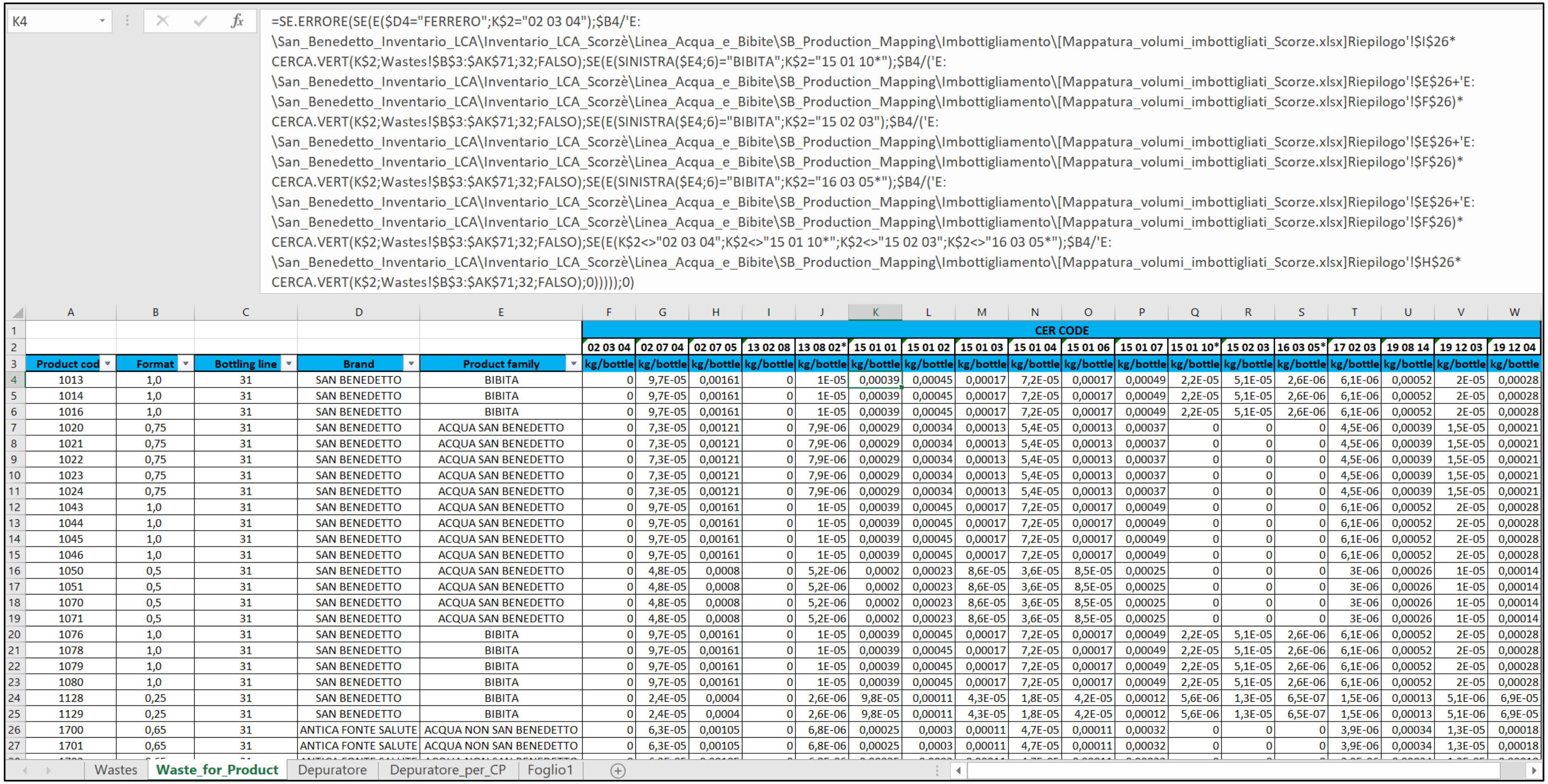
G6

=SE($D6="TRASPORTATORE";$E6*INDICE('E:\Copia\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Acqua_e_Bibite\SB_Environmental_Services_Mapping\[Database_Percentuali_Recupero_Smaltimento.xlsx]Percentuali_R_D'!$A$3:$U$300;CONFRONTA($A6&$F6;INDICE('E:\Copia\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Acqua_e_Bibite\SB_Environmental_Services_Mapping\[Database_Percentuali_Recupero_Smaltimento.xlsx]Percentuali_R_D'!$A$3:$A$300&'E:\Copia\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Acqua_e_Bibite\SB_Environmental_Services_Mapping\[Database_Percentuali_Recupero_Smaltimento.xlsx]Percentuali_R_D'!$B$3:$B$300;);0);3);SE(E(G$2="R01";$D6="RECUPERO ENERGIA");$E6;0))

	A	B	C	D	E	F	G	H
2	WASTE CLASSIFICATION	CER CODE	RECEIVER	TYPE OF CONFERMENT	QUANTITY [kg/year]	REGION OF RECIVER	R01	R02
3	Rifiuti della preparazione di alimenti e di prodotti alimentari di origine animale (NP)	02 03 04	CENTRO VENETO SERVIZI	TRASPORTATORE	2.137.546	VENETO	0	0
4	Rifiuti della preparazione di alimenti e di prodotti alimentari di origine animale (NP)	02 03 04	SESA	RECUPERO MATERIA	1.107.920	VENETO	0	0
5	Rifiuti della preparazione di alimenti e di prodotti alimentari di origine animale (NP)	02 07 04	RISORSE ECOLOGICHE SRL	TRASPORTATORE	186.070	LOMBARDIA	755	0
6	Fanghi derivanti da acque reflue industriali (NP)	02 07 05	CAVIRO DISTILLERIE	RECUPERO ENERGIA	3.092.800	EMILIA ROMAGNA	3.092.800	0
7	Rifiuti chimici (P)	12 03 01*	SEFI AMBIENTE	TRASPORTATORE	839	VENETO	0	29
8	Oli usati (P)	13 02 08*	SEFI AMBIENTE	TRASPORTATORE	28.730	VENETO	0	3
9	Oli usati (P)	13 08 02*	SEFI AMBIENTE	TRASPORTATORE	20.171	VENETO	0	2
10	Rifiuti in carta e cartone (NP)	15 01 01	CECCATO GIOVANNI	RECUPERO MATERIA	366.652	VENETO	0	0
11	Rifiuti in plastica (NP)	15 01 02	ALIPLAST	RECUPERO MATERIA	866.098	VENETO	0	0
12	Rifiuti in legno (NP)	15 01 03	NUOVA ECOLOGICA 2000	TRASPORTATORE	285.770	VENETO	188.332	0
13	Rifiuti metallici misti, ferrosi e non ferrosi (NP)	15 01 04	EUROVENETA FUSTI	RECUPERO MATERIA	34.346	VENETO	0	0
14	Rifiuti metallici misti, ferrosi e non ferrosi (NP)	15 01 04	NICE	RECUPERO MATERIA	14.380	VENETO	0	0
15	Rifiuti metallici misti, ferrosi e non ferrosi (NP)	15 01 04	VENETA FUSTI	RECUPERO MATERIA	22.840	VENETO	0	0
16	Materiali misti e indifferenziati (NP)	15 01 06	NUOVA ECOLOGICA 2000	TRASPORTATORE	305.040	VENETO	9.052	8
17	Rifiuti in vetro (NP)	15 01 07	ECORICICLI	RECUPERO MATERIA	37.050	VENETO	0	0
18	Rifiuti in vetro (NP)	15 01 07	RIVETRO	RECUPERO MATERIA	910.060	VENETO	0	0
19	Materiali misti e indifferenziati (P)	15 01 10*	SEFI AMBIENTE	TRASPORTATORE	14.050	VENETO	0	0
20	Materiali misti e indifferenziati (P)	15 02 02*	SEFI AMBIENTE	TRASPORTATORE	9.424	VENETO	0	0
21	Rifiuti tessili (NP)	15 02 03	SEFI AMBIENTE	TRASPORTATORE	12.798	VENETO	0	0
22	Rifiuti chimici (NP)	16 03 06	SEFI AMBIENTE	TRASPORTATORE	2.650	VENETO	0	17
23	Batterie e accumulatori (P)	16 06 01*	SEFI AMBIENTE	TRASPORTATORE	1.191	VENETO	0	0
24	Rifiuti metallici non ferrosi (NP)	17 04 02	SOLIGON	RECUPERO MATERIA	2.742	VENETO	0	0
25	Rifiuti metallici ferrosi (NP)	17 04 05	SOLIGON	RECUPERO MATERIA	163.860	VENETO	0	0
26	Rifiuti minerali della costruzione e della demolizione (P)	17 06 03*	SEFI AMBIENTE	TRASPORTATORE	4.544	VENETO	0	0
27	Fanghi derivanti da acque reflue industriali (NP)	19 08 14	ALTO TREVIGIANO SERVIZI	TRASPORTATORE	995.430	VENETO	0	105
28	Rifiuti metallici non ferrosi (NP)	19 12 03	SOLIGON	RECUPERO MATERIA	39.347	VENETO	0	0
29	Rifiuti in plastica (NP)	19 12 04	ALIPLAST	RECUPERO MATERIA	531.945	VENETO	0	0
30	Rifiuti domestici e simili (NP)	20 01 08	BERICA UTILYA	RECUPERO ENERGIA	13.290	VENETO	13.290	0
31	Rifiuti chimici (NP)	08 03 18	SEFI AMBIENTE	TRASPORTATORE	698	VENETO	0	4
32	Rifiuti metallici misti, ferrosi e non ferrosi (NP)	15 01 04	COMETFER	TRASPORTATORE	45.860	VENETO	0	0
33	Veicoli fuori uso (P)	16 01 21*	SEFI AMBIENTE	TRASPORTATORE	1.530	VENETO	0	0
34	Apparecchiature scartate (esclusi i veicoli fuori uso, le batterie e gli accumulatori) (P)	16 02 11*	SEFI AMBIENTE	TRASPORTATORE	71	VENETO	0	0
35	Apparecchiature scartate (esclusi i veicoli fuori uso, le batterie e gli accumulatori) (P)	16 02 13*	SEFI AMBIENTE	TRASPORTATORE	557	VENETO	0	0
36	Apparecchiature scartate (esclusi i veicoli fuori uso, le batterie e gli accumulatori) (NP)	16 02 14	SEFI AMBIENTE	TRASPORTATORE	11.655	VENETO	0	0
37	Rifiuti minerali della costruzione e della demolizione (NP)	17 01 07	COSMO	TRASPORTATORE	12.840	VENETO	0	0
38	Rifiuti in plastica (NP)	17 02 03	SEFI AMBIENTE	TRASPORTATORE	11.634	VENETO	218	0
39	Rifiuti minerali della costruzione e della demolizione (NP)	17 08 02	COSMO	TRASPORTATORE	640	VENETO	0	0
40	Materiali misti e indifferenziati (P)	20 01 21*	SEFI AMBIENTE	TRASPORTATORE	456	VENETO	0	0
41	Fanghi comuni (NP)	20 03 03	VALLORTIGARA	TRASPORTATORE	23.500	VENETO	0	0
42	Rifiuti chimici (NP)	08 04 10	SEFI AMBIENTE	TRASPORTATORE	1.516	VENETO	0	10
43	Rifiuti in plastica (NP)	12 01 05	SEFI AMBIENTE	TRASPORTATORE	21.896	VENETO	410	0
44	Materiali misti e indifferenziati (P)	16 03 05*	SEFI AMBIENTE	TRASPORTATORE	1.635	VENETO	0	0
45	Rifiuti chimici (P)	16 05 06*	SEFI AMBIENTE	TRASPORTATORE	503	VENETO	0	17
46	Rifiuti minerali della costruzione e della demolizione (NP)	17 06 04	SEFI AMBIENTE	TRASPORTATORE	2.914	VENETO	0	0
47	Rifiuti della sanità e biologici (P)	18 01 03*	NESTAMBIENTE	RECUPERO ENERGIA	20	VENETO	20	0
48	Rifiuti della sanità e biologici (NP)	18 01 04	NESTAMBIENTE	RECUPERO ENERGIA	4.685	VENETO	4.685	0

Wastes | Waste_for_Product | Depuratore | Depuratore_per_CP | Foglio1

Figure 96 EID_SB_ Environmental_service_mapping interface (Wastes management scenarios – Part 1)



K4

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CERCA.VERT(K$2;Wastes!$B$3:$AK$71;32;FALSO);SE(E(SINISTRA($E4;6)="BIBITA";K$2="15 01 10*");$B4/('E:
\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Acqua_e_Bibite\SB_Production_Mapping\Imbottigliamento\[Mappatura_volumi_imbottigliati_Scorze.xlsx]Riepilogo'!$E$26+'E:
\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Acqua_e_Bibite\SB_Production_Mapping\Imbottigliamento\[Mappatura_volumi_imbottigliati_Scorze.xlsx]Riepilogo'!$F$26)*
CERCA.VERT(K$2;Wastes!$B$3:$AK$71;32;FALSO);SE(E(SINISTRA($E4;6)="BIBITA";K$2="15 02 03");$B4/('E:
\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Acqua_e_Bibite\SB_Production_Mapping\Imbottigliamento\[Mappatura_volumi_imbottigliati_Scorze.xlsx]Riepilogo'!$E$26+'E:
\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Acqua_e_Bibite\SB_Production_Mapping\Imbottigliamento\[Mappatura_volumi_imbottigliati_Scorze.xlsx]Riepilogo'!$F$26)*
CERCA.VERT(K$2;Wastes!$B$3:$AK$71;32;FALSO);SE(E(SINISTRA($E4;6)="BIBITA";K$2="16 03 05*");$B4/('E:
\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Acqua_e_Bibite\SB_Production_Mapping\Imbottigliamento\[Mappatura_volumi_imbottigliati_Scorze.xlsx]Riepilogo'!$E$26+'E:
\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Acqua_e_Bibite\SB_Production_Mapping\Imbottigliamento\[Mappatura_volumi_imbottigliati_Scorze.xlsx]Riepilogo'!$F$26)*
CERCA.VERT(K$2;Wastes!$B$3:$AK$71;32;FALSO);SE(E(K$2<>"02 03 04";K$2<>"15 01 10*";K$2<>"15 02 03";K$2<>"16 03 05*");$B4/'E:
\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Acqua_e_Bibite\SB_Production_Mapping\Imbottigliamento\[Mappatura_volumi_imbottigliati_Scorze.xlsx]Riepilogo'!$H$26*
CERCA.VERT(K$2;Wastes!$B$3:$AK$71;32;FALSO);0)))));0)
```

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
1						CER CODE																	
2						02 03 04	02 07 04	02 07 05	13 02 08	13 08 02*	15 01 01	15 01 02	15 01 03	15 01 04	15 01 06	15 01 07	15 01 10*	15 02 03	16 03 05*	17 02 03	19 08 14	19 12 03	19 12 04
3	Product cod	Format	Bottling line	Brand	Product family	kg/bottle	kg/bottle	kg/bottle	kg/bottle	kg/bottle	kg/bottle	kg/bottle	kg/bottle	kg/bottle	kg/bottle	kg/bottle	kg/bottle	kg/bottle	kg/bottle	kg/bottle	kg/bottle	kg/bottle	kg/bottle
4	1013	1,0	31	SAN BENEDETTO	BIBITA	0	9,7E-05	0,00161	0	1E-05	0,00039	0,00045	0,00017	7,2E-05	0,00017	0,00049	2,2E-05	5,1E-05	2,6E-06	6,1E-06	0,00052	2E-05	0,00028
5	1014	1,0	31	SAN BENEDETTO	BIBITA	0	9,7E-05	0,00161	0	1E-05	0,00039	0,00045	0,00017	7,2E-05	0,00017	0,00049	2,2E-05	5,1E-05	2,6E-06	6,1E-06	0,00052	2E-05	0,00028
6	1016	1,0	31	SAN BENEDETTO	BIBITA	0	9,7E-05	0,00161	0	1E-05	0,00039	0,00045	0,00017	7,2E-05	0,00017	0,00049	2,2E-05	5,1E-05	2,6E-06	6,1E-06	0,00052	2E-05	0,00028
7	1020	0,75	31	SAN BENEDETTO	ACQUA SAN BENEDETTO	0	7,3E-05	0,00121	0	7,9E-06	0,00029	0,00034	0,00013	5,4E-05	0,00013	0,00037	0	0	0	4,5E-06	0,00039	1,5E-05	0,00021
8	1021	0,75	31	SAN BENEDETTO	ACQUA SAN BENEDETTO	0	7,3E-05	0,00121	0	7,9E-06	0,00029	0,00034	0,00013	5,4E-05	0,00013	0,00037	0	0	0	4,5E-06	0,00039	1,5E-05	0,00021
9	1022	0,75	31	SAN BENEDETTO	ACQUA SAN BENEDETTO	0	7,3E-05	0,00121	0	7,9E-06	0,00029	0,00034	0,00013	5,4E-05	0,00013	0,00037	0	0	0	4,5E-06	0,00039	1,5E-05	0,00021
10	1023	0,75	31	SAN BENEDETTO	ACQUA SAN BENEDETTO	0	7,3E-05	0,00121	0	7,9E-06	0,00029	0,00034	0,00013	5,4E-05	0,00013	0,00037	0	0	0	4,5E-06	0,00039	1,5E-05	0,00021
11	1024	0,75	31	SAN BENEDETTO	ACQUA SAN BENEDETTO	0	7,3E-05	0,00121	0	7,9E-06	0,00029	0,00034	0,00013	5,4E-05	0,00013	0,00037	0	0	0	4,5E-06	0,00039	1,5E-05	0,00021
12	1043	1,0	31	SAN BENEDETTO	ACQUA SAN BENEDETTO	0	9,7E-05	0,00161	0	1E-05	0,00039	0,00045	0,00017	7,2E-05	0,00017	0,00049	0	0	0	6,1E-06	0,00052	2E-05	0,00028
13	1044	1,0	31	SAN BENEDETTO	ACQUA SAN BENEDETTO	0	9,7E-05	0,00161	0	1E-05	0,00039	0,00045	0,00017	7,2E-05	0,00017	0,00049	0	0	0	6,1E-06	0,00052	2E-05	0,00028
14	1045	1,0	31	SAN BENEDETTO	ACQUA SAN BENEDETTO	0	9,7E-05	0,00161	0	1E-05	0,00039	0,00045	0,00017	7,2E-05	0,00017	0,00049	0	0	0	6,1E-06	0,00052	2E-05	0,00028
15	1046	1,0	31	SAN BENEDETTO	ACQUA SAN BENEDETTO	0	9,7E-05	0,00161	0	1E-05	0,00039	0,00045	0,00017	7,2E-05	0,00017	0,00049	0	0	0	6,1E-06	0,00052	2E-05	0,00028
16	1050	0,5	31	SAN BENEDETTO	ACQUA SAN BENEDETTO	0	4,8E-05	0,0008	0	5,2E-06	0,0002	0,00023	8,6E-05	3,6E-05	8,5E-05	0,00025	0	0	0	3E-06	0,00026	1E-05	0,00014
17	1051	0,5	31	SAN BENEDETTO	ACQUA SAN BENEDETTO	0	4,8E-05	0,0008	0	5,2E-06	0,0002	0,00023	8,6E-05	3,6E-05	8,5E-05	0,00025	0	0	0	3E-06	0,00026	1E-05	0,00014
18	1070	0,5	31	SAN BENEDETTO	ACQUA SAN BENEDETTO	0	4,8E-05	0,0008	0	5,2E-06	0,0002	0,00023	8,6E-05	3,6E-05	8,5E-05	0,00025	0	0	0	3E-06	0,00026	1E-05	0,00014
19	1071	0,5	31	SAN BENEDETTO	ACQUA SAN BENEDETTO	0	4,8E-05	0,0008	0	5,2E-06	0,0002	0,00023	8,6E-05	3,6E-05	8,5E-05	0,00025	0	0	0	3E-06	0,00026	1E-05	0,00014
20	1076	1,0	31	SAN BENEDETTO	BIBITA	0	9,7E-05	0,00161	0	1E-05	0,00039	0,00045	0,00017	7,2E-05	0,00017	0,00049	2,2E-05	5,1E-05	2,6E-06	6,1E-06	0,00052	2E-05	0,00028
21	1078	1,0	31	SAN BENEDETTO	BIBITA	0	9,7E-05	0,00161	0	1E-05	0,00039	0,00045	0,00017	7,2E-05	0,00017	0,00049	2,2E-05	5,1E-05	2,6E-06	6,1E-06	0,00052	2E-05	0,00028
22	1079	1,0	31	SAN BENEDETTO	BIBITA	0	9,7E-05	0,00161	0	1E-05	0,00039	0,00045	0,00017	7,2E-05	0,00017	0,00049	2,2E-05	5,1E-05	2,6E-06	6,1E-06	0,00052	2E-05	0,00028
23	1080	1,0	31	SAN BENEDETTO	BIBITA	0	9,7E-05	0,00161	0	1E-05	0,00039	0,00045	0,00017	7,2E-05	0,00017	0,00049	2,2E-05	5,1E-05	2,6E-06	6,1E-06	0,00052	2E-05	0,00028
24	1128	0,25	31	SAN BENEDETTO	BIBITA	0	2,4E-05	0,0004	0	2,6E-06	9,8E-05	0,00011	4,3E-05	1,8E-05	4,2E-05	0,00012	5,6E-06	1,3E-05	6,5E-07	1,5E-06	0,00013	5,1E-06	6,9E-05
25	1129	0,25	31	SAN BENEDETTO	BIBITA	0	2,4E-05	0,0004	0	2,6E-06	9,8E-05	0,00011	4,3E-05	1,8E-05	4,2E-05	0,00012	5,6E-06	1,3E-05	6,5E-07	1,5E-06	0,00013	5,1E-06	6,9E-05
26	1700	0,65	31	ANTICA FONTE SALUTE	ACQUA NON SAN BENEDETTO	0	6,3E-05	0,00105	0	6,8E-06	0,00025	0,0003	0,00011	4,7E-05	0,00011	0,00032	0	0	0	3,9E-06	0,00034	1,3E-05	0,00018
27	1701	0,65	31	ANTICA FONTE SALUTE	ACQUA NON SAN BENEDETTO	0	6,3E-05	0,00105	0	6,8E-06	0,00025	0,0003	0,00011	4,7E-05	0,00011	0,00032	0	0	0	3,9E-06	0,00034	1,3E-05	0,00018

Wastes | Waste_for_Product | Depuratore | Depuratore_per_CP | Foglio1

Figure 97 EID_SB_ Environmental_service_mapping interface (Wastes quantities allocated per product– Part 2)

F5 =SE.ERRORE(CERCA.VERT(F3;'E:\Copia\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Acqua_e_Bibite\SB_Chemicals_Mapping\[Sorgente_consumo_CH_magazzino_Scorze.xlsx]Sheet2'!$A$2:$E$49;5;FALSO);0)

A	B	C	E	F	G	H	I	K	L	M	N	T	V	W	
CHEMICAL COMPOUND CODE		10050046	10050048	10050050	10050052	10050054	10050056	10050062	10050063	10050065	10050067	10050080	10050081	10050083	
CHEMICAL COMPOUND DESCRIPTION		OR 30 IN CISTERNA 1200 KG	P3 SUPER L 23 CISTERNA 1200 KG	P3- LUBOSTAR CP (FUSTI 200KG)	SUPRACLOR 1001 (SACCHI 25KG)	REMOVIL EXTRA (TANICHE 25KG)	DIVOSAN FORTE (TANICHE 23KG)	DRY TECH 5 VL 96 (FUSTI 200KG)	ANTIFOAM HD VB 3 (TANICHE 20,8KG)	P3 SUPER L 23 SFUSO (LIT X 1,49KG)	P3 OXONIA ACTIVE (TANICHE 21KG)	P3 TOPAX 91 (CANESTRI 10KG)	P3 TOPAX 66 (TANICHE 22KG)	P3 HOROLITH ECO (TANICHE 10KG)	23
TOTAL CHEMICAL COMPOUND CONSUMPTION		17.868,00	1.500,00	26.150,00	1.475,00	49.400,00	6.900,00	1.600,00	1.144,20	7.244,00	13.965,00	70,00	8.140,00	5.220,00	
U.M.		kg	kg	kg	kg	kg	kg	kg	kg	kg	kg	kg	kg	kg	
BOOLEAN CONTROL MATRIX	31					SI		SI	SI						
	32					SI									
	34					SI									
	35					SI									
	39					SI							SI		
	42					SI							SI		
	43					SI									
	46														
	50					SI							SI		
	51											SI			
	52			SI								SI			
	53			SI								SI			
	54			SI								SI			
	55			SI								SI			
	56			SI								SI			
	57			SI						SI		SI			
	58			SI								SI			
	60	SI	SI										SI		
	61	SI				SI							SI		
	63	SI	SI	SI						SI	SI		SI		
	64	SI	SI	SI						SI	SI		SI		
	65	SI	SI	SI						SI	SI		SI		
	66			SI			SI						SI		
	67														
		kg/litre	kg/litre	kg/litre	kg/litre	kg/litre	kg/litre	kg/litre	kg/litre	kg/litre	kg/litre	kg/litre	kg/litre	kg/litre	
CHEMICAL CONSUMPTIONS MATRIX	31					1,35E-04		2,57E-05	1,83E-05						
	32					1,35E-04									
	34					1,35E-04									
	35					1,35E-04									
	39					1,35E-04							2,15E-05		
	42					1,35E-04							2,15E-05		
	43					1,35E-04									
	46														
	50					1,35E-04							2,15E-05		
	51											4,86E-08			
	52			1,98E-05								4,86E-08			
	53			1,98E-05								4,86E-08			
	54			1,98E-05								4,86E-08			
	55			1,98E-05								4,86E-08			
	56			1,98E-05								4,86E-08			
	57			1,98E-05						2,00E-05		4,86E-08			
	58			1,98E-05								4,86E-08			
	60	2,82E-05	5,78E-06										2,15E-05		
	61	2,82E-05				1,35E-04							2,15E-05		
	63	2,82E-05	5,78E-06	1,98E-05						2,00E-05	9,97E-06		2,15E-05		
	64	2,82E-05	5,78E-06	1,98E-05						2,00E-05	9,97E-06		2,15E-05		
	65	2,82E-05	5,78E-06	1,98E-05						2,00E-05	9,97E-06		2,15E-05		
	66			1,98E-05			3,32E-04						2,15E-05		
	67														

Chemical_for_product | Chimici circuiti energia | Soda-AcidSolforico | Magazzino ricambi | Produzione tot per linee 2016

Figure 98 EID_SB_ Chemicals_mapping interface

3.2.1.2.3.7. Inventory data collection – EID_SB_Downstream_distance_mapping

Finally, this last interface permits to assess the distances travelled in truck, train and ship by every produced product. The interface elaborates all the data acquires from the specific software that monitors all the shipments of every product occurred in all the days of the year under assessment. In order to assess the distances has been developed a database where for every production site have been inserted all the distances with all the delivery destinations. In this way, considering the mass delivered for each transport of product, the weighted average distances travelled in truck, train and ship have been calculated. In the calculation of distances travelled have also been considered the distances to reach intermedia warehouses for the stock of products.

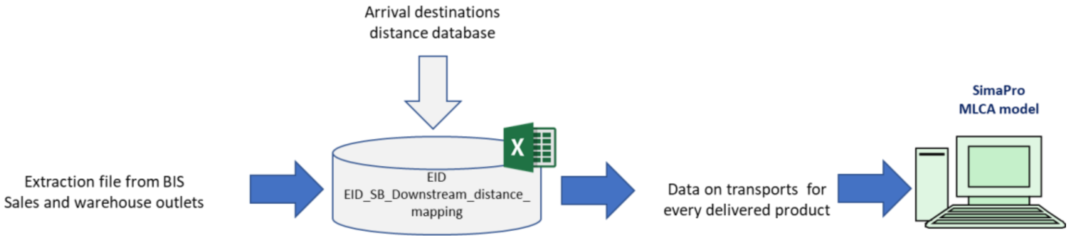
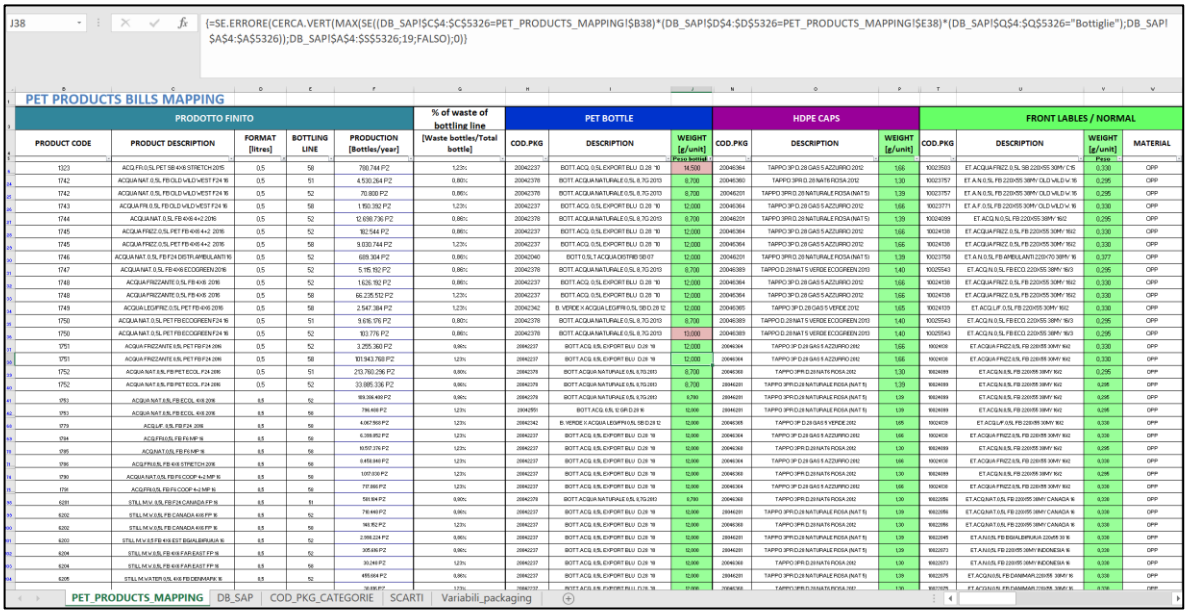


Figure 99 Simplified flowchart of EID_SB_Downstream_distance_mapping

3.2.1.2.3.8. Automatic validation of data

The EID interfaces have been programmed also to perform automatic operations of data validation. Two types of validation criteria have been inserted:

- Statistical criterion: a warning is returned, when the value is higher or lower respectively of the sum of the value with the deviation standard and of the difference between the value and the deviation standard calculated on homogeneous set. An example is reported in the figure below, the two bottles of 0,5L with weight equal to 14,5 g and 13 g have been identified as anomalies. The deviation standard has been calculated on the base of all bottle weights for the set of products with 0,5L format.
- Mass balance and energy balance consistency: for example, in the case of energy consumption also a top down data control has been programmed. The total of energy consumption acquired by EID interface from the energy monitor software has been verify comparing the total energy from bills.



H2

=SE.ERRORE(SE($C2<0;CERCA.VERT($D2;'E:\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Acqua_e_Bibite\SB_Downstream_Distance_Mapping\[Database_distanze_Scorze.xlsx]Z001'!$A$3:$G$6001;RIF.COLONNA(E2);FALSO)*2;CERCA.VERT($D2;'E:\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Acqua_e_Bibite\SB_Downstream_Distance_Mapping\[Database_distanze_Scorze.xlsx]Z001'!$A$3:$G$6001;RIF.COLONNA(E2);FALSO));"")

	PRODUCT CODE	PRODUCT DESCRIPTION	DELIVY QUANTITY [bottles/transport]	DESTINATION CITY	DESTINATION REGION	NATION ID	STINATION NATI	km TRUCK	km SHIP	km TRAIN	TOTAL WEIGHT PER BOTTLE [g/bottle]	TOTAL WEIGHT DELIVERED [kg/transport	kg*km TRUCK	kg*km SHIP	kg*Km TRAIN
2	1760	ACQUA NATURALE 2L FB PROMO 2016	14136	Como	Lombardia	IT	Italia	308	0	0	2.101	29.699	9.147.317	0	0
3	1760	ACQUA NATURALE 2L FB PROMO 2016	14136	Rimini	Emilia-Romagna	IT	Italia	260	0	0	2.101	29.699	7.721.761	0	0
4	1760	ACQUA NATURALE 2L FB PROMO 2016	1368	Venezia	Veneto	IT	Italia	28	0	0	2.101	2.874	80.475	0	0
5	1760	ACQUA NATURALE 2L FB PROMO 2016	14136	Bologna	Emilia-Romagna	IT	Italia	153	0	0	2.101	29.699	4.543.960	0	0
6	1760	ACQUA NATURALE 2L FB PROMO 2016	14136	Novara	Piemonte	IT	Italia	311	0	0	2.101	29.699	9.236.414	0	0
7	1760	ACQUA NATURALE 2L FB PROMO 2016	3192	Bologna	Emilia-Romagna	IT	Italia	153	0	0	2.101	6.706	1.026.055	0	0
8	1760	ACQUA NATURALE 2L FB PROMO 2016	5472	Cagliari	Sardegna	IT	Italia	607	308	0	2.101	11.496	6.978.326	3.540.897	0
9	1760	ACQUA NATURALE 2L FB PROMO 2016	13680	Cagliari	Sardegna	IT	Italia	607	308	0	2.101	28.741	17.445.815	8.852.242	0
10	1760	ACQUA NATURALE 2L FB PROMO 2016	8208	Verona	Veneto	IT	Italia	114	0	0	2.101	17.245	1.965.888	0	0
11	1760	ACQUA NATURALE 2L FB PROMO 2016	13680	Cagliari	Sardegna	IT	Italia	607	308	0	2.101	28.741	17.445.815	8.852.242	0
12	1760	ACQUA NATURALE 2L FB PROMO 2016	14136	Novara	Piemonte	IT	Italia	311	0	0	2.101	29.699	9.236.414	0	0
13	1760	ACQUA NATURALE 2L FB PROMO 2016	5472	La Spezia	Liguria	IT	Italia	372	0	0	2.101	11.496	4.276.668	0	0
14	1760	ACQUA NATURALE 2L FB PROMO 2016	13680	Pavia	Lombardia	IT	Italia	302	0	0	2.101	28.741	8.679.796	0	0
15	1760	ACQUA NATURALE 2L FB PROMO 2016	2736	Medio Campidano	Sardegna	IT	Italia	574	308	0	2.101	5.748	3.299.472	1.770.448	0
16	1760	ACQUA NATURALE 2L FB PROMO 2016	4560	Bergamo	Lombardia	IT	Italia	225	0	0	2.101	9.580	2.155.579	0	0
17	1760	ACQUA NATURALE 2L FB PROMO 2016	14136	Rovigo	Veneto	IT	Italia	83	0	0	2.101	29.699	2.465.024	0	0
18	1760	ACQUA NATURALE 2L FB PROMO 2016	8208	Cagliari	Sardegna	IT	Italia	607	308	0	2.101	17.245	10.467.489	5.311.345	0
19	1760	ACQUA NATURALE 2L FB PROMO 2016	7752	Roma	Lazio	IT	Italia	534	0	0	2.101	16.287	8.697.041	0	0
20	1760	ACQUA NATURALE 2L FB PROMO 2016	14136	Reggio Emilia	Emilia-Romagna	IT	Italia	218	0	0	2.101	29.699	6.474.400	0	0
21	1760	ACQUA NATURALE 2L FB PROMO 2016	13680	Bergamo	Lombardia	IT	Italia	225	0	0	2.101	28.741	6.466.736	0	0
22	1760	ACQUA NATURALE 2L FB PROMO 2016	13680	Bergamo	Lombardia	IT	Italia	225	0	0	2.101	28.741	6.466.736	0	0
23	1760	ACQUA NATURALE 2L FB PROMO 2016	1824	Brescia	Lombardia	IT	Italia	179	0	0	2.101	3.832	685.953	0	0
24	1760	ACQUA NATURALE 2L FB PROMO 2016	1026	Grosseto	Toscana	IT	Italia	391	0	0	2.101	2.156	842.831	0	0
25	1760	ACQUA NATURALE 2L FB PROMO 2016	342	Padova	Veneto	IT	Italia	40	0	0	2.101	719	28.741	0	0
26	1760	ACQUA NATURALE 2L FB PROMO 2016	1230	Padova	Veneto	IT	Italia	40	0	0	2.101	2.584	103.367	0	0
27	1760	ACQUA NATURALE 2L FB PROMO 2016	6384	Treviso	Veneto	IT	Italia	20	0	0	2.101	13.412	268.250	0	0
28	1760	ACQUA NATURALE 2L FB PROMO 2016	5472	Roma	Lazio	IT	Italia	534	0	0	2.101	11.496	6.139.088	0	0
29	1760	ACQUA NATURALE 2L FB PROMO 2016	456	Perugia	Umbria	IT	Italia	385	0	0	2.101	958	368.843	0	0
30	1760	ACQUA NATURALE 2L FB PROMO 2016	456	Rovigo	Veneto	IT	Italia	83	0	0	2.101	958	79.517	0	0
31	1760	ACQUA NATURALE 2L FB PROMO 2016	684	Venezia	Veneto	IT	Italia	28	0	0	2.101	1.437	40.237	0	0
32	1760	ACQUA NATURALE 2L FB PROMO 2016	912	Pordenone	Friuli-Venezia Giuli	IT	Italia	87	0	0	2.101	1.916	166.698	0	0
33	1760	ACQUA NATURALE 2L FB PROMO 2016	13680	Varese	Lombardia	IT	Italia	317	0	0	2.101	28.741	9.110.912	0	0
34	1760	ACQUA NATURALE 2L FB PROMO 2016	14136	Varese	Lombardia	IT	Italia	317	0	0	2.101	29.699	9.414.609	0	0
35	1760	ACQUA NATURALE 2L FB PROMO 2016	9576	Bergamo	Lombardia	IT	Italia	225	0	0	2.101	20.119	4.526.715	0	0
36	1760	ACQUA NATURALE 2L FB PROMO 2016	14136	Bologna	Emilia-Romagna	IT	Italia	153	0	0	2.101	29.699	4.543.960	0	0
37	1760	ACQUA NATURALE 2L FB PROMO 2016	14136	Venezia	Veneto	IT	Italia	28	0	0	2.101	29.699	831.574	0	0

Informazioni | Total Results | Z001-Scorzè | Z006-DN Log | Z007-Esperia | Z010-Strammiello | Z015-Pesce | Z016-FAG | Z017-Prandelli | Z019-Rivoldrink | Z02 ...

Figure 100 EID_SB_ Downstream_distance_mapping interface (Delivery destinations - Part 1)

D3

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=SOMMA.PIÙ.SE('Z001-Scorzè'!$O$2:$O$800000;'Z001-Scorzè'!$A$2:$A$800000;'Total Results'!$A3)+SOMMA.PIÙ.SE('Z006-DN Log'!$O$2:$O$800000;'Z006-DN Log'!$A$2:$A$800000;'Total Results'!$A3)+SOMMA.PIÙ.SE('Z007-Esperia'!$O$2:$O$800000;'Z007-Esperia'!$A$2:$A$800000;'Total Results'!$A3)+SOMMA.PIÙ.SE('Z010-Strammiello'!$O$2:$O$800000;'Z010-Strammiello'!$A$2:$A$800000;'Total Results'!$A3)+SOMMA.PIÙ.SE('Z015-Pesce'!$O$2:$O$800000;'Z015-Pesce'!$A$2:$A$800000;'Total Results'!$A3)+SOMMA.PIÙ.SE('Z016-FAG'!$O$2:$O$800000;'Z016-FAG'!$A$2:$A$800000;'Total Results'!$A3)+SOMMA.PIÙ.SE('Z017-Prandelli'!$O$2:$O$800000;'Z017-Prandelli'!$A$2:$A$800000;'Total Results'!$A3)+SOMMA.PIÙ.SE('Z019-Rivoldrink'!$O$2:$O$800000;'Z019-Rivoldrink'!$A$2:$A$800000;'Total Results'!$A3)+SOMMA.PIÙ.SE('Z020-Timossi'!$O$2:$O$800000;'Z020-Timossi'!$A$2:$A$800000;'Total Results'!$A3)+SOMMA.PIÙ.SE('Z021-C.D.L.'!$O$2:$O$800000;'Z021-C.D.L.'!$A$2:$A$800000;'Total Results'!$A3)+SOMMA.PIÙ.SE('Z022-Cestaro'!$O$2:$O$800000;'Z022-Cestaro'!$A$2:$A$800000;'Total Results'!$A3)+SOMMA.PIÙ.SE('Z023-Galimberti'!$O$2:$O$800000;'Z023-Galimberti'!$A$2:$A$800000;'Total Results'!$A3)+SOMMA.PIÙ.SE('Z024-Turcilog'!$O$2:$O$800000;'Z024-Turcilog'!$A$2:$A$800000;'Total Results'!$A3)+SOMMA.PIÙ.SE('Z025-Sanges'!$O$2:$O$800000;'Z025-Sanges'!$A$2:$A$800000;'Total Results'!$A3)+SOMMA.PIÙ.SE('Z030-Cianfrocca'!$O$2:$O$800000;'Z030-Cianfrocca'!$A$2:$A$800000;'Total Results'!$A3)+SOMMA.PIÙ.SE('Z031-Abruzzo Distr.'!$O$2:$O$800000;'Z031-Abruzzo Distr.'!$A$2:$A$800000;'Total Results'!$A3)+SOMMA.PIÙ.SE('Z032-Dogan Guadalupe'!$O$2:$O$800000;'Z032-Dogan Guadalupe'!$A$2:$A$800000;'Total Results'!$A3)+SOMMA.PIÙ.SE('Z033-Sarda Frigo'!$O$2:$O$800000;'Z033-Sarda Frigo'!$A$2:$A$800000;'Total Results'!$A3)+SOMMA.PIÙ.SE('Z034-Cablog'!$O$2:$O$800000;'Z034-Cablog'!$A$2:$A$800000;'Total Results'!$A3)+SOMMA.PIÙ.SE('Z036-Neska'!$O$2:$O$800000;'Z036-Neska'!$A$2:$A$800000;'Total Results'!$A3)+SOMMA.PIÙ.SE('Z037-MyBeverages'!$O$2:$O$800000;'Z037-MyBeverages'!$A$2:$A$800000;'Total Results'!$A3)+SOMMA.PIÙ.SE('Z039-Pohl&Co'!$O$2:$O$800000;'Z039-Pohl&Co'!$A$2:$A$800000;'Total Results'!$A3)+SOMMA.PIÙ.SE('Z040-Sabel'!$O$2:$O$800000;'Z040-Sabel'!$A$2:$A$800000;'Total Results'!$A3)+SOMMA.PIÙ.SE(Rilanci!$R$2:$R$800000;Rilanci!$A$2:$A$800000;'Total Results'!$A3)
```

	A	B	C	D	E	F	G	H
1		km* Tot Kg CON Rilanci			AVERAGE WEIGHTED DISTANCES			
2	PRODUCT CODE	TRAUCK	SHIP	TRAIN	TOTAL MASS	km TRUCK	km SHIP	km TRAIN
3	1323	124.529.587	0	7.754.716	485.954	256,3	0,0	16,0
4	1342	2.360.752.272	0	0	8.159.507	289,3	0,0	0,0
5	1727	2.225.010.932	87.761.756	84.007.229	4.778.167	465,7	18,4	17,6
6	1728	4.469.307.403	1.435.563.564	3.917.228.955	14.181.195	315,2	101,2	276,2
7	1729	1.505.021.273	2.232.391.240	795.012.257	4.726.165	318,4	472,3	168,2
8	1730	52.076.178	21.481.341	36.578.332	253.318	205,6	84,8	144,4
9	1731	21.820.042	21.385.946	0	119.134	183,2	179,5	0,0
10	1732	2.449.345.911	34.562.937	461.665.215	7.002.123	349,8	4,9	65,9
11	1733	1.049.367.359	14.001.582	105.201.893	3.506.401	299,3	4,0	30,0
12	1734	190.123.357	0	23.058.061	370.561	513,1	0,0	62,2
13	1735	1.107.719.395	117.455.932	192.726.570	3.200.627	346,1	36,7	60,2
14	1736	871.087.314	68.017.347	57.641.877	2.320.633	375,4	29,3	24,8
15	1737	111.840.705	1.177.783.393	15.336.876	364.822	306,6	3228,4	42,0
16	1738	62.849.901	1.149.852.249	9.167.514	124.772	503,7	9215,7	73,5
17	1739	41.897.242	1.146.534.907	1.366.168	100.490	416,9	11409,5	13,6
18	1740	111.304.001	90.608.061	23.630.610	376.427	295,7	240,7	62,8
19	1741	68.192.536	75.403.538	22.091.333	213.564	319,3	353,1	103,4
20	1742	728.055.976	0	0	2.528.336	288,0	0,0	0,0
21	1743	180.087.312	0	0	631.159	285,3	0,0	0,0
22	1744	1.978.128.333	371.714	35.289.974	6.943.126	284,9	0,1	5,1
23	1745	1.408.174.677	1.454.429	8.516.842	5.055.338	278,6	0,3	1,7

Informazioni | Total Results | Z001-Scorzè | Z006-DN Log | Z007-Esperia | Z010-Strammiello | Z015-Pesce | Z016-FAG | Z017-Prandelli | Z019-Rivoldrink | Z02 ...

Figure 101 EID_SB_ Downstream_distance_mapping interface (Average weighted distances - Part 2)

Life cycle stage	Specific flow of process	Dataset identification	Notes
Raw materials and packaging components	PET granulate	Polyethylene terephthalate, granulate, bottle grade {RoW} | production | Alloc Rec U	Regionalized using specific energy country mix and water flows
	RPET granulate	Electricity, medium voltage {AT}, market for | Alloc Rec, U", "Electricity, medium voltage {PL}, market for | Alloc Rec, U", "Electricity, medium voltage {TR}| market for | Alloc Rec, U	Modelled according Ecoinvent
	Masterbatch	Rutile, 95% Titanium dioxide {GLO}| market for | Alloc Rec U	-
	Glass bottle	Packaging glass, white, {RER w/o CH+DE} | production | Alloc Rec U	Considered when applicable the reusing factor
	HDPE	Polyethylene, high density, granulate {GLO}| Market for | Alloc Rec U	Regionalized using specific energy country mix and water flows
	PP	Polyethylene, high density, granulate {GLO}| Market for | Alloc Rec U	Regionalized using specific energy country mix and water flows
	PE labels	Polypropylene, granulate {GLO}| market for | Alloc Rec U Extrusion, plastic film {RER} | production | Alloc Rec U	-
	PET labels	Polyethylene, linear low density, granulate {GLO}| market for | Alloc Rec U Extrusion, plastic film {RER} | production | Alloc Rec U	-
	Caps for glass bottles	Aluminium, wrought alloy {RER} | alluminium production, primary | Alloc Def U and Metal working, average for alluminium product manufcturing {RER}| processing | Alloc Rec U	-
	Aluminium and Kraft paper labels	Aluminium, wrought alloy {RER} | alluminium production, primary | Alloc Rec U" and "Kraft paper, bleached {GLO}| market for | Alloc Rec U	-
	Kraft paper labels	Kraft paper, bleached {GLO}| market for | Alloc Rec U	-
	Paper handles	Kraft paper, bleached {GLO}| market for | Alloc Rec U	-
	Adhesive for paper handles	Polypropylene, granulate {GLO}| market for | Alloc Rec U Extrusion, plastic film {RER} | production | Alloc Rec U	-
	Glue	Phenolic resin {GLO} | market for | Alloc Rec U	-
	Pallet label	Kraft paper, bleached {GLO}| market for | Alloc Rec U	-
	Stretch film	Polyethylene, linear low density, granulate {GLO}| market for | Alloc Rec U Extrusion, plastic film {RER} | production | Alloc Rec U	-
	Shrink film	Polyethylene, low density, granulate {GLO}| market for | Alloc Rec U Extrusion, plastic film {RER} | production | Alloc Rec U	-
	Top cover	Polyethylene, low density, granulate {GLO}| market for | Alloc Rec U Extrusion, plastic film {RER} | production | Alloc Rec U	-
	Plastic case for glass bottles	HDPE "Polyethylene, high density, granulate {GLO}| market for | Alloc Rec U and Thermoforming, with calendering {RER}| production | Alloc Rec U	
	Cardboard interlayer	Fluting medium {RER}| market for flutig medium | Alloc Rec U	-
	Pallet and minipallet	EUR-flat pallet {GLO}| market for | Alloc Rec U Wood chipping, industrial residual wood, stationary electric chipper {RER}| processing | Alloc Rec U	-
	Strap	Polypropylene, granulate {GLO}| market for | Alloc Rec U Extrusion, plastic film {RER} | production | Alloc Rec U	-
	Cardboard trays	Linerboard {RER}| market for lineboard | Alloc Rec U	-

Life cycle stage	Specific flow of process	Dataset identification	Notes
		Carton board box production, with, gravure printing {CH}, carton board box production service, with, gravure printing | Alloc Rec U	
	Cardboard boxes	Corrugated board box {GLO}| market for corrugated board box | Alloc Rec U and Carton board box production, with, gravure printing {CH}, carton board box production service, with, gravure printing | Alloc Rec U	
	Transport by truck of auxiliary materials	Transport, freight lorry 16-32 metric ton, EURO4 {RoW}| transport, freight, lorry 16-32 metric ton, EURO4 | Alloc Rec U	-
	Transport by ship of auxiliary materials	Transport, freight, sea, transoceanic ship {GLO} | processing | Alloc Rec U	-
Production	Electricity by grid	Electricity, medium voltage {IT}, market for | Alloc Rec U	-
	Electricity by solar	Electricity, low voltage {IT}| electricity production, photovoltaic, 3kWp slanted-roof installation, multi-Si, panel, mounted | Alloc Rec, U	Technological adjustment considering plant specific data
	Electricity by cogeneration	Electricity, high voltage {RoW}| heat and power co-generation, natural gas, combined cycle power plant, 400MW electrical | Alloc Rec, U	Technological adjustment considering plant specific data
	Natural gas	Process steam from natural gas, heat plant, consumption mix, at plant, MJ IT S	-
	Liquid carbon dioxide	Carbon dioxide, liquid {GLO} | market for | Alloc Rec U	-
	Liquid nitrogen	Nitrogen, liquid {GLO} | market for | Alloc Rec	-
	Sodium hypochlorite	Sodium hypochlorite, without water, in 15% solution state {RER}| sodium hypochlorite production, product in 15% solution state | Alloc Rec U	Use real concentration
	Hydrochloric acid	Hydrochloric acid, without water, in 30% solution state {RER}| hydrochloric acid production, from the reaction of hydrogen with chlorine| Alloc Rec U	Use real concentration
	Sulphuric acid	Sulphuric acid {RER}| production | Alloc Rec U	Use real concentration
	Lubricating oil	Lubricating oil {RER}| production | Alloc Rec U	Use real concentration
	Oxonia	Mix of Acetic acid, without water, in 98% solution state {RER}| acetic acid production, product in 98% solution state | Alloc Rec U" and "Hydrogen peroxide, without water, in 50% solution state {RER}| hydrogen peroxide production, product in 50% solution state | Alloc Rec U	Use real concentration
	Other disinfectant chemical compounds	Mix of Sodium hydroxide, without water, in 50% solution state {RER}| sodium hydroxide production, product in 50% solution state | Alloc Rec U" and Sodium hypochlorite, without water, in 15% solution state {RER}| sodium hypochlorite production, product in 15% solution state | Alloc Rec U	Use real concentration
	Discarding chemical compounds	Mix of Phosphoric acid, industrial grade, without water, in 85% solution state {RER}| purification of wet-process phosphoric acid to industrial grade, product in 85% solution state | Alloc Rec U and Nitric acid, without water, in 50% solution state {GLO}| market for | Alloc Rec U".	Use real concentration
	Caustic detergents	Sodium hydroxide, without water, in 50% solution state {RER}| sodium hydroxide production, product in 50% solution state | Alloc Rec U	Use real concentration
	Acid detergents	Mix of Nitric acid, without water, in 50% solution state {GLO}| market for | Alloc Rec U and Phosphoric acid, industrial grade, without water, in 85% solution state {RER}| purification of wet-process phosphoric acid to industrial grade, product in 85% solution state | Alloc Rec U	Use real concentration
	Hydrogen peroxide	Hydrogen peroxide, without water, in 50% solution state {RER}| hydrogen peroxide production, product in 50% solution state | Alloc Rec U	Use real concentration
	Defoamers	Dioxane {GLO}| market for | Alloc Rec U	Use real concentration
	Sodium hydroxide	Sodium hydroxide, without water, in 50% solution state {RER}| sodium hydroxide production, product in 50% solution state | Alloc Rec U	Use real concentration

Life cycle stage	Specific flow of process	Dataset identification	Notes
	Urea	Urea, as N {GLO}| market for | Alloc Rec U	Use real concentration
	Aluminium chloride	Aluminium fluoride, {GLO}| market for | Alloc Rec U	Use real concentration
	Liquid oxygen	Oxygen, liquid {GLO}| market for | Alloc Rec U	Use real concentration
	Calcium oxide	Lime, hydrated, packed {GLO} | market for | Alloc Rec U	Use real concentration
	Flocculants	Chemicals inorganic {GLO}| market for chemicals, inorganic | Alloc Rec U	Use real concentration
	Iron chloride	Iron (III) chloride, without water, in 40% solution state {GLO| market for | Alloc Rec U	Use real concentration
	Phosphoric acid	Phosphoric acid, industrial grade, without water, in 85% solution state {RER}| purification of wet-process phosphoric acid to industrial grade, product in 85% solution state | Alloc Rec U	Use real concentration
	Wastes transport	Municipal waste collection service by 21 metric ton lorry {CH}| market for | Alloc Rec U	-
	Waste CER 150107	100% recycled. Packaging glass, white (waste treatment) {GLO}| recycling of packaging glass, white | Alloc Rec, U	Following regional specific data on waste disposal scenarios (ISPRA)
	Waste CER 150106	83% recycled. Mixed plastics (waste treatment) {GLO}| recycling of mixed plastics | Alloc Rec, U. 14% landfill. Municipal solid waste {CH}| treatment of, sanitary landfill | Alloc Rec, U. 3% incinerated. Municipal solid waste {IT}| treatment of, incineration | Alloc Rec, U".	Following regional specific data on waste disposal scenarios (ISPRA)
	Waste CER 150104	100% recycled. Aluminium (waste treatment) {GLO}| recycling of aluminium | Alloc Rec, U	Following regional specific data on waste disposal scenarios (ISPRA)
	Waste CER 150103	34% recycled. Recycling wood/RER U. 66% incinerated. Waste wood, untreated {GLO}| market for | Alloc Rec, U	Following regional specific data on waste disposal scenarios (ISPRA)
	Waste CER 150102	100% recycled. PET (waste treatment) {GLO}| recycling of PET | Alloc Rec, U	Following regional specific data on waste disposal scenarios (ISPRA)
	Waste CER 150101	100% recycled. Recycling cardboard/RER U	Following regional specific data on waste disposal scenarios (ISPRA)
	Transport by truck of auxiliary materials	Transport, freight lorry 16-32 metric ton, EURO4 {RoW}| transport, freight, lorry 16-32 metric ton, EURO4 | Alloc Rec U	-
	Transport by ship of auxiliary materials	Transport, freight, sea, transoceanic ship {GLO} | processing | Alloc Rec U	-
Products delivery	Transport by truck for product delivery	Average of different EURO classes. Transport, freight, lorry>32 metric ton, EURO3 {RER}| market for | Alloc Rec U, Transport, freight, lorry>32 metric ton, EURO4 {RER}| market for | Alloc Rec U, Transport, freight, lorry>32 metric ton, EURO5 {RER}| market for | Alloc Rec U	Using specific mix EURO class of San Benedetto S.p.A.
	Transport by train for product delivery	Transport, freight, train {IT}| processing | Alloc Rec U	-
	Transport by ship for product delivery	Transport, freight, sea, transoceanic ship {GLO}| market for | Alloc Rec U	-
	Product cooling at store	Electricity, low voltage {IT}, market for | Alloc Rec U	-
	End of life stretch film and shrink film	38% recycling. PE (waste treatment) {GLO}| recycling of PE | Alloc Rec, U. 36% incinerated. Waste polyethylene {CH}| treatment of, municipal incineration | Alloc Rec, U. 26% landfill. Waste polyethylene {CH}| treatment of, sanitary landfill | Alloc Rec, U.	Following national specific data on waste disposal scenarios (ISPRA)
	End of life cardboard trays and boxes	80% recycled. Recycling cardboard/RER U. 8% incinerated. Disposal, packaging cardboard, 19,6% water, to municipal incineration/CH U. 12% landfill. Disposal, packaging cardboard, 19,6% water, to sanitary landfill/CH U	Following national specific data on waste disposal scenarios (ISPRA)
	End of life strap	38% recycled. PP (waste treatment) {GLO}| recycling of PP | Alloc Rec, U. 36% incinerated. Waste polypropylene {CH}| treatment of, municipal incineration | Alloc Rec, U. 26% landfill. Waste polypropylene {CH}| treatment of, sanitary landfill | Alloc Rec, U	Following national specific data on waste disposal scenarios (ISPRA)

Life cycle stage	Specific flow of process	Dataset identification	Notes
	End of life pallet	69% recycled. Recycling wood RER U. 31% landfill. Waste wood, untreated {CH}| treatment of, sanitary landfill | Alloc Rec, U	Following national specific data on waste disposal scenarios (ISPRA)
	End of life paper handles adhesive	38% recycled. PP (waste treatment) {GLO}| recycling of PP | Alloc Rec, U. 36% incinerated. Waste polypropylene {CH}| treatment of, municipal incineration | Alloc Rec, U. 26% landfill. Waste polypropylene {CH}| treatment of, sanitary landfill | Alloc Rec, U	Following national specific data on waste disposal scenarios (ISPRA)
	End of life cardboard interlayers	80% recycled. Recycling cardboard/RER U. 8% incinerated. Disposal, packaging cardboard, 19,6% water, to municipal incineration/CH U. 12% landfill. Disposal, packaging cardboard, 19,6% water, to sanitary landfill/CH U	Following national specific data on waste disposal scenarios (ISPRA)
	End of life pallet labels	80% recycled. Paper (waste treatment) {GLO}| recycling of paper | Alloc Rec, U. 8% incinerated. Waste graphical paper {CH}| treatment of, sanitary landfill | Alloc Rec. 12% landfill. Waste graphical paper {CH}| treatment of, sanitary landfill | Alloc Rec,	Following national specific data on waste disposal scenarios (ISPRA)
	End of life paper handle	80% recycled. Paper (waste treatment) {GLO}| recycling of paper | Alloc Rec, U. 8% incinerated. Waste graphical paper {CH}| treatment of, sanitary landfill | Alloc Rec. 12% landfill. Waste graphical paper {CH}| treatment of, sanitary landfill | Alloc Rec,	Following national specific data on waste disposal scenarios (ISPRA)
	End of life top cover	38% recycled. PE (waste treatment) {GLO}| recycling of PE | Alloc Rec, U. 36% incinerated. Waste polyethylene {CH}| treatment of, municipal incineration | Alloc Rec, U. 26% landfill. Waste polyethylene {CH}| treatment of, sanitary landfill | Alloc Rec, U	Following national specific data on waste disposal scenarios (ISPRA)
Use stage	Consumer transport	Transport, van<3,5t/RER U".	-
	Domestic product cooling	Electricity, low voltage {IT}, market for | Alloc Rec, U".	-
Products End of Life	End of life PET bottle	37,4% recycled. PET (waste treatment) {GLO}| recycling of PET | Alloc Rec, U. 35,2% incinerated. Waste polyethylene terephtalate {CH}| treatment of, municipal incineration | Alloc Rec, U. 27,4% landfill. Waste polyethylene terephtalate {CH}| treatment of, sanitary landfill | Alloc Rec, U	Following national specific data on waste disposal scenarios (ISPRA)
	End of life plastic flat caps	37,4% recycled. PE (waste treatment) {GLO}| recycling of PE | Alloc Rec, U. 35,2% incinerated. Waste polyethylene {CH}| treatment of, municipal incineration | Alloc Rec, U. 27,4% landfill. Waste polyethylene {CH}| treatment of, sanitary landfill | Alloc Rec, U	Following national specific data on waste disposal scenarios (ISPRA)
	End of life plastic Push&Pull caps	Body part: 37,4% recycled. PE (waste treatment) {GLO}| recycling of PE | Alloc Rec, U. Waste polyethylene {CH}| treatment of, municipal incineration | Alloc Rec, U. 27,4% landfill. Waste polyethylene {CH}| treatment of, sanitary landfill | Alloc Rec, U Dispenser and hood parts: 37,4% recycled. "PP (waste treatment) {GLO}| recycling of PP | Alloc Rec, U. Waste polypropylene {CH}| treatment of, municipal incineration | Alloc Rec, U. 27,4% landfill. Waste polypropylene {CH}| treatment of, sanitary landfill | Alloc Rec, U	Following national specific data on waste disposal scenarios (ISPRA)
	End of life PET labels	38% recycled. PET (waste treatment) {GLO}| recycling of PET | Alloc Rec, U. 36% incinerated. Waste polyethylene terephtalate {CH}| treatment of, municipal incineration | Alloc Rec, U. 26% landfill. Waste polyethylene terephtalate {CH}| treatment of, sanitary landfill | Alloc Rec, U	Following national specific data on waste disposal scenarios (ISPRA)
	End of life PP labels	38% recycled. PP (waste treatment) {GLO}| recycling of PP | Alloc Rec, U. 36% incinerated. Waste polypropylene {CH}| treatment of, municipal incineration | Alloc Rec, U. 26% landfill. Waste polypropylene {CH}| treatment of, sanitary landfill | Alloc Rec, U	Following national specific data on waste disposal scenarios (ISPRA)
	End of life Paper labels	80% recycled. Paper (waste treatment) {GLO}| recycling of paper | Alloc Rec, U. 8,1% incinerated. Waste graphical paper {CH}| treatment of, municipal incineration | Alloc Rec, U. 11,9% landfill. Waste graphical paper {CH}| treatment of, sanitary landfill | Alloc Rec, U	Following national specific data on waste disposal scenarios (ISPRA)

Table 41 List of main Ecoinvnet database used to complete the life cycle inventory in the case of PET products.

3.2.1.2.4. Secondary data collection – The selection of database

In this paragraph have been descripted the database used to complete the inventory (see table 41). The database used are internationally recognized and are provided by Ecoinvent. Ecoinvent data is maintained by the Ecoinvent Research Centre. Created in 1997, the Ecoinvent Research Centre (Frishknet et al., 2005; Althaus et al., 2007). Database have been opportunity modifies in order to improve for example geographical representatively (e.g. database on PET production has an energy mix from different RoW countries, but since the suppliers are known, the same quantity of energy has been associated to specific supplier country). The database selection has been verified by third during two LCA audits (CSQA certification body accredited by ACCREDIA)

3.2.1.2.5. Inventory analysis results management: The application of ERD interface

The Environmental Results Database introduced by OES2 permits the automatic inventory analysis. The use of ERD is essential to assess automatically the resource consumptions for all the assessment scales in order to identify contributions and hotpots. In the following figure has been shown the role of ERD interface at level of inventory analysis.

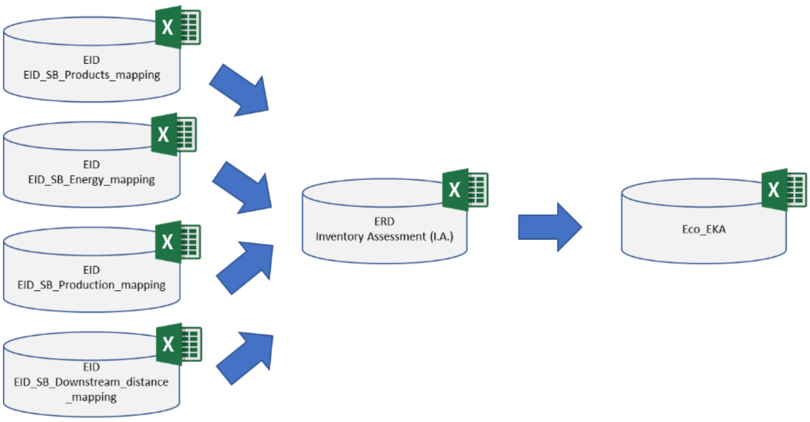


Figure 102 Simplified flowchart of ERD_Inventory_Assessment Part

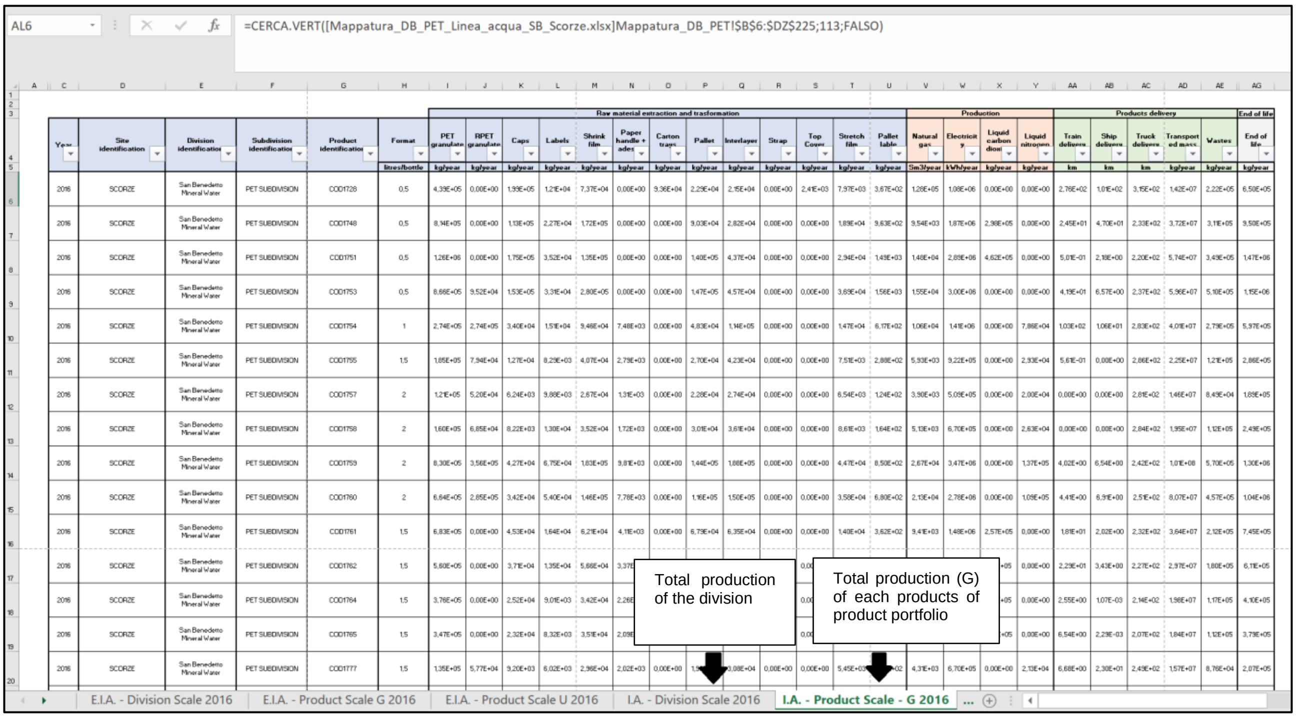


Figure 103 The ERD interface structures inventory results for the different assessment scales.

The previously figure shows a screenshot of ERD interface, it fills automatically the inventory consumption matrices, loading data from EID interfaces in order to collect all inventory results for simplified the interpretation of the results and the successively performance tracking assessment (with Eco-EKA). In fact, the ERD permits to structure inventory results in matrices adapted to the calculation of IOPIs. For every assessment year a historical copy of ERD interface has saved.

3.2.1.2.5.1. Inventory resource consumptions – Division and sites assessment scale

In the table 42 has been shown an example of the results returned by the ERD interface at inventory level for the organizational scale. In this case the ERD interface permits to assess the global consumptions of inventory resources for the total production of products related to the San Benedetto Italian PET Water Division and the contributions of the single productive sites. These results are very important to assess rapidly the trend of the organization. The different columns are associated to different life cycle processes. This table in ERD is a matrix auto compiled. These results have been obtained also for the glass division.

3.2.1.2.5.2. Inventory resource consumptions – Product assessment scale

Instead, in the table 43 has been shown an example of the results returned by the ERD interface at inventory level for the product scale. In this case the ERD interface permits to assess the specific consumptions of inventory resources for the total production of every product code of the San Benedetto Italian PET Water Division. These results are strategic to assess the contributions of different products to the inventory consumptions of the organization. The different columns are associated to different life cycle processes. This table in ERD is a matrix auto compiled. These results have been obtained also for the glass products.

3.2.1.2.5.3. Inventory resource consumptions – Process assessment scale

At the process scale significant information are provided by the tables 42 and 43 inasmuch the columns represent the main life cycle processes. However, detailed matrixes on specific production processes consumptions, for example for bottling processes are available as demonstrated by EID interfaces that collects many data at process scale (e.g. energy consumptions for every machinery).

			Raw material extraction and transformation													Production				Products delivery					End of life
Site identification	Division identification	Subdivision identification	PET granulate	RPET granulate	Caps	Labels	Shrink film	Paper handle + adhesive	Carton trays	Pallet	Interlayer	Strap	Top Cover	Stretch film	Pallet label	Natural gas	Electricity	Liquid carbon dioxide	Liquid nitrogen	Train delivery	Ship delivery	Truck delivery	Transported mass	Wastes	Wastes
			kg/year	kg/year	kg/year	kg/year	kg/year	kg/year	kg/year	kg/year	kg/year	kg/year	kg/year	kg/year	kg/year	Sm3/year	kWh/year	kg/year	kg/year	km	km	km	kg/year	kg/year	kg/year
SCORZE	San Benedetto Mineral Water	PET SUBDIVISION	1,54E+07	1,63E+06	1,89E+06	5,84E+05	2,43E+06	6,53E+04	1,70E+05	1,88E+06	1,93E+06	2,52E+04	3,37E+03	4,71E+05	1,67E+04	4,92E+05	4,36E+07	2,50E+06	5,69E+05	3,20E+01	4,88E+02	2,97E+02	9,88E+08	7,00E+06	1,95E+07
POPOLI	San Benedetto Mineral Water	PET SUBDIVISION	3,29E+06	0,00E+00	3,03E+05	1,01E+05	5,00E+05	1,09E+04	0,00E+00	2,85E+05	2,98E+05	0,00E+00	0,00E+00	7,13E+04	1,52E+03	3,31E+05	1,09E+07	1,77E+05	7,32E+04	6,00E-01	5,10E+01	2,43E+02	2,98E+08	1,17E+06	3,69E+06
VIGGIANELLO	San Benedetto Mineral Water	PET SUBDIVISION	2,30E+06	8,63E+03	1,34E+05	6,11E+04	2,82E+05	1,58E+04	0,00E+00	2,15E+05	3,47E+05	0,00E+00	0,00E+00	7,47E+04	1,15E+03	0,00E+00	3,60E+06	0,00E+00	0,00E+00	0,00E+00	2,80E+00	3,65E+02	1,80E+08	9,36E+05	2,50E+06
DONATO	San Benedetto Mineral Water	PET SUBDIVISION	1,07E+06	0,00E+00	1,35E+05	2,82E+04	1,12E+05	1,86E+03	0,00E+00	8,25E+04	1,51E+05	0,00E+00	0,00E+00	3,47E+04	5,00E+02	0,00E+00	1,75E+06	2,85E+05	1,88E+03	0,00E+00	0,00E+00	1,50E+02	5,86E+07	3,83E+05	1,23E+06
ATELLA	San Benedetto Mineral Water	PET SUBDIVISION	1,03E+05	0,00E+00	6,61E+03	1,68E+03	7,54E+03	0,00E+00	0,00E+00	5,32E+03	9,01E+03	0,00E+00	8,14E+02	1,85E+03	2,52E+01	7,52E+04	9,70E+03	4,20E+03	0,00E+00	0,00E+00	2,50E+00	3,97E+02	3,23E+06	2,46E+04	1,11E+05
TOTAL ITALIAN SAN BENEDETTO WATER DIVISION	San Benedetto Mineral Water	TOTAL PET SUBDIVISION	2,22E+07	1,64E+06	2,47E+06	7,76E+05	3,34E+06	9,39E+04	1,70E+05	2,46E+06	2,74E+06	2,52E+04	4,19E+03	6,54E+05	1,99E+04	8,98E+05	5,98E+07	2,97E+06	6,44E+05	2,08E+01	3,26E+02	2,89E+02	1,53E+09	9,51E+06	2,70E+07

Table 42 ERD results- Inventory resource consumptions – Organizational scale

					Raw material extraction and transformation													Production				Products delivery					End of life
Site identification	Division identification	Subdivision identification	Product identification	Format	PET granulate	RPET granulate	Caps	Labels	Shrink film	Paper handle + adhesive	Carton trays	Pallet	Interlayer	Strap	Top Cover	Stretch film	Pallet label	Natural gas	Electricity	Liquid carbon dioxide	Liquid nitrogen	Train delivery	Ship delivery	Truck delivery	Transported mass	Wastes	End of life
				litres/bottle	kg/year	kg/year	kg/year	kg/year	kg/year	kg/year	kg/year	kg/year	kg/year	kg/year	kg/year	kg/year	kg/year	Sm3/year	kWh/year	kg/year	kg/year	km	km	km	kg/year	kg/year	kg/year
SCORZE	San Benedetto Mineral Water	PET SUBDIVISION	COD1728	0,5	4,4E+05	0,0E+00	2,0E+05	1,2E+04	7,4E+04	0,0E+00	9,4E+04	2,3E+04	2,1E+04	0,0E+00	2,4E+03	8,0E+03	3,7E+02	1,3E+05	1,1E+06	0,0E+00	0,0E+00	2,8E+02	1,0E+02	3,2E+02	1,4E+07	2,2E+05	6,5E+05
SCORZE	San Benedetto Mineral Water	PET SUBDIVISION	COD1748	0,5	8,1E+05	0,0E+00	1,1E+05	2,3E+04	1,7E+05	0,0E+00	0,0E+00	9,0E+04	2,8E+04	0,0E+00	0,0E+00	1,9E+04	9,6E+02	9,5E+03	1,9E+06	3,0E+05	0,0E+00	2,5E+01	4,7E+01	2,3E+02	3,7E+07	3,1E+05	9,5E+05
SCORZE	San Benedetto Mineral Water	PET SUBDIVISION	COD1751	0,5	1,3E+06	0,0E+00	1,7E+05	3,5E+04	1,3E+05	0,0E+00	0,0E+00	1,4E+05	4,4E+04	0,0E+00	0,0E+00	2,9E+04	1,5E+03	1,5E+04	2,9E+06	4,6E+05	0,0E+00	5,0E-01	2,2E+00	2,2E+02	5,7E+07	3,5E+05	1,5E+06
SCORZE	San Benedetto Mineral Water	PET SUBDIVISION	COD1753	0,5	8,7E+05	9,5E+04	1,5E+05	3,3E+04	2,8E+05	0,0E+00	0,0E+00	1,5E+05	4,6E+04	0,0E+00	0,0E+00	3,7E+04	1,6E+03	1,5E+04	3,0E+06	0,0E+00	0,0E+00	4,2E+01	6,6E+00	2,4E+02	6,0E+07	5,1E+05	1,1E+06
SCORZE	San Benedetto Mineral Water	PET SUBDIVISION	COD1754	1	2,7E+05	2,7E+05	3,4E+04	1,5E+04	9,5E+04	7,5E+03	0,0E+00	4,8E+04	1,1E+05	0,0E+00	0,0E+00	1,5E+04	6,2E+02	1,1E+04	1,4E+06	0,0E+00	7,9E+04	1,0E+02	1,1E+01	2,8E+02	4,0E+07	2,8E+05	6,0E+05
SCORZE	San Benedetto Mineral Water	PET SUBDIVISION	COD1755	1,5	1,9E+05	7,9E+04	1,3E+04	8,3E+03	4,1E+04	2,8E+03	0,0E+00	2,7E+04	4,2E+04	0,0E+00	0,0E+00	7,5E+03	2,9E+02	5,9E+03	9,2E+05	0,0E+00	2,9E+04	5,6E-01	0,0E+00	2,9E+02	2,3E+07	1,2E+05	2,9E+05
SCORZE	San Benedetto Mineral Water	PET SUBDIVISION	COD1757	2	1,2E+05	5,2E+04	6,2E+03	9,9E+03	2,7E+04	1,3E+03	0,0E+00	2,3E+04	2,7E+04	0,0E+00	0,0E+00	6,5E+03	1,2E+02	3,9E+03	5,1E+05	0,0E+00	2,0E+04	0,0E+00	0,0E+00	2,8E+02	1,5E+07	8,5E+04	1,9E+05
SCORZE	San Benedetto Mineral Water	PET SUBDIVISION	COD1758	2	1,6E+05	6,8E+04	8,2E+03	1,3E+04	3,5E+04	1,7E+03	0,0E+00	3,0E+04	3,6E+04	0,0E+00	0,0E+00	8,6E+03	1,6E+02	5,1E+03	6,7E+05	0,0E+00	2,6E+04	0,0E+00	0,0E+00	2,8E+02	2,0E+07	1,1E+05	2,5E+05
SCORZE	San Benedetto Mineral Water	PET SUBDIVISION	COD1759	2	8,3E+05	3,6E+05	4,3E+04	6,8E+04	1,8E+05	9,8E+03	0,0E+00	1,4E+05	1,9E+05	0,0E+00	0,0E+00	4,5E+04	8,5E+02	2,7E+04	3,5E+06	0,0E+00	1,4E+05	4,0E+00	6,5E+00	2,4E+02	1,0E+08	5,7E+05	1,3E+06
SCORZE	San Benedetto Mineral Water	PET SUBDIVISION	COD1760	2	6,6E+05	2,8E+05	3,4E+04	5,4E+04	1,5E+05	7,8E+03	0,0E+00	1,2E+05	1,5E+05	0,0E+00	0,0E+00	3,6E+04	6,8E+02	2,1E+04	2,8E+06	0,0E+00	1,1E+05	4,4E+00	6,9E+00	2,5E+02	8,1E+07	4,6E+05	1,0E+06
SCORZE	San Benedetto Mineral Water	PET SUBDIVISION	COD1761	1,5	6,8E+05	0,0E+00	4,5E+04	1,6E+04	6,2E+04	4,1E+03	0,0E+00	6,8E+04	6,4E+04	0,0E+00	0,0E+00	1,4E+04	3,6E+02	9,4E+03	1,5E+06	2,6E+05	0,0E+00	1,8E+01	2,0E+00	2,3E+02	3,6E+07	2,1E+05	7,4E+05
SCORZE	San Benedetto Mineral Water	PET SUBDIVISION	COD1762	1,5	5,6E+05	0,0E+00	3,7E+04	1,3E+04	5,7E+04	3,4E+03	0,0E+00	5,6E+04	5,2E+04	0,0E+00	0,0E+00	1,2E+04	3,0E+02	7,7E+03	1,2E+06	2,1E+05	0,0E+00	2,3E+01	3,4E+00	2,3E+02	3,0E+07	1,8E+05	6,1E+05
SCORZE	San Benedetto Mineral Water	PET SUBDIVISION	COD1764	1,5	3,8E+05	0,0E+00	2,5E+04	9,0E+03	3,4E+04	2,3E+03	0,0E+00	3,7E+04	3,5E+04	0,0E+00	0,0E+00	8,4E+03	2,0E+02	5,2E+03	8,1E+05	1,2E+05	0,0E+00	2,6E+00	1,1E-03	2,1E+02	2,0E+07	1,2E+05	4,1E+05
SCORZE	San Benedetto Mineral Water	PET SUBDIVISION	COD1765	1,5	3,5E+05	0,0E+00	2,3E+04	8,3E+03	3,5E+04	2,1E+03	0,0E+00	3,5E+04	3,2E+04	0,0E+00	0,0E+00	7,8E+03	1,8E+02	4,8E+03	7,5E+05	1,1E+05	0,0E+00	6,5E+00	2,3E-03	2,1E+02	1,8E+07	1,1E+05	3,8E+05
SCORZE	San Benedetto Mineral Water	PET SUBDIVISION	COD1777	1,5	1,3E+05	5,8E+04	9,2E+03	6,0E+03	3,0E+04	2,0E+03	0,0E+00	2,0E+04	3,1E+04	0,0E+00	0,0E+00	5,5E+03	2,1E+02	4,3E+03	6,7E+05	0,0E+00	2,1E+04	6,7E+00	2,3E+01	2,5E+02	1,6E+07	8,8E+04	2,1E+05
SCORZE	San Benedetto Mineral Water	PET SUBDIVISION	OTHER PRODUCTS	-	7,7E+06	3,7E+05	9,7E+05	2,6E+05	1,0E+06	2,1E+04	7,6E+04	8,7E+05	1,0E+06	2,5E+04	9,7E+02	2,1E+05	8,3E+03	2,2E+05	2,0E+07	1,1E+06	1,5E+05	- 4,8E+02	2,8E+02	- 3,5E+03	4,2E+08	3,3E+06	9,3E+06

Table 43 ERD results- Inventory resource consumptions – Product scale

3.2.1.3. Life Cycle Environmental Impact Assessment

The impact assessment stage permits to identify the environmental impacts generated by the organization with a multiscale perspective. In fact, the OES2 introduce the innovative MLCA model that permits to assess environmental impacts for all the scales: organization, singe site, single products and life cycle processes. In the following paragraph have been descripted the implementation of:

- the MLCA SimaPro model;
- the Environmental Results Database (ERD) – Environmental Impact Analysis Part.

3.2.1.3.1. Multiscale LCA (MLCA) model

The MLCA model is the innovative model proposed in OES2 for the multiscale assessment of the environmental impacts. The impacts can be study consistently with a top down approach or a bottom up approach in function of the organization needs. The MCLA model has been developing with SimaPro programming language. The model has been developed modelling all the inventory flows and the life cycle processes for all products realized by the organization. In figure 104 have been shown some processes modelled in SimaPro. Details on theoretical methodology have been provided in chapter 2. The model has the characteristics to be very detailed, in fact, for example the bottling process have been distinguished for specific bottling lines, while, the process of bottle production has been distinguished in function of specific machinery and specific bottle design specification. In fact, for example the same product code that is produced from two different bottling lines, has been modelled considering separately the two bottling processes inasmuch differences in terms of performance can be existing (e.g. energy consumption, chemical consumptions, packaging components (e.g. one of the two bottling lines can work with a film stretch of lesser grammage respect to the other bottling line)). This choice makes the model able to assess the real differences in terms of environmental performance of different products and different technologies. Furthermore, this choice is consistently with the very detailed inventory analysis performed with EID interfaces. The SimaPro software permits to model inventory flows and life cycle processes creating modules. The modules have a standard structure. The compilation of the modules requires to specify inputs (for example from natural resources, from technosfera that are pre-processed raw materials, etc.) and outputs (to following life cycle process, to waste disposal processes or to environmental compartment (emissions to water, air, ground)) that are requested for the production of the specified quantity of inventory flow or processes modelled. The MLCA model has been developed using a mass and energy balance approach, where the mass and the energy that exit from a process are the same that enter in the next process in order to ensure the respect of mass and energy balances. A very large number of modules have been created in SimaPro, one for each different inventory flow and life cycle processes identified during the inventory data collection. In this way have been modelled:

- All raw materials and auxiliary materials with specific information on the transports (consistently with data acquired by EID_SB_Upstram_distance_mapping);
- All products and packaging components (consistently with data acquired by EID_SB_Products_mapping);
- All production processes specifically for each bottling lines and each machinery for bottle production (consistently with data acquired by EID_SB_Production_mapping, EID_SB_Energy_mapping, EID_SB_Chemicals_mapping and EID_SB_EnvironmentalServices_mapping);
- All delivery transports specifically for each product (consistently with data acquired by EID_SB_Downstream_mapping);
- The usage stage and the end of life stage for each product.

The connections of the different modules flows have been performed following the real succession of the life cycle processes and the real relationship between processes and inventory flows.

The high complexity of the model has been compensate introducing two innovative solutions:

- The multiparametric programming, that permits to define variables and mathematical functions to model the inputs and the outputs of each modules. An example of multiparametric programming is shown in figure 105.
- The connection with EID interfaces, that permits the automatic load of all inventory data to the modules. The connection off EID interfaces and MLCA SimaPro model has required the programming of specific links, an example has been shown in figure 106.

The realized MLCA model has been shown in the figures 107, 108, 109, 110 respectively for the total San Benedetto Italian Mineral Water Division, for the Scorzè site, for the production of a specific product and for a specific bottle production process in order to give evidence of the multiscale assessment capacity of the MLCA model developed. As it is possible to notice, the MLCA model permits a complete life cycle assessment and management.

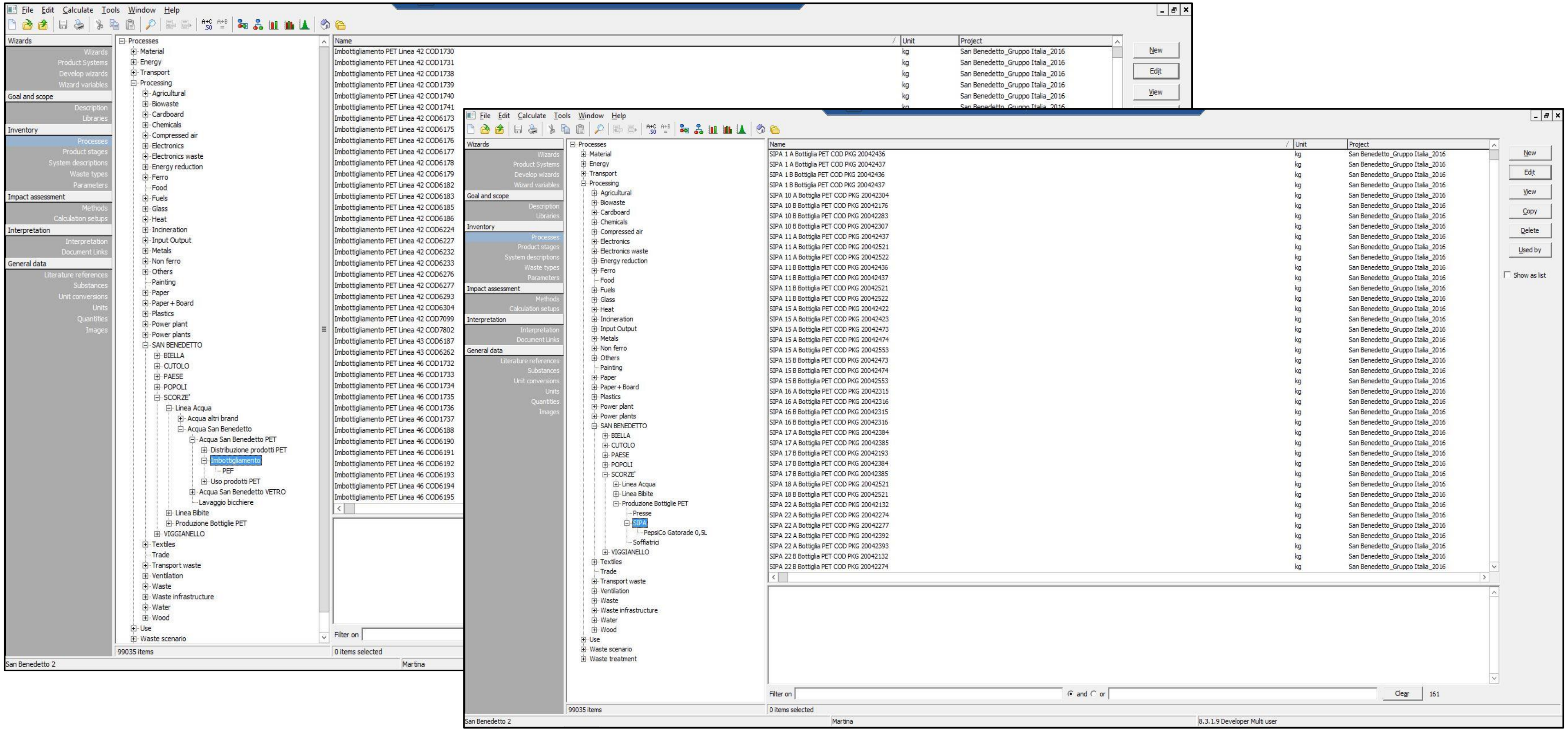


Figure 104 Example of list of bottling processes and bottle production processes modelled in the SimaPro with specific reference to each machinery and specific product code a bottle code realized.

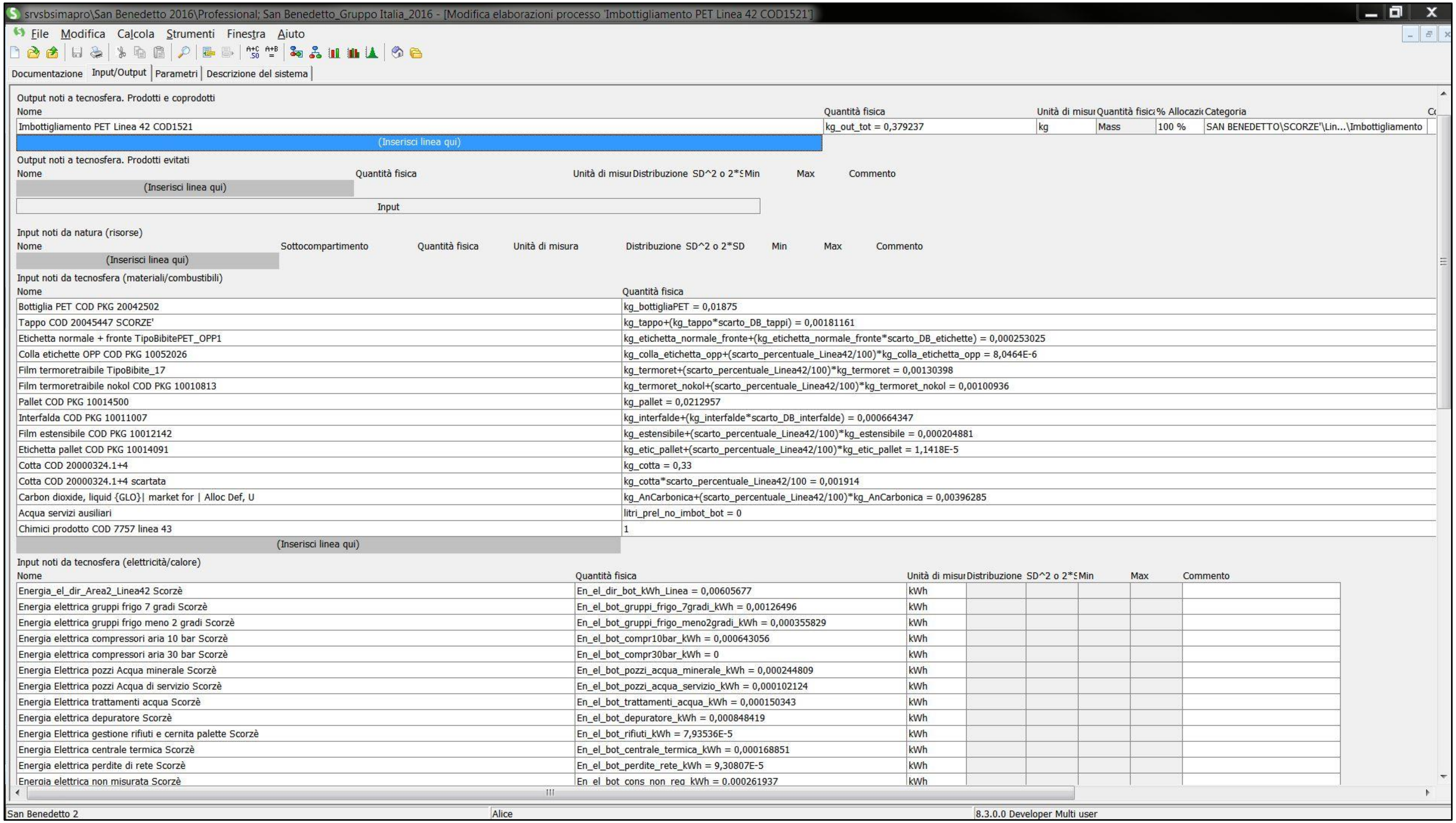
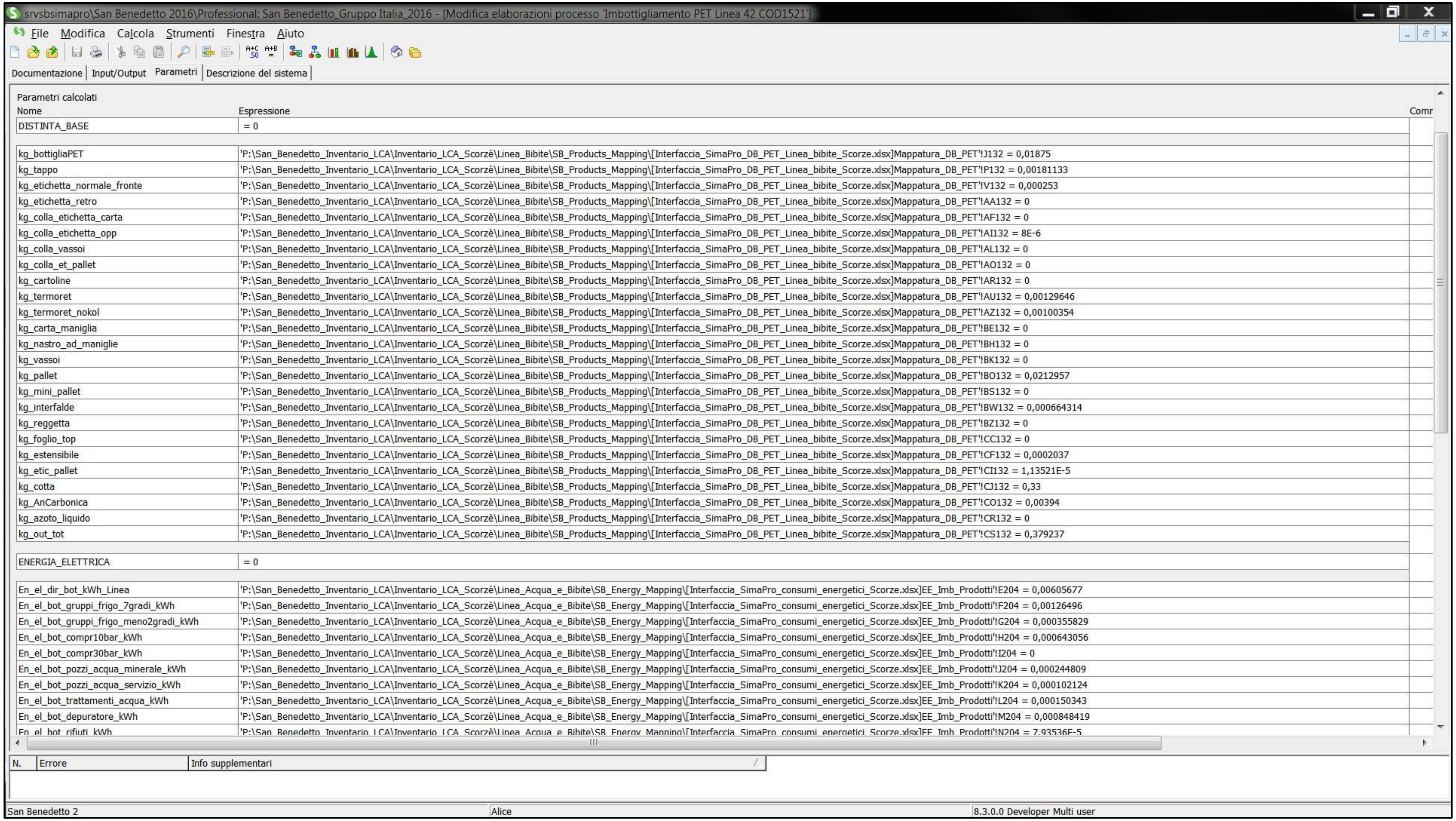


Figure 105 Example of multiparametric programming for a bottling process.



srvsbsimapro\San Benedetto 2016\Professional; San Benedetto_Gruppo Italia_2016 - [Modifica elaborazioni processo 'Imbottigliamento PET Linea 42 COD1521']

File Modifica Calcola Strumenti Finestra Aiuto

Documentazione | Input/Output | Parametri | Descrizione del sistema

Parametri calcolati

Nome	Espressione
DISTINTA_BASE	= 0
kg_bottigliaPET	'P:\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Bibite\SB_Products_Mapping\[Interfaccia_SimaPro_DB_PET_Linea_bibite_Scorze.xlsx]Mappatura_DB_PET'!J132 = 0,01875
kg_tappo	'P:\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Bibite\SB_Products_Mapping\[Interfaccia_SimaPro_DB_PET_Linea_bibite_Scorze.xlsx]Mappatura_DB_PET'!P132 = 0,00181133
kg_etichetta_normale_fronte	'P:\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Bibite\SB_Products_Mapping\[Interfaccia_SimaPro_DB_PET_Linea_bibite_Scorze.xlsx]Mappatura_DB_PET'!V132 = 0,000253
kg_etichetta_retro	'P:\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Bibite\SB_Products_Mapping\[Interfaccia_SimaPro_DB_PET_Linea_bibite_Scorze.xlsx]Mappatura_DB_PET'!AA132 = 0
kg_colla_etichetta_carta	'P:\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Bibite\SB_Products_Mapping\[Interfaccia_SimaPro_DB_PET_Linea_bibite_Scorze.xlsx]Mappatura_DB_PET'!AF132 = 0
kg_colla_etichetta_opp	'P:\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Bibite\SB_Products_Mapping\[Interfaccia_SimaPro_DB_PET_Linea_bibite_Scorze.xlsx]Mappatura_DB_PET'!AI132 = 8E-6
kg_colla_vassoi	'P:\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Bibite\SB_Products_Mapping\[Interfaccia_SimaPro_DB_PET_Linea_bibite_Scorze.xlsx]Mappatura_DB_PET'!AL132 = 0
kg_colla_et_pallet	'P:\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Bibite\SB_Products_Mapping\[Interfaccia_SimaPro_DB_PET_Linea_bibite_Scorze.xlsx]Mappatura_DB_PET'!AO132 = 0
kg_cartoline	'P:\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Bibite\SB_Products_Mapping\[Interfaccia_SimaPro_DB_PET_Linea_bibite_Scorze.xlsx]Mappatura_DB_PET'!AR132 = 0
kg_termoret	'P:\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Bibite\SB_Products_Mapping\[Interfaccia_SimaPro_DB_PET_Linea_bibite_Scorze.xlsx]Mappatura_DB_PET'!AU132 = 0,00129646
kg_termoret_nokol	'P:\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Bibite\SB_Products_Mapping\[Interfaccia_SimaPro_DB_PET_Linea_bibite_Scorze.xlsx]Mappatura_DB_PET'!AZ132 = 0,00100354
kg_carta_maniglia	'P:\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Bibite\SB_Products_Mapping\[Interfaccia_SimaPro_DB_PET_Linea_bibite_Scorze.xlsx]Mappatura_DB_PET'!BE132 = 0
kg_nastro_ad_maniglie	'P:\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Bibite\SB_Products_Mapping\[Interfaccia_SimaPro_DB_PET_Linea_bibite_Scorze.xlsx]Mappatura_DB_PET'!BH132 = 0
kg_vassoi	'P:\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Bibite\SB_Products_Mapping\[Interfaccia_SimaPro_DB_PET_Linea_bibite_Scorze.xlsx]Mappatura_DB_PET'!BK132 = 0
kg_pallet	'P:\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Bibite\SB_Products_Mapping\[Interfaccia_SimaPro_DB_PET_Linea_bibite_Scorze.xlsx]Mappatura_DB_PET'!BO132 = 0,0212957
kg_mini_pallet	'P:\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Bibite\SB_Products_Mapping\[Interfaccia_SimaPro_DB_PET_Linea_bibite_Scorze.xlsx]Mappatura_DB_PET'!BS132 = 0
kg_interfalde	'P:\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Bibite\SB_Products_Mapping\[Interfaccia_SimaPro_DB_PET_Linea_bibite_Scorze.xlsx]Mappatura_DB_PET'!BW132 = 0,000664314
kg_reggetta	'P:\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Bibite\SB_Products_Mapping\[Interfaccia_SimaPro_DB_PET_Linea_bibite_Scorze.xlsx]Mappatura_DB_PET'!BZ132 = 0
kg_foglio_top	'P:\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Bibite\SB_Products_Mapping\[Interfaccia_SimaPro_DB_PET_Linea_bibite_Scorze.xlsx]Mappatura_DB_PET'!CC132 = 0
kg_estensibile	'P:\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Bibite\SB_Products_Mapping\[Interfaccia_SimaPro_DB_PET_Linea_bibite_Scorze.xlsx]Mappatura_DB_PET'!CF132 = 0,0002037
kg_etic_pallet	'P:\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Bibite\SB_Products_Mapping\[Interfaccia_SimaPro_DB_PET_Linea_bibite_Scorze.xlsx]Mappatura_DB_PET'!CI132 = 1,13521E-5
kg_cotta	'P:\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Bibite\SB_Products_Mapping\[Interfaccia_SimaPro_DB_PET_Linea_bibite_Scorze.xlsx]Mappatura_DB_PET'!CJ132 = 0,33
kg_AnCarbonica	'P:\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Bibite\SB_Products_Mapping\[Interfaccia_SimaPro_DB_PET_Linea_bibite_Scorze.xlsx]Mappatura_DB_PET'!CO132 = 0,00394
kg_azoto_liquido	'P:\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Bibite\SB_Products_Mapping\[Interfaccia_SimaPro_DB_PET_Linea_bibite_Scorze.xlsx]Mappatura_DB_PET'!CR132 = 0
kg_out_tot	'P:\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Bibite\SB_Products_Mapping\[Interfaccia_SimaPro_DB_PET_Linea_bibite_Scorze.xlsx]Mappatura_DB_PET'!CS132 = 0,379237
ENERGIA_ELETTRICA	= 0
En_el_dir_bot_kWh_Linea	'P:\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Acqua_e_Bibite\SB_Energy_Mapping\[Interfaccia_SimaPro_consumi_energetici_Scorze.xlsx]EE_Imb_Prodotti'!E204 = 0,00605677
En_el_bot_gruppi_frigo_7gradi_kWh	'P:\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Acqua_e_Bibite\SB_Energy_Mapping\[Interfaccia_SimaPro_consumi_energetici_Scorze.xlsx]EE_Imb_Prodotti'!F204 = 0,00126496
En_el_bot_gruppi_frigo_meno2gradi_kWh	'P:\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Acqua_e_Bibite\SB_Energy_Mapping\[Interfaccia_SimaPro_consumi_energetici_Scorze.xlsx]EE_Imb_Prodotti'!G204 = 0,000355829
En_el_bot_compr10bar_kWh	'P:\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Acqua_e_Bibite\SB_Energy_Mapping\[Interfaccia_SimaPro_consumi_energetici_Scorze.xlsx]EE_Imb_Prodotti'!H204 = 0,000643056
En_el_bot_compr30bar_kWh	'P:\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Acqua_e_Bibite\SB_Energy_Mapping\[Interfaccia_SimaPro_consumi_energetici_Scorze.xlsx]EE_Imb_Prodotti'!I204 = 0
En_el_bot_pozzi_acqua_minerale_kWh	'P:\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Acqua_e_Bibite\SB_Energy_Mapping\[Interfaccia_SimaPro_consumi_energetici_Scorze.xlsx]EE_Imb_Prodotti'!J204 = 0,000244809
En_el_bot_pozzi_acqua_servizio_kWh	'P:\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Acqua_e_Bibite\SB_Energy_Mapping\[Interfaccia_SimaPro_consumi_energetici_Scorze.xlsx]EE_Imb_Prodotti'!K204 = 0,000102124
En_el_bot_trattamenti_acqua_kWh	'P:\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Acqua_e_Bibite\SB_Energy_Mapping\[Interfaccia_SimaPro_consumi_energetici_Scorze.xlsx]EE_Imb_Prodotti'!L204 = 0,000150343
En_el_bot_depuratore_kWh	'P:\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Acqua_e_Bibite\SB_Energy_Mapping\[Interfaccia_SimaPro_consumi_energetici_Scorze.xlsx]EE_Imb_Prodotti'!M204 = 0,000848419
En_el_bot_rifiuti_kWh	'P:\San_Benedetto_Inventario_LCA\Inventario_LCA_Scorzè\Linea_Acqua_e_Bibite\SB_Energy_Mapping\[Interfaccia_SimaPro_consumi_energetici_Scorze.xlsx]EE_Imb_Prodotti'!N204 = 7,93536E-5

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San Benedetto 2 | Alice | 8.3.0.0 Developer Multi user

Figure 106 Example of programmed links between EID interfaces and modules of MLCA SimaPro model

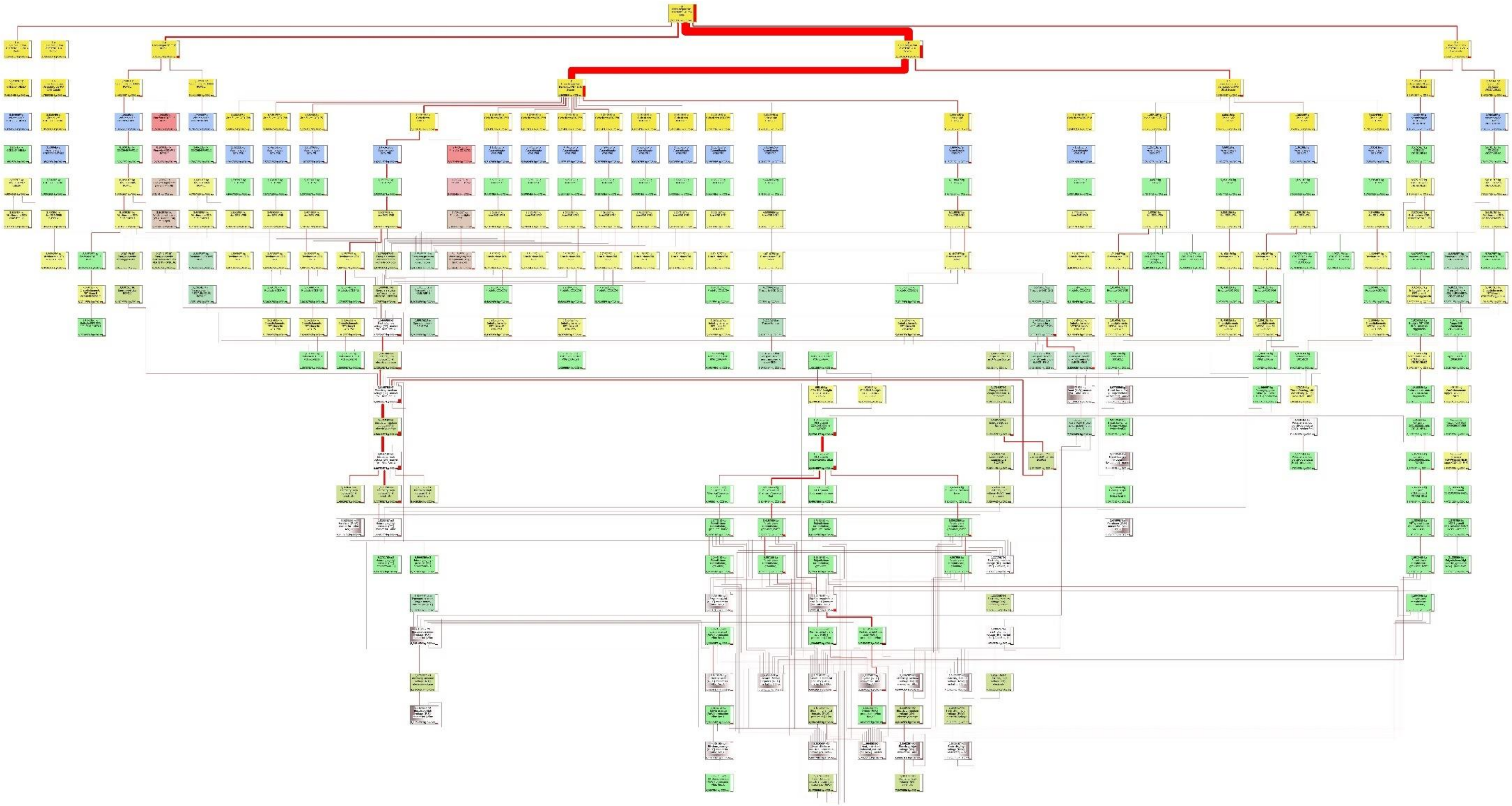


Figure 107 MLCA model, San Benedetto Italian Mineral Water Division

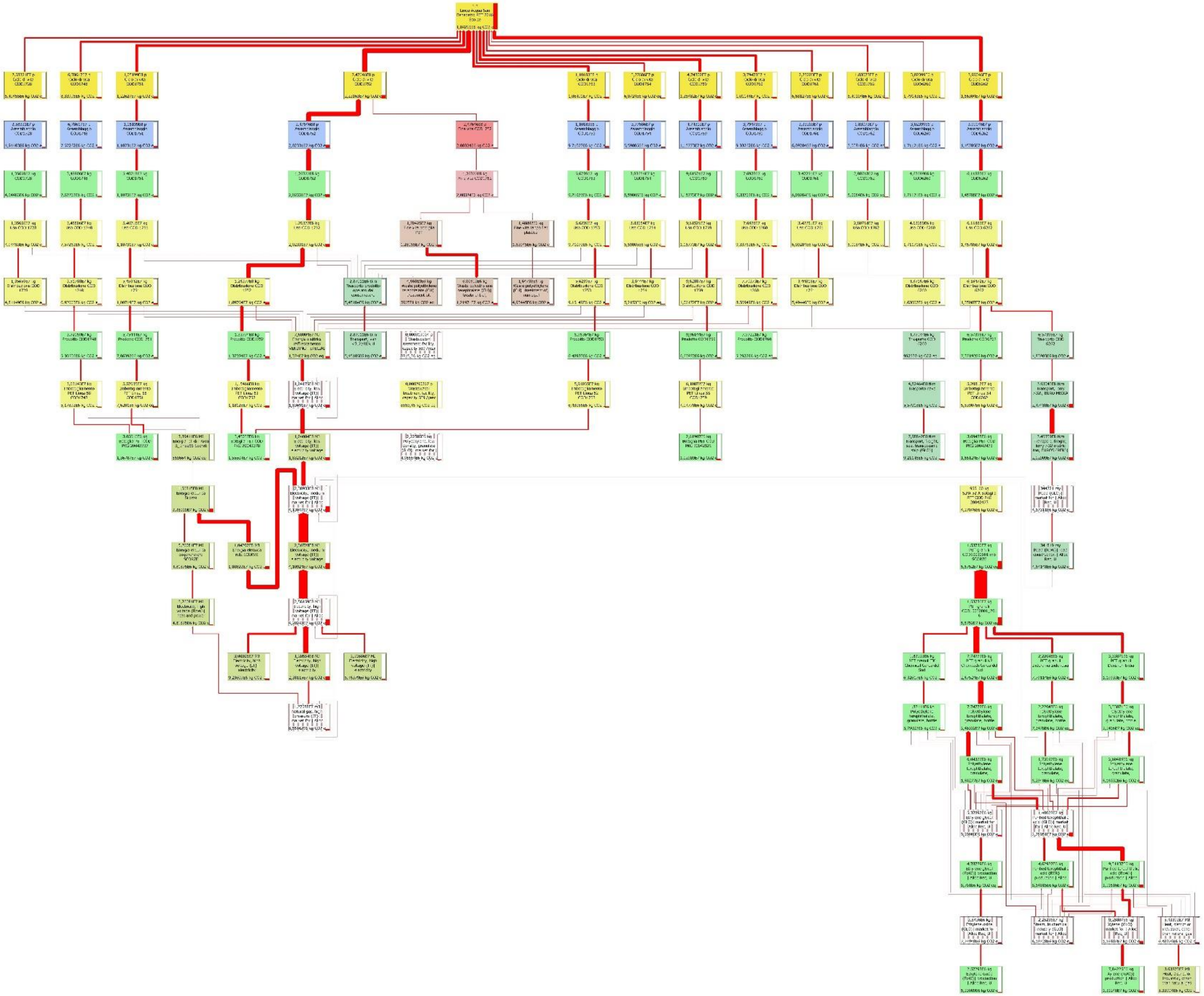


Figure 108 MLCA model, Scorzè (VE) production site.

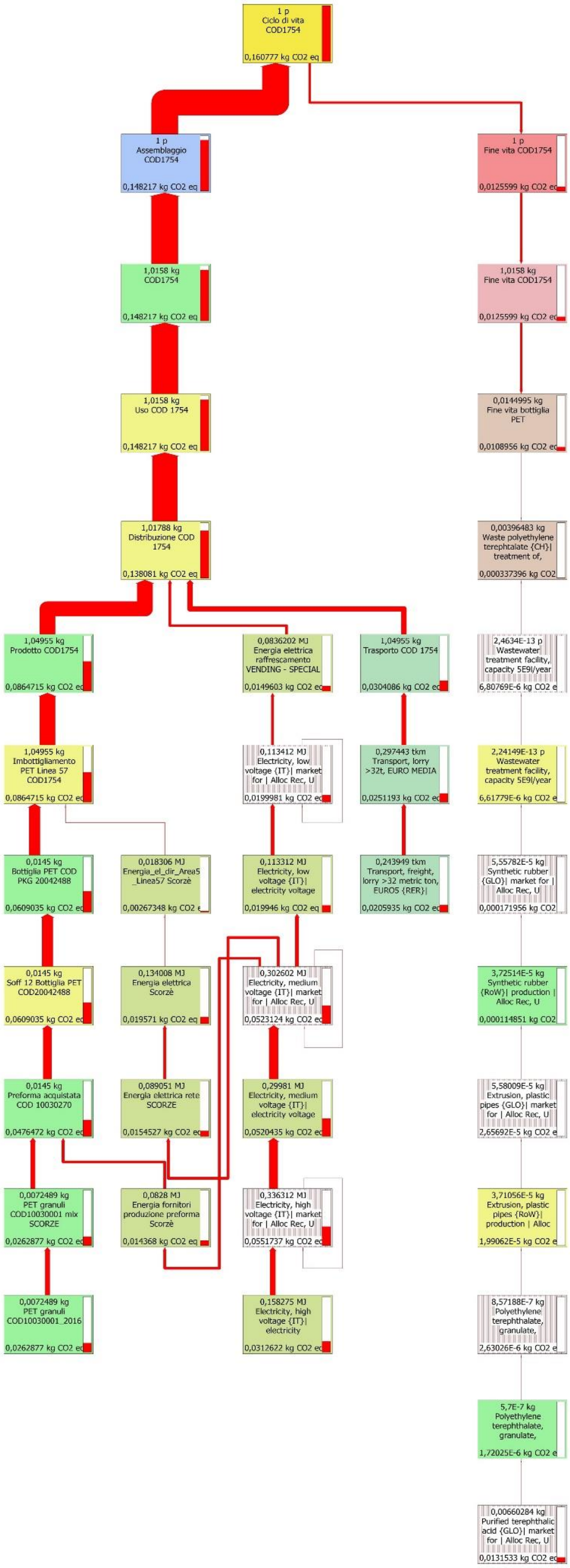


Figure 109 MLCA model, specific product

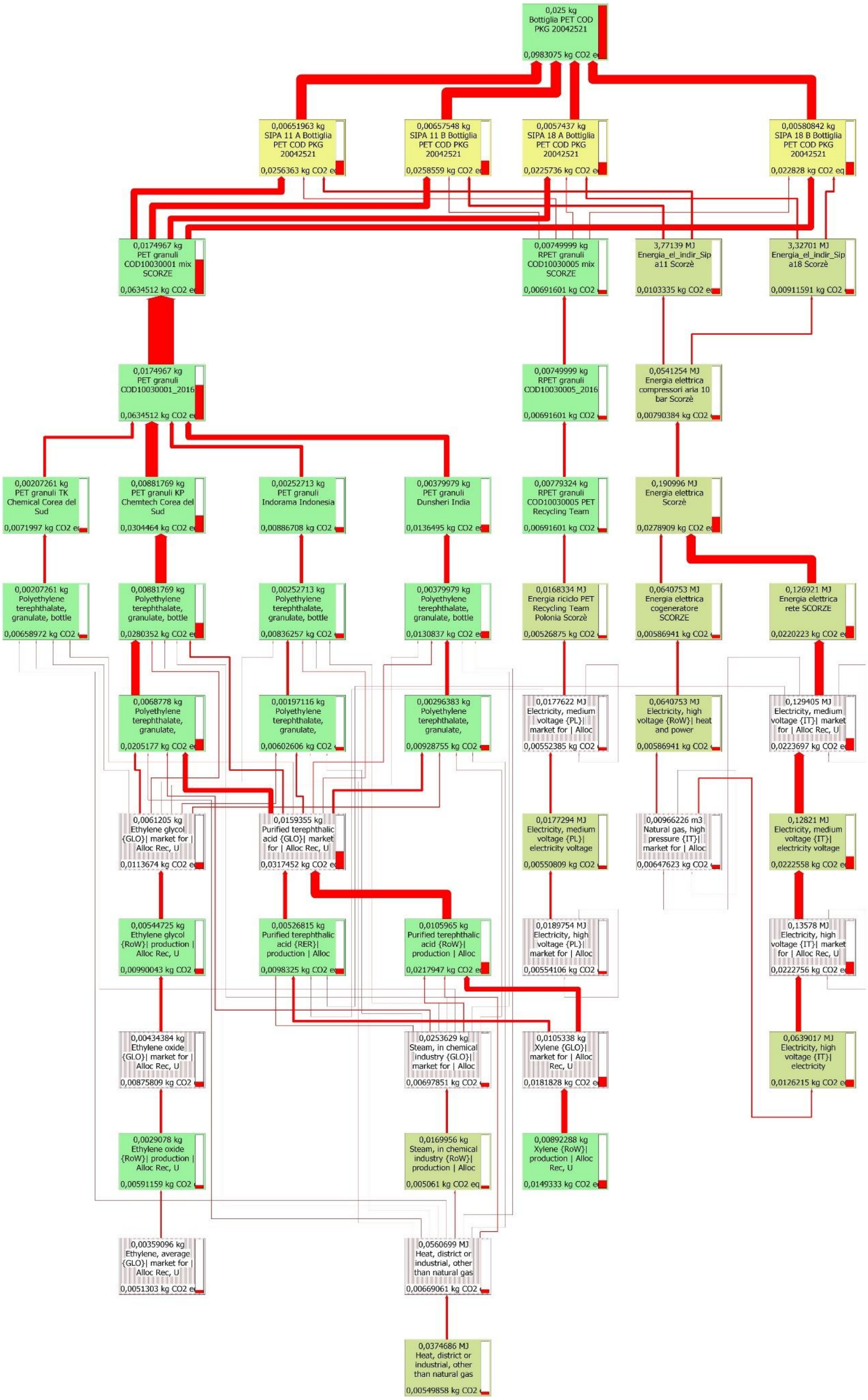


Figure 110 MLCA model, specific bottling process

3.2.1.3.2. Environmental impacts assessment results management: The application of ERD interface

The Environmental Results Database introduced by OES2 permits also the automatic environmental impact assessment analysis. The use of ERD is essential to manage automatically the results regarding the environmental impact for all the assessment scales in order to identify contributions and hotpots. In the following figure has been shown the role of ERD interface at level of impact assessment analysis.

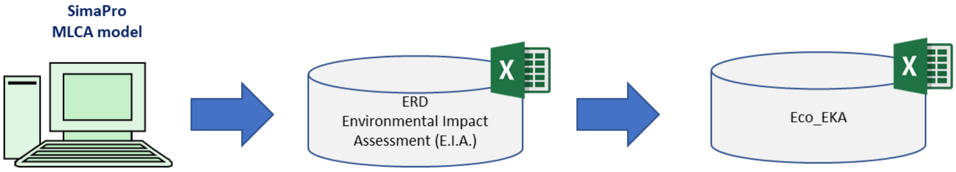


Figure 111 Simplified flowchart of ERD_Environmental_Imppact_Assessment Part

The SimaPro software permits to run one group analysis at a time, therefore the extracted results, especially when many products have been assessed, are fragmented and contained in raw files (see the example below).

	A	B	C	D	E	F	G	H	I
1	SimaPro 8.3.1.9	Impact ass	Date:	18/09/2017	Time:	11:31			
2	Project	San Benedetto_Gruppo Italia_2016							
3									
4									
5	Calculation:	Analyze							
6	Results:	Impact assessment							
7	Product:	1 p Linea Acqua San Benedetto PET 2016 Scorzè (of project San Benedetto_Gruppo Italia_2016)							
8	Method:	IMPACT 2002+ V2.12 / IMPACT 2002+							
9	Indicator:	Characterization							
10	Skip categories:	Never							
11	Exclude infrastructure processes:	No							
12	Exclude long-term emissions:	No							
13	Sorted on item:	Impact category							
14	Sort order:	Ascending							
15									
16	Impact category	Unit	Total	Ciclo di vita COD1323	Ciclo di vit	Ciclo di vit	Ciclo di vit	Ciclo di vit	Ciclo di vit
17	Carcinogens	kg C2H3Cl	24382134	14515,53344	113169	221083	747023,6	385563,8	24859,77
18	Non-carcinogens	kg C2H3Cl	2767934	1370,99145	16967,88	22395,4	72578,78	34530,04	2078,886
19	Respiratory inorganics	kg PM2.5	159734,2	73,08648666	854,2002	1221,495	4052,903	1903,094	103,0815
20	Ionizing radiation	Bq C-14 e	1,89E+09	911865,4384	11384649	16676975	55587001	24161156	1056367
21	Ozone layer depletion	kg CFC-11	17,81038	0,007842751	0,113339	0,151519	0,455426	0,185473	0,007989
22	Respiratory organics	kg C2H4 e	89466,5	44,68287179	499,1483	773,5236	2645,509	1351,847	57,47103
23	Aquatic ecotoxicity	kg TEG w	1,17E+10	5465861,047	77259663	88991592	2,73E+08	1,17E+08	6682682
24	Terrestrial ecotoxicity	kg TEG sc	4,56E+09	1961187,164	32226957	33532687	90721126	36154921	1850772
25	Terrestrial acid/nutri	kg SO2 ec	3073087	1305,124602	15980,46	22471,7	75215,37	35611,15	1732,287
26	Land occupation	m2org.ara	4877685	2124,093911	34457,05	40718,2	116542,3	47649,75	2012,906
27	Aquatic acidification	kg SO2 ec	846657,1	374,0086393	4350,007	6383,653	21672,66	10347,97	520,294
28	Aquatic eutrophication	kg PO4 P-	24878,81	12,27380634	152,66	216,4537	696,6893	302,482	16,25177
29	Global warming	kg CO2 ec	1,73E+08	87042,51699	989607,5	1508749	5126726	2427173	109401,6
30	Non-renewable energy	MJ primar	3,36E+09	1711901,621	18782084	31156851	1,06E+08	52000905	2264641
31	Mineral extraction	MJ surplus	7270120	4083,183283	37354,25	58452,74	199933,2	90438,58	6898,953

	A	J	K	L	M	N	O	P	Q	R	S
16	Impact category	Ciclo di vit	Ciclo di vit	Ciclo di vit	Ciclo di vit	Ciclo di vit	Ciclo di vit	Ciclo di vit	Ciclo di vit	Ciclo di vit	Ciclo di vit
17	Carcinogens	11414,92	316636,2	159865,8	16446,51	199043,1	141369,4	18699,33	8324,866	6575,221	29195,59
18	Non-carcinogens	947,2061	28802,34	14313,48	1610,807	17018,5	12312,66	1666,214	846,9787	673,316	2330,228
19	Respiratory inorganics	46,67837	1532,176	758,3817	84,55537	899,6909	645,1186	117,9836	73,63956	63,86793	125,7086
20	Ionizing radiation	480847,5	17525859	8939207	970038,1	9873610	7272980	1058450	526438	432777,9	1335407
21	Ozone layer depletion	0,003585	0,157128	0,077015	0,009144	0,084695	0,06176	0,009502	0,005352	0,004437	0,010712
22	Respiratory organics	26,22714	859,7513	425,2466	48,18101	503,4789	363,0143	53,58481	28,55565	23,35238	73,07046
23	Aquatic ecotoxicity	3033393	1,1E+08	54569477	6282823	61506431	44751439	6099050	3095133	2451109	7886334
24	Terrestrial ecotoxicity	828790	40451599	19264695	2566058	21496869	16004890	2059386	1074478	812799,2	2536312
25	Terrestrial acid/nutri	786,9369	26807,09	13215,07	1501,648	15542,64	11176,33	2386,097	1625,861	1446,998	2188,084
26	Land occupation	885,8866	42946,58	20444,35	2646,705	22917,59	16807,89	2070,19	1043,883	774,7188	2336,55
27	Aquatic acidification	236,9906	7669,533	3819,424	419,8727	4500,438	3230,342	660,5749	437,0579	387,5808	640,6323
28	Aquatic eutrophication	7,487355	248,6457	127,0905	13,6291	144,7415	106,2569	14,86832	7,055807	5,73227	19,31242
29	Global warming	51072,24	1661174	859342,7	93487,55	964905,9	722779,1	104281,8	51677,8	42941,67	136371,8
30	Non-renewable energy	1034855	33616458	16855234	1837540	19710197	14215586	2009495	1004706	813818,4	2854256
31	Mineral extraction	3199,304	82960,05	43363,07	4556,335	50157,39	37457,45	5083,796	2511,837	2019,456	7025,581

Results extraction

Figure 112 Example of raw results file returned by SimaPro

The ERD permits to automatically load results from raw results files extracted by SimaPro and fills matrices of environmental impacts for all assessment scales. The figure below shows a screenshot of ERD interface, it fills automatically the environmental impact matrices, loading results from files extracted by SimaPro in order to collect all impact assessment results for simplified the interpretation of the results and the successively performance tracking assessment (with Eco-EKA). In fact, the ERD permits to structure also the impact assessment results in matrices adapted to the calculation of EOPIs. For every assessment year a historical copy of ERD interface has saved.

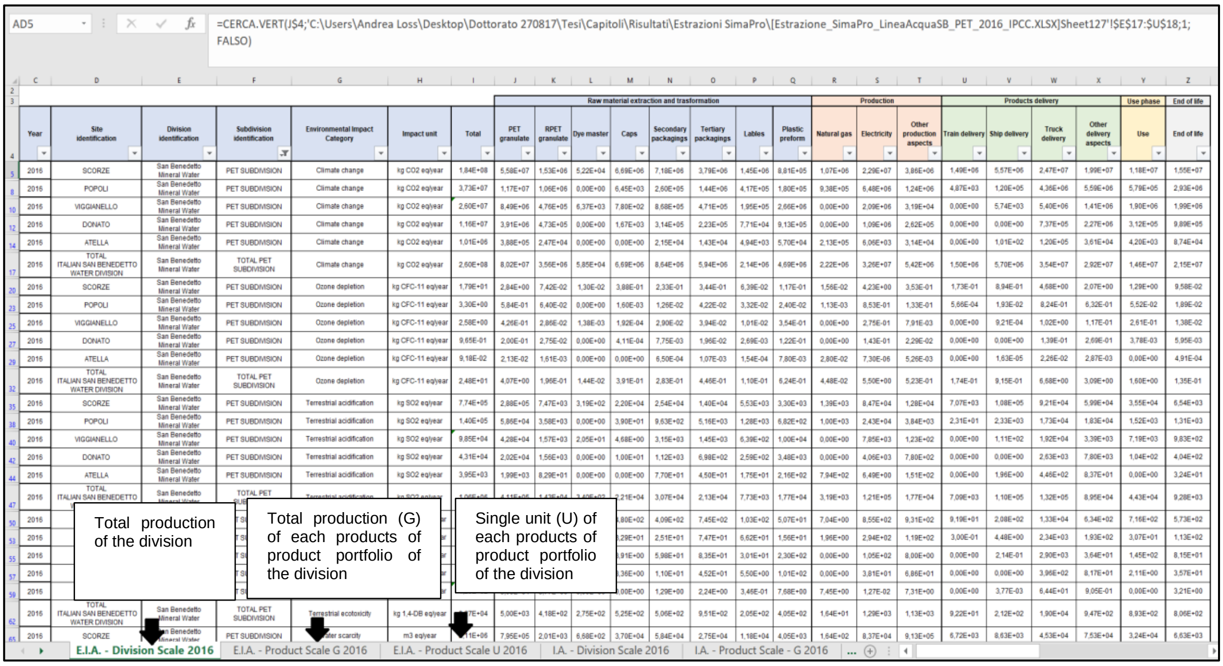


Figure 113 The ERD interface structures environmental impact assessment results for the different assessment scales.

3.2.1.3.2.1. Environmental Impacts – Division and sites assessment scale

In the table 44 have been shown an example of the results returned by the ERD interface at environmental impact level for the organizational scale. In this case the ERD interface permits to assess the global environmental impacts for the total production of products related to the San Benedetto Italian PET Water Division and the contributions of the single productive sites for all international standardized impact categories. These results are very important to assess the OLCA profile and rapidly understand the trend of the organization. The different columns are associated to different life cycle processes. These results have been obtained also for the glass division (table 45).

3.2.1.3.2.2. Environmental Impacts – Product assessment scale

Instead, in the table 46 has been shown an example of the results returned by the ERD interface at environmental impact level for the product scale. In this case the ERD interface permits to assess the specific environmental impact of every product code of the San Benedetto Italian PET Water Division for each international standardized impact category. These results are strategic to assess the contributions of different products to the global environmental impacts of the organization and to compare environmental performance of different products. The different columns are associated to different life cycle processes and permits to assess the contributions of the life cycle processes to the global impacts of the organization or of products. These results have been obtained also for the glass products.

3.2.1.3.2.3. Environmental Impacts – Process assessment scale

The same consideration made at inventory level is valid. The columns of the tables 44, 45 and 46 provide indications on the main life cycle processes. At the need every, with MLCA model, every life cycle process can be assessed in detail as shown in the figure 110 where a specific bottle production process has been studied considering separately the four machineries used for the production in order to assess the differences in terms of environmental performance.

						Raw material extraction and transformation								Production			Products delivery				Use phase	End of life
Site identification	Division identification	Subdivision identification	Environmental Impact Category	Impact unit	Total	PET granulate	RPET granulate	Dye master	Caps	Secondary packaging	Tertiary packaging	Labels	Plastic preform	Natural gas	Electricity	Other production aspects	Train delivery	Ship delivery	Truck delivery	Other delivery aspects	Use	End of life
SCORZE	San Benedetto Mineral Water	PET SUBDIVISION	Climate change	kg CO2 eq/year	1,84E+08	5,58E+07	1,53E+06	5,22E+04	6,69E+06	7,18E+06	3,79E+06	1,45E+06	8,81E+05	1,07E+06	2,29E+07	3,86E+06	1,49E+06	5,57E+06	2,47E+07	1,99E+07	1,18E+07	1,55E+07
POPOLI	San Benedetto Mineral Water	PET SUBDIVISION	Climate change	kg CO2 eq/year	3,73E+07	1,17E+07	0,00E+00	6,45E+03	1,06E+06	2,60E+05	1,44E+06	4,17E+05	1,80E+05	9,38E+05	6,48E+06	1,24E+06	4,87E+03	1,20E+05	4,36E+06	5,59E+06	5,79E+05	2,93E+06
VIGGIANELLO	San Benedetto Mineral Water	PET SUBDIVISION	Climate change	kg CO2 eq/year	2,60E+07	8,49E+06	6,37E+03	7,80E+02	4,76E+05	8,68E+05	4,71E+05	1,95E+05	2,66E+06	0,00E+00	2,09E+06	3,19E+04	0,00E+00	5,74E+03	5,40E+06	1,41E+06	1,90E+06	1,99E+06
DONATO	San Benedetto Mineral Water	PET SUBDIVISION	Climate change	kg CO2 eq/year	1,16E+07	3,91E+06	0,00E+00	1,67E+03	4,73E+05	3,14E+05	2,23E+05	7,71E+04	9,13E+05	0,00E+00	1,09E+06	2,62E+05	0,00E+00	0,00E+00	7,37E+05	2,27E+06	3,12E+05	9,89E+05
ATELLA	San Benedetto Mineral Water	PET SUBDIVISION	Climate change	kg CO2 eq/year	1,01E+06	3,88E+05	0,00E+00	0,00E+00	2,47E+04	2,15E+04	1,43E+04	4,94E+03	5,70E+04	6,06E+03	2,13E+05	3,14E+04	0,00E+00	1,01E+02	1,20E+05	3,61E+04	4,20E+03	8,74E+04
TOTAL ITALIAN SB WATER DIVISION	San Benedetto Mineral Water	TOTAL PET SUBDIVISION	Climate change	kg CO2 eq/year	2,60E+08	8,02E+07	1,53E+06	6,11E+04	8,72E+06	8,64E+06	5,94E+06	2,14E+06	4,69E+06	2,02E+06	3,28E+07	5,42E+06	1,50E+06	5,70E+06	3,54E+07	2,92E+07	1,46E+07	2,15E+07
SCORZE	San Benedetto Mineral Water	PET SUBDIVISION	Ozone depletion	kg CFC-11 eq/year	1,79E+01	2,84E+00	7,42E-02	1,30E-02	3,88E-01	2,33E-01	3,44E-01	6,39E-02	1,17E-01	1,56E-02	4,23E+00	3,53E-01	1,73E-01	8,94E-01	4,68E+00	2,07E+00	1,29E+00	9,58E-02
POPOLI	San Benedetto Mineral Water	PET SUBDIVISION	Ozone depletion	kg CFC-11 eq/year	3,30E+00	5,84E-01	0,00E+00	1,60E-03	6,40E-02	1,26E-02	4,22E-02	3,32E-02	2,40E-02	1,13E-03	8,53E-01	1,33E-01	5,66E-04	1,93E-02	8,24E-01	6,32E-01	5,52E-02	1,89E-02
VIGGIANELLO	San Benedetto Mineral Water	PET SUBDIVISION	Ozone depletion	kg CFC-11 eq/year	2,58E+00	4,26E-01	1,38E-03	1,92E-04	2,86E-02	2,90E-02	3,94E-02	1,01E-02	3,54E-01	0,00E+00	2,75E-01	7,91E-03	0,00E+00	9,21E-04	1,02E+00	1,17E-01	2,61E-01	1,38E-02
DONATO	San Benedetto Mineral Water	PET SUBDIVISION	Ozone depletion	kg CFC-11 eq/year	9,65E-01	2,00E-01	0,00E+00	4,11E-04	2,75E-02	7,75E-03	1,96E-02	2,69E-03	1,22E-01	0,00E+00	1,43E-01	2,29E-02	0,00E+00	0,00E+00	1,39E-01	2,69E-01	3,78E-03	5,95E-03
ATELLA	San Benedetto Mineral Water	PET SUBDIVISION	Ozone depletion	kg CFC-11 eq/year	9,18E-02	2,13E-02	0,00E+00	0,00E+00	1,61E-03	6,50E-04	1,07E-03	1,54E-04	7,80E-03	7,30E-06	2,80E-02	5,26E-03	0,00E+00	1,63E-05	2,26E-02	2,87E-03	0,00E+00	4,91E-04
TOTAL ITALIAN SB WATER DIVISION	San Benedetto Mineral Water	TOTAL PET SUBDIVISION	Ozone depletion	kg CFC-11 eq/year	2,48E+01	4,07E+00	7,56E-02	1,52E-02	5,10E-01	2,83E-01	4,46E-01	1,10E-01	6,24E-01	1,68E-02	5,53E+00	5,23E-01	1,74E-01	9,15E-01	6,68E+00	3,09E+00	1,60E+00	1,35E-01
SCORZE	San Benedetto Mineral Water	PET SUBDIVISION	Terrestrial acidification	kg SO2 eq/year	7,74E+05	2,88E+05	7,47E+03	3,19E+02	2,20E+04	2,54E+04	1,40E+04	5,53E+03	3,30E+03	1,39E+03	8,47E+04	1,28E+04	7,07E+03	1,08E+05	9,21E+04	5,99E+04	3,55E+04	6,54E+03
POPOLI	San Benedetto Mineral Water	PET SUBDIVISION	Terrestrial acidification	kg SO2 eq/year	1,40E+05	5,86E+04	0,00E+00	3,90E+01	3,58E+03	9,63E+02	5,16E+03	1,28E+03	6,82E+02	1,00E+03	2,43E+04	3,84E+03	2,31E+01	2,33E+03	1,73E+04	1,83E+04	1,52E+03	1,31E+03
VIGGIANELLO	San Benedetto Mineral Water	PET SUBDIVISION	Terrestrial acidification	kg SO2 eq/year	9,85E+04	4,28E+04	2,05E+01	4,68E+00	1,57E+03	3,15E+03	1,45E+03	6,39E+02	1,00E+04	0,00E+00	7,85E+03	1,23E+02	0,00E+00	1,11E+02	1,92E+04	3,39E+03	7,19E+03	9,83E+02
DONATO	San Benedetto Mineral Water	PET SUBDIVISION	Terrestrial acidification	kg SO2 eq/year	4,31E+04	2,02E+04	0,00E+00	1,00E+01	1,56E+03	1,12E+03	6,98E+02	2,59E+02	3,48E+03	0,00E+00	4,06E+03	7,80E+02	0,00E+00	0,00E+00	2,63E+03	7,80E+03	1,04E+02	4,04E+02
ATELLA	San Benedetto Mineral Water	PET SUBDIVISION	Terrestrial acidification	kg SO2 eq/year	3,95E+03	1,99E+03	0,00E+00	0,00E+00	8,29E+01	7,70E+01	4,50E+01	1,75E+01	2,16E+02	6,49E+00	7,94E+02	1,51E+02	0,00E+00	1,96E+00	4,46E+02	8,37E+01	0,00E+00	3,24E+01
TOTAL ITALIAN SB WATER DIVISION	San Benedetto Mineral Water	TOTAL PET SUBDIVISION	Terrestrial acidification	kg SO2 eq/year	1,06E+06	4,11E+05	7,49E+03	3,73E+02	2,88E+04	3,07E+04	2,13E+04	7,73E+03	1,77E+04	2,40E+03	1,22E+05	1,77E+04	7,09E+03	1,10E+05	1,32E+05	8,95E+04	4,43E+04	9,28E+03
SCORZE	San Benedetto Mineral Water	PET SUBDIVISION	Terrestrial ecotoxicity	kg 1,4-DB eq/year	2,30E+04	3,34E+03	2,63E+02	2,74E+02	4,80E+02	4,09E+02	7,45E+02	1,03E+02	5,07E+01	7,04E+00	8,55E+02	9,31E+02	9,19E+01	2,08E+02	1,33E+04	6,34E+02	7,16E+02	5,73E+02
POPOLI	San Benedetto Mineral Water	PET SUBDIVISION	Terrestrial ecotoxicity	kg 1,4-DB eq/year	4,19E+03	8,07E+02	0,00E+00	3,29E+01	7,12E+01	2,51E+01	7,47E+01	6,62E+01	1,56E+01	1,96E+00	2,94E+02	1,19E+02	3,00E-01	4,48E+00	2,34E+03	1,93E+02	3,07E+01	1,13E+02
VIGGIANELLO	San Benedetto Mineral Water	PET SUBDIVISION	Terrestrial ecotoxicity	kg 1,4-DB eq/year	4,31E+03	5,84E+02	1,39E+00	3,91E+00	4,16E+01	5,98E+01	8,35E+01	3,01E+01	2,30E+02	0,00E+00	1,05E+02	8,00E+00	0,00E+00	2,14E-01	2,90E+03	3,64E+01	1,45E+02	8,15E+01
DONATO	San Benedetto Mineral Water	PET SUBDIVISION	Terrestrial ecotoxicity	kg 1,4-DB eq/year	1,07E+03	2,40E+02	0,00E+00	8,36E+00	3,86E+01	1,10E+01	4,52E+01	5,50E+00	1,01E+02	0,00E+00	3,81E+01	6,86E+01	0,00E+00	0,00E+00	3,96E+02	8,17E+01	2,11E+00	3,57E+01
ATELLA	San Benedetto Mineral Water	PET SUBDIVISION	Terrestrial ecotoxicity	kg 1,4-DB eq/year	1,29E+02	3,08E+01	0,00E+00	0,00E+00	3,77E+00	1,29E+00	2,24E+00	3,46E-01	7,68E+00	1,27E-02	7,45E+00	7,31E+00	0,00E+00	3,77E-03	6,44E+01	9,05E-01	0,00E+00	3,21E+00
TOTAL ITALIAN SB WATER DIVISION	San Benedetto Mineral Water	TOTAL PET SUBDIVISION	Terrestrial ecotoxicity	kg 1,4-DB eq/year	3,27E+04	5,00E+03	2,64E+02	3,19E+02	6,35E+02	5,06E+02	9,51E+02	2,05E+02	4,05E+02	9,01E+00	1,30E+03	1,13E+03	9,22E+01	2,12E+02	1,90E+04	9,47E+02	8,93E+02	8,06E+02
SCORZE	San Benedetto Mineral Water	PET SUBDIVISION	Water scarcity	m3 eq/year	2,11E+06	7,95E+05	2,01E+03	6,68E+02	3,70E+04	5,84E+04	2,75E+04	1,18E+04	4,05E+03	1,64E+02	8,37E+04	9,13E+05	6,72E+03	8,63E+03	4,53E+04	7,53E+04	3,24E+04	6,63E+03
POPOLI	San Benedetto Mineral Water	PET SUBDIVISION	Water scarcity	m3 eq/year	4,44E+05	1,67E+05	0,00E+00	8,02E+01	4,86E+03	2,02E+03	1,08E+04	3,03E+03	8,15E+02	7,92E+01	3,08E+04	1,91E+05	2,19E+01	1,86E+02	7,97E+03	2,29E+04	1,39E+03	1,37E+03
VIGGIANELLO	San Benedetto Mineral Water	PET SUBDIVISION	Water scarcity	m3 eq/year	3,47E+05	1,22E+05	1,18E+01	9,52E+00	2,70E+03	6,44E+03	3,20E+03	1,17E+03	1,20E+04	0,00E+00	9,99E+03	1,68E+05	0,00E+00	8,89E+00	9,88E+03	4,34E+03	6,57E+03	1,07E+03
DON ATO	San Benedetto Mineral Water	PET SUBDIVISION	Water scarcity	m3 eq/year	1,41E+05	5,56E+04	0,00E+00	2,03E+01	2,67E+03	2,29E+03	1,49E+03	5,41E+02	4,06E+03	0,00E+00	5,10E+03	5,72E+04	0,00E+00	0,00E+00	1,35E+03	9,71E+03	9,52E+01	4,06E+02
ATELLA	San Benedetto Mineral Water	PET SUBDIVISION	Water scarcity	m3 eq/year	1,11E+04	5,40E+03	0,00E+00	0,00E+00	1,29E+02	1,52E+02	9,61E+01	3,34E+01	2,44E+02	5,12E-01	9,97E+02	3,72E+03	0,00E+00	1,57E-01	2,19E+02	1,07E+02	0,00E+00	2,96E+01

						Raw material extraction and transformation								Production			Products delivery				Use phase	End of life
Site identification	Division identification	Subdivision identification	Environmental Impact Category	Impact unit	Total	PET granulate	RPET granulate	Dye master	Caps	Secondary packaging	Tertiary packaging	Labels	Plastic preform	Natural gas	Electricity	Other production aspects	Train delivery	Ship delivery	Truck delivery	Other delivery aspects	Use	End of life
TOTAL ITALIAN SB WATER DIVISION	San Benedetto Mineral Water	TOTAL PET SUBDIVISION	Water scarcity	m3 eq/year	3,05E+06	1,14E+06	2,02E+03	7,78E+02	4,74E+04	6,93E+04	4,31E+04	1,66E+04	2,11E+04	2,44E+02	1,31E+05	1,33E+06	6,75E+03	8,82E+03	6,47E+04	1,12E+05	4,04E+04	9,52E+03
SCORZE	San Benedetto Mineral Water	PET SUBDIVISION	Aquatic eutrophication	kg PO4 P-lim/year	2,49E+04	1,05E+04	4,46E+02	1,32E+01	2,73E+02	4,70E+02	6,44E+02	2,66E+02	6,81E+01	1,46E+01	1,55E+03	1,13E+03	1,97E+02	5,48E+02	2,63E+03	1,56E+03	1,33E+03	3,20E+03
POPOLI	San Benedetto Mineral Water	PET SUBDIVISION	Aquatic eutrophication	kg PO4 P-lim/year	4,97E+03	2,16E+03	0,00E+00	1,61E+00	6,90E+01	4,81E+01	8,02E+01	5,94E+01	1,55E+01	1,27E+01	5,01E+02	3,12E+02	6,43E-01	1,18E+01	4,64E+02	4,78E+02	5,71E+01	6,99E+02
VIGGIANELLO	San Benedetto Mineral Water	PET SUBDIVISION	Aquatic eutrophication	kg PO4 P-lim/year	3,65E+03	1,58E+03	4,60E-01	1,92E-01	1,83E+01	5,96E+01	6,81E+01	1,98E+01	2,24E+02	0,00E+00	1,66E+02	6,56E+00	0,00E+00	5,64E-01	5,75E+02	8,83E+01	2,69E+02	5,82E+02
DONATO	San Benedetto Mineral Water	PET SUBDIVISION	Aquatic eutrophication	kg PO4 P-lim/year	1,50E+03	7,38E+02	0,00E+00	4,10E-01	1,77E+01	1,50E+01	3,13E+01	9,94E+00	8,40E+01	0,00E+00	7,96E+01	5,33E+01	0,00E+00	0,00E+00	7,84E+01	2,02E+02	3,91E+00	1,91E+02
ATELLA	San Benedetto Mineral Water	PET SUBDIVISION	Aquatic eutrophication	kg PO4 P-lim/year	1,33E+02	7,25E+01	0,00E+00	0,00E+00	1,05E+00	1,04E+00	1,86E+00	2,67E-01	4,91E+00	8,19E-02	1,55E+01	9,08E+00	0,00E+00	9,95E-03	1,27E+01	2,20E+00	0,00E+00	1,17E+01
TOTAL ITALIAN SB WATER DIVISION	San Benedetto Mineral Water	TOTAL PET SUBDIVISION	Aquatic eutrophication	kg PO4 P-lim/year	3,51E+04	1,51E+04	4,47E+02	1,54E+01	3,79E+02	5,94E+02	8,26E+02	3,56E+02	3,97E+02	2,74E+01	2,31E+03	1,51E+03	1,98E+02	5,60E+02	3,76E+03	2,33E+03	1,66E+03	4,68E+03
SCORZE	San Benedetto Mineral Water	PET SUBDIVISION	Aquatic ecotoxicity	kg TEG water/year	1,17E+10	2,75E+09	5,61E+07	4,02E+06	1,73E+08	2,14E+08	2,66E+08	8,10E+07	3,79E+07	4,85E+06	9,85E+08	1,82E+08	7,51E+07	2,12E+08	2,65E+09	7,82E+08	5,01E+08	2,74E+09
POPOLI	San Benedetto Mineral Water	PET SUBDIVISION	Aquatic ecotoxicity	kg TEG water/year	2,34E+09	5,85E+08	0,00E+00	5,09E+05	3,30E+07	1,52E+07	4,20E+07	1,79E+07	8,63E+06	2,26E+05	2,61E+08	5,96E+07	2,45E+05	4,57E+06	4,67E+08	2,41E+08	2,15E+07	5,80E+08
VIGGIANELLO	San Benedetto Mineral Water	PET SUBDIVISION	Aquatic ecotoxicity	kg TEG water/year	1,90E+09	4,26E+08	3,47E+05	6,23E+04	1,47E+07	3,03E+07	2,13E+07	7,47E+06	1,26E+08	0,00E+00	8,47E+07	2,92E+06	0,00E+00	2,18E+05	5,79E+08	4,37E+07	1,02E+08	4,65E+08
DONATO	San Benedetto Mineral Water	PET SUBDIVISION	Aquatic ecotoxicity	kg TEG water/year	6,78E+08	1,93E+08	0,00E+00	1,34E+05	1,32E+07	7,79E+06	1,09E+07	2,61E+06	4,71E+07	0,00E+00	4,33E+07	1,10E+07	0,00E+00	0,00E+00	7,90E+07	1,02E+08	1,47E+06	1,66E+08
ATELLA	San Benedetto Mineral Water	PET SUBDIVISION	Aquatic ecotoxicity	kg TEG water/year	6,23E+07	2,01E+07	0,00E+00	0,00E+00	7,66E+05	6,09E+05	6,01E+05	1,48E+05	3,07E+06	1,46E+03	8,45E+06	2,93E+06	0,00E+00	3,85E+03	1,28E+07	1,09E+06	0,00E+00	1,17E+07
TOTAL ITALIAN SB WATER DIVISION	San Benedetto Mineral Water	TOTAL PET SUBDIVISION	Aquatic ecotoxicity	kg TEG water/year	1,67E+10	3,97E+09	5,65E+07	4,72E+06	2,34E+08	2,68E+08	3,41E+08	1,09E+08	2,23E+08	5,08E+06	1,38E+09	2,58E+08	7,54E+07	2,16E+08	3,79E+09	1,17E+09	6,26E+08	3,96E+09
SCORZE	San Benedetto Mineral Water	PET SUBDIVISION	Aquatic acidification	kg SO2 eq/year	8,47E+05	3,13E+05	8,17E+03	3,50E+02	2,39E+04	2,76E+04	1,50E+04	6,07E+03	3,54E+03	1,55E+03	9,06E+04	1,43E+04	7,82E+03	1,18E+05	1,05E+05	6,45E+04	3,97E+04	7,54E+03
POPOLI	San Benedetto Mineral Water	PET SUBDIVISION	Aquatic acidification	kg SO2 eq/year	1,53E+05	6,37E+04	0,00E+00	4,29E+01	3,89E+03	1,06E+03	5,63E+03	1,34E+03	7,32E+02	1,15E+03	2,60E+04	4,38E+03	2,55E+01	2,54E+03	2,00E+04	1,97E+04	1,71E+03	1,51E+03
VIGGIANELLO	San Benedetto Mineral Water	PET SUBDIVISION	Aquatic acidification	kg SO2 eq/year	1,08E+05	4,65E+04	2,29E+01	5,15E+00	1,71E+03	3,44E+03	1,51E+03	7,06E+02	1,08E+04	0,00E+00	8,40E+03	1,36E+02	0,00E+00	1,21E+02	2,19E+04	3,69E+03	8,05E+03	1,12E+03
DONATO	San Benedetto Mineral Water	PET SUBDIVISION	Aquatic acidification	kg SO2 eq/year	4,67E+04	2,19E+04	0,00E+00	1,10E+01	1,69E+03	1,22E+03	7,32E+02	2,83E+02	3,73E+03	0,00E+00	4,35E+03	8,42E+02	0,00E+00	0,00E+00	3,00E+03	8,37E+03	1,17E+02	4,67E+02
ATELLA	San Benedetto Mineral Water	PET SUBDIVISION	Aquatic acidification	kg SO2 eq/year	4,30E+03	2,17E+03	0,00E+00	0,00E+00	9,02E+01	8,40E+01	4,71E+01	1,91E+01	2,34E+02	7,41E+00	8,50E+02	1,62E+02	0,00E+00	2,14E+00	5,10E+02	9,09E+01	0,00E+00	3,79E+01
TOTAL ITALIAN SB WATER DIVISION	San Benedetto Mineral Water	TOTAL PET SUBDIVISION	Aquatic acidification	kg SO2 eq/year	1,16E+06	4,47E+05	8,19E+03	4,09E+02	3,12E+04	3,34E+04	2,29E+04	8,42E+03	1,90E+04	2,70E+03	1,30E+05	1,98E+04	7,84E+03	1,21E+05	1,51E+05	9,64E+04	4,96E+04	1,07E+04
SCORZE	San Benedetto Mineral Water	PET SUBDIVISION	Human toxicity	kg 1,4-DB eq/year	4,47E+07	1,81E+07	9,49E+05	1,56E+05	6,03E+05	8,30E+05	9,10E+05	2,18E+05	1,27E+05	9,94E+03	3,06E+06	1,37E+06	3,87E+05	5,72E+05	7,76E+06	4,20E+06	2,15E+06	3,28E+06
POPOLI	San Benedetto Mineral Water	PET SUBDIVISION	Human toxicity	kg 1,4-DB eq/year	8,76E+06	3,75E+06	0,00E+00	1,88E+04	1,48E+05	4,09E+04	1,63E+05	7,94E+04	2,79E+04	3,05E+03	9,42E+05	3,65E+05	1,26E+03	1,24E+04	1,37E+06	1,12E+06	9,24E+04	6,23E+05
VIGGIANELLO	San Benedetto Mineral Water	PET SUBDIVISION	Human toxicity	kg 1,4-DB eq/year	6,62E+06	2,73E+06	1,16E+03	2,23E+03	4,35E+04	1,09E+05	9,32E+04	2,96E+04	4,12E+05	0,00E+00	3,12E+05	1,85E+04	0,00E+00	5,90E+02	1,68E+06	3,18E+05	4,36E+05	4,28E+05
DONATO	San Benedetto Mineral Water	PET SUBDIVISION	Human toxicity	kg 1,4-DB eq/year	2,69E+06	1,27E+06	0,00E+00	4,77E+03	4,33E+04	3,22E+04	4,59E+04	9,75E+03	1,49E+05	0,00E+00	1,49E+05	1,04E+05	0,00E+00	0,00E+00	2,30E+05	4,39E+05	6,33E+03	2,09E+05
ATELLA	San Benedetto Mineral Water	PET SUBDIVISION	Human toxicity	kg 1,4-DB eq/year	2,52E+05	1,27E+05	0,00E+00	0,00E+00	3,28E+03	2,42E+03	2,62E+03	5,71E+02	9,84E+03	1,97E+01	2,91E+04	1,33E+04	0,00E+00	1,04E+01	3,75E+04	8,15E+03	0,00E+00	1,82E+04
TOTAL ITALIAN SB WATER DIVISION	San Benedetto Mineral Water	TOTAL PET SUBDIVISION	Human toxicity	kg 1,4-DB eq/year	6,30E+07	2,60E+07	9,50E+05	1,82E+05	8,41E+05	1,01E+06	1,21E+06	3,37E+05	7,26E+05	1,30E+04	4,49E+06	1,87E+06	3,88E+05	5,85E+05	1,11E+07	6,08E+06	2,69E+06	4,56E+06
SCORZE	San Benedetto Mineral Water	PET SUBDIVISION	Land occupation	m2org.arable/year	4,88E+06	5,24E+05	2,41E+04	1,71E+03	4,10E+04	1,88E+05	1,38E+06	1,16E+05	9,41E+03	6,89E+01	1,02E+05	4,45E+04	4,83E+04	2,96E+04	2,09E+06	1,21E+05	1,43E+05	2,15E+04
POPOLI	San Benedetto Mineral Water	PET SUBDIVISION	Land occupation	m2org.arable/year	6,75E+05	1,17E+05	0,00E+00	2,14E+02	1,03E+04	2,11E+04	2,64E+04	4,03E+04	3,95E+03	0,00E+00	3,40E+04	1,19E+04	1,58E+02	6,40E+02	3,67E+05	3,14E+04	6,15E+03	4,15E+03
VIGGIANELLO	San Benedetto Mineral Water	PET SUBDIVISION	Land occupation	m2org.arable/year	7,20E+05	8,48E+04	9,80E+01	2,60E+01	4,14E+03	2,27E+04	4,32E+04	4,44E+03	5,19E+04	0,00E+00	1,10E+04	6,45E+02	0,00E+00	3,05E+01	4,56E+05	9,01E+03	2,90E+04	2,93E+03
DONATO	San Benedetto Mineral Water	PET SUBDIVISION	Land occupation	m2org.arable/year	1,79E+05	3,70E+04	0,00E+00	5,57E+01	3,48E+03	4,23E+03	1,91E+04	3,23E+03	2,69E+04	0,00E+00	5,66E+03	2,58E+03	0,00E+00	0,00E+00	6,22E+04	1,26E+04	4,22E+02	1,35E+03

						Raw material extraction and transformation								Production			Products delivery				Use phase	End of life
Site identification	Division identification	Subdivision identification	Environmental Impact Category	Impact unit	Total	PET granulate	RPET granulate	Dye master	Caps	Secondary packaging	Tertiary packaging	Labels	Plastic preform	Natural gas	Electricity	Other production aspects	Train delivery	Ship delivery	Truck delivery	Other delivery aspects	Use	End of life
ATELLA	San Benedetto Mineral Water	PET SUBDIVISION	Land occupation	m2org.arable/year	1,90E+04	4,03E+03	0,00E+00	0,00E+00	1,96E+02	2,95E+02	1,14E+03	9,88E+01	1,22E+03	0,00E+00	1,11E+03	5,07E+02	0,00E+00	5,38E-01	1,01E+04	2,23E+02	0,00E+00	1,17E+02
TOTAL ITALIAN SB WATER DIVISION	San Benedetto Mineral Water	TOTAL PET SUBDIVISION	Land occupation	m2org.arable/year	6,47E+06	7,67E+05	2,42E+04	2,01E+03	5,91E+04	2,37E+05	1,47E+06	1,64E+05	9,33E+04	6,89E+01	1,54E+05	6,02E+04	4,85E+04	3,03E+04	2,98E+06	1,74E+05	1,79E+05	3,00E+04
SCORZE	San Benedetto Mineral Water	PET SUBDIVISION	Metal depletion	kg Fe eq/year	7,42E+06	4,10E+06	2,06E+04	4,95E+03	5,07E+04	8,53E+04	1,85E+05	2,37E+04	1,26E+04	1,58E+03	3,29E+05	2,31E+05	1,90E+05	1,48E+05	9,07E+05	4,22E+05	6,11E+05	9,65E+04
POPOLI	San Benedetto Mineral Water	PET SUBDIVISION	Metal depletion	kg Fe eq/year	1,38E+06	8,50E+05	0,00E+00	6,00E+02	1,18E+04	4,45E+03	1,60E+04	1,08E+04	2,91E+03	6,52E+02	1,01E+05	3,57E+04	6,21E+02	3,20E+03	1,60E+05	1,33E+05	2,62E+04	2,04E+04
VIGGIANELLO	San Benedetto Mineral Water	PET SUBDIVISION	Metal depletion	kg Fe eq/year	1,09E+06	6,20E+05	1,33E+02	7,17E+01	4,13E+03	1,06E+04	1,24E+04	2,99E+03	4,23E+04	0,00E+00	3,51E+04	1,66E+03	0,00E+00	1,52E+02	1,98E+05	2,24E+04	1,24E+05	1,63E+04
DONATO	San Benedetto Mineral Water	PET SUBDIVISION	Metal depletion	kg Fe eq/year	4,45E+05	2,87E+05	0,00E+00	1,53E+02	3,79E+03	3,21E+03	5,90E+03	1,03E+03	1,60E+04	0,00E+00	1,42E+04	2,33E+04	0,00E+00	0,00E+00	2,70E+04	5,55E+04	1,80E+03	5,85E+03
ATELLA	San Benedetto Mineral Water	PET SUBDIVISION	Metal depletion	kg Fe eq/year	4,01E+04	2,82E+04	0,00E+00	0,00E+00	2,42E+02	2,42E+02	3,41E+02	5,86E+01	1,01E+03	4,21E+00	2,78E+03	1,93E+03	0,00E+00	2,69E+00	4,39E+03	5,66E+02	0,00E+00	4,02E+02
TOTAL ITALIAN SB WATER DIVISION	San Benedetto Mineral Water	TOTAL PET SUBDIVISION	Metal depletion	kg Fe eq/year	1,04E+07	5,89E+06	2,07E+04	5,77E+03	7,07E+04	1,04E+05	2,20E+05	3,85E+04	7,48E+04	2,24E+03	4,82E+05	2,94E+05	1,91E+05	1,51E+05	1,30E+06	6,33E+05	7,62E+05	1,39E+05
SCORZE	San Benedetto Mineral Water	PET SUBDIVISION	Fossil depletion	kg oil eq/year	6,95E+07	2,78E+07	4,44E+05	1,47E+04	3,93E+06	4,52E+06	1,72E+06	7,91E+05	2,64E+05	3,70E+05	9,39E+06	8,74E+05	4,26E+05	1,83E+06	9,24E+06	4,68E+06	2,98E+06	1,85E+05
POPOLI	San Benedetto Mineral Water	PET SUBDIVISION	Fossil depletion	kg oil eq/year	1,35E+07	5,77E+06	0,00E+00	1,84E+03	6,39E+05	1,36E+05	9,07E+05	1,97E+05	5,43E+04	3,20E+05	1,93E+06	2,65E+05	1,39E+03	3,96E+04	1,63E+06	1,43E+06	1,28E+05	3,64E+04
VIGGIANELLO	San Benedetto Mineral Water	PET SUBDIVISION	Fossil depletion	kg oil eq/year	9,71E+06	4,21E+06	2,27E+03	2,23E+02	2,82E+05	5,36E+05	2,17E+05	1,17E+05	8,01E+05	0,00E+00	6,21E+05	1,13E+04	0,00E+00	1,89E+03	2,02E+06	2,64E+05	6,04E+05	2,64E+04
DONATO	San Benedetto Mineral Water	PET SUBDIVISION	Fossil depletion	kg oil eq/year	4,14E+06	1,95E+06	0,00E+00	4,79E+02	2,81E+05	2,00E+05	1,03E+05	4,62E+04	2,76E+05	0,00E+00	3,25E+05	5,72E+04	0,00E+00	0,00E+00	2,75E+05	6,11E+05	8,77E+03	1,15E+04
ATELLA	San Benedetto Mineral Water	PET SUBDIVISION	Fossil depletion	kg oil eq/year	3,74E+05	1,92E+05	0,00E+00	0,00E+00	1,42E+04	1,35E+04	6,91E+03	2,97E+03	1,74E+04	2,07E+03	6,34E+04	9,43E+03	0,00E+00	3,33E+01	4,47E+04	6,50E+03	0,00E+00	9,56E+02
TOTAL ITALIAN SB WATER DIVISION	San Benedetto Mineral Water	TOTAL PET SUBDIVISION	Fossil depletion	kg oil eq/year	9,72E+07	4,00E+07	4,47E+05	1,72E+04	5,15E+06	5,41E+06	2,95E+06	1,15E+06	1,41E+06	6,92E+05	1,23E+07	1,22E+06	4,27E+05	1,87E+06	1,32E+07	6,99E+06	3,72E+06	2,60E+05

Table 44 ERD results- Environmental impacts – Organizational scale – San Benedetto Italian Mineral Water PET

						Raw material extraction and transformation				**Production**			**Products delivery**				**Use phase**	**End of life**
Site identification	**Division identification**	**Subdivision identification**	**Environmental Impact Category**	**Impact unit**	**Total**	**Glass bottles**	**Caps**	**Labels**	**Other packaging**	**Natural gas**	**Electricity**	**Other production aspects**	**Ship delivery**	**Truck delivery**	**Train delivery**	**Other delivery aspects**	**Use**	**End of life**
SCORZE	San Benedetto Mineral Water	GLASS SUBDIVISION	Climate change	kg CO2 eq/year	2,87E+07	1,19E+07	2,48E+06	4,93E+05	1,70E+06	1,69E+06	1,19E+06	1,68E+06	1,60E+06	4,47E+06	1,87E+05	6,12E+05	4,07E+05	2,65E+05
ATELLA	San Benedetto Mineral Water	GLASS SUBDIVISION	Climate change	kg CO2 eq/year	1,79E+06	3,18E+05	1,31E+05	1,66E+04	1,66E+04	3,55E+05	2,05E+05	1,45E+05	5,15E+02	5,20E+05	0,00E+00	5,90E+04	7,49E+03	1,16E+04
TOTAL ITALIAN SAN BENEDETTO WATER DIVISION	San Benedetto Mineral Water	TOTAL GLASS SUBDIVISION	Climate change	kg CO2 eq/year	3,05E+07	1,22E+07	2,61E+06	5,10E+05	1,71E+06	2,05E+06	1,40E+06	1,83E+06	1,60E+06	4,99E+06	1,87E+05	6,71E+05	4,15E+05	2,77E+05
SCORZE	San Benedetto Mineral Water	GLASS SUBDIVISION	Ozone depletion	kg CFC-11 eq/year	4,19E+00	1,56E+00	2,95E-01	3,30E-02	1,44E-01	2,47E-02	2,20E-01	6,91E-01	2,57E-01	8,45E-01	2,17E-02	4,59E-02	2,43E-02	3,12E-02
ATELLA	San Benedetto Mineral Water	GLASS SUBDIVISION	Ozone depletion	kg CFC-11 eq/year	2,30E-01	4,19E-02	1,15E-02	1,53E-03	6,94E-04	4,27E-04	2,70E-02	4,14E-02	8,27E-05	9,83E-02	0,00E+00	5,95E-03	1,44E-06	9,82E-04
TOTAL ITALIAN SAN BENEDETTO WATER DIVISION	San Benedetto Mineral Water	TOTAL GLASS SUBDIVISION	Ozone depletion	kg CFC-11 eq/year	4,42E+00	1,60E+00	3,06E-01	3,45E-02	1,45E-01	2,51E-02	2,47E-01	7,32E-01	2,57E-01	9,43E-01	2,17E-02	5,19E-02	2,43E-02	3,21E-02
SCORZE	San Benedetto Mineral Water	GLASS SUBDIVISION	Terrestrial acidification	kg SO2 eq/year	1,80E+05	8,54E+04	1,72E+04	1,76E+03	8,33E+03	2,20E+03	4,40E+03	9,10E+03	3,11E+04	1,66E+04	8,85E+02	1,35E+03	7,04E+02	9,67E+02

						Raw material extraction and transformation				Production			Products delivery				Use phase	End of life
Site identification	**Division identification**	**Subdivision identification**	**Environmental Impact Category**	**Impact unit**	**Total**	**Glass bottles**	**Caps**	**Labels**	**Other packaging**	**Natural gas**	**Electricity**	**Other production aspects**	**Ship delivery**	**Truck delivery**	**Train delivery**	**Other delivery aspects**	**Use**	**End of life**
ATELLA	San Benedetto Mineral Water	GLASS SUBDIVISION	Terrestrial acidification	kg SO2 eq/year	7,68E+03	2,21E+03	1,10E+03	8,54E+01	5,79E+01	3,80E+02	7,64E+02	9,20E+02	9,99E+00	1,94E+03	0,00E+00	1,71E+02	4,15E-02	3,84E+01
TOTAL ITALIAN SAN BENEDETTO WATER DIVISION	San Benedetto Mineral Water	TOTAL GLASS SUBDIVISION	Terrestrial acidification	kg SO2 eq/year	1,88E+05	8,77E+04	1,83E+04	1,85E+03	8,39E+03	2,58E+03	5,17E+03	1,00E+04	3,11E+04	1,86E+04	8,85E+02	1,53E+03	7,04E+02	1,01E+03
SCORZE	San Benedetto Mineral Water	GLASS SUBDIVISION	Terrestrial ecotoxicity	kg 1,4-DB eq/year	7,57E+03	3,24E+03	7,44E+02	1,74E+02	6,50E+02	1,11E+01	4,45E+01	1,96E+02	5,97E+01	2,40E+03	1,15E+01	1,44E+01	7,32E+00	1,69E+01
ATELLA	San Benedetto Mineral Water	GLASS SUBDIVISION	Terrestrial ecotoxicity	kg 1,4-DB eq/year	4,32E+02	9,23E+01	1,20E+01	2,66E+00	1,03E+00	7,41E-01	7,17E+00	3,38E+01	1,92E-02	2,80E+02	0,00E+00	1,84E+00	4,32E-04	1,00E+00
TOTAL ITALIAN SAN BENEDETTO WATER DIVISION	San Benedetto Mineral Water	TOTAL GLASS SUBDIVISION	Terrestrial ecotoxicity	kg 1,4-DB eq/year	8,00E+03	3,33E+03	7,56E+02	1,76E+02	6,51E+02	1,19E+01	5,16E+01	2,30E+02	5,97E+01	2,68E+03	1,15E+01	1,62E+01	7,32E+00	1,80E+01
SCORZE	San Benedetto Mineral Water	GLASS SUBDIVISION	Water scarcity	m3 eq/year	2,12E+05	3,34E+04	5,68E+03	4,47E+03	6,78E+03	2,60E+02	4,35E+03	1,42E+05	2,48E+03	8,18E+03	8,42E+02	1,82E+03	8,71E+02	6,77E+02
ATELLA	San Benedetto Mineral Water	GLASS SUBDIVISION	Water scarcity	m3 eq/year	1,20E+04	8,89E+02	3,52E+02	1,84E+02	1,72E+02	3,00E+01	9,60E+02	8,23E+03	7,98E-01	9,52E+02	0,00E+00	2,26E+02	5,14E-02	3,72E+01
TOTAL ITALIAN SAN BENEDETTO WATER DIVISION	San Benedetto Mineral Water	TOTAL GLASS SUBDIVISION	Water scarcity	m3 eq/year	2,24E+05	3,43E+04	6,03E+03	4,65E+03	6,95E+03	2,90E+02	5,31E+03	1,51E+05	2,48E+03	9,13E+03	8,42E+02	2,05E+03	8,71E+02	7,15E+02
SCORZE	San Benedetto Mineral Water	GLASS SUBDIVISION	Aquatic eutrophication	kg PO4 P-lim/year	4,46E+03	1,61E+03	3,02E+02	8,50E+01	3,93E+02	2,31E+01	8,05E+01	1,02E+03	1,57E+02	4,76E+02	2,47E+01	4,14E+01	1,81E+01	2,19E+02
ATELLA	San Benedetto Mineral Water	GLASS SUBDIVISION	Aquatic eutrophication	kg PO4 P-lim/year	2,09E+02	4,25E+01	1,69E+01	6,71E+00	1,06E+00	4,80E+00	1,50E+01	4,24E+01	5,07E-02	5,54E+01	0,00E+00	4,63E+00	1,07E-03	2,01E+01
TOTAL ITALIAN SAN BENEDETTO WATER DIVISION	San Benedetto Mineral Water	TOTAL GLASS SUBDIVISION	Aquatic eutrophication	kg PO4 P-lim/year	4,67E+03	1,66E+03	3,19E+02	9,17E+01	3,94E+02	2,79E+01	9,55E+01	1,06E+03	1,58E+02	5,31E+02	2,47E+01	4,60E+01	1,81E+01	2,40E+02
SCORZE	San Benedetto Mineral Water	GLASS SUBDIVISION	Aquatic ecotoxicity	kg TEG water/year	2,80E+09	1,27E+09	2,96E+08	2,14E+07	1,61E+08	7,66E+06	5,12E+07	9,83E+07	6,09E+07	4,79E+08	9,40E+06	1,70E+07	9,22E+06	3,19E+08
ATELLA	San Benedetto Mineral Water	GLASS SUBDIVISION	Aquatic ecotoxicity	kg TEG water/year	1,58E+08	3,38E+07	1,49E+07	2,44E+06	5,34E+05	8,55E+04	8,14E+06	1,36E+07	1,96E+04	5,58E+07	0,00E+00	2,17E+06	5,44E+02	2,65E+07
TOTAL ITALIAN SAN BENEDETTO WATER DIVISION	San Benedetto Mineral Water	TOTAL GLASS SUBDIVISION	Aquatic ecotoxicity	kg TEG water/year	2,95E+09	1,30E+09	3,11E+08	2,38E+07	1,62E+08	7,75E+06	5,94E+07	1,12E+08	6,09E+07	5,35E+08	9,40E+06	1,91E+07	9,22E+06	3,46E+08
SCORZE	San Benedetto Mineral Water	GLASS SUBDIVISION	Aquatic acidification	kg SO2 eq/year	1,96E+05	9,20E+04	1,88E+04	1,90E+03	8,87E+03	2,45E+03	4,71E+03	1,00E+04	3,39E+04	1,91E+04	9,79E+02	1,51E+03	7,53E+02	1,13E+03
ATELLA	San Benedetto Mineral Water	GLASS SUBDIVISION	Aquatic acidification	kg SO2 eq/year	8,42E+03	2,39E+03	1,18E+03	9,52E+01	6,33E+01	4,34E+02	8,18E+02	9,81E+02	1,09E+01	2,22E+03	0,00E+00	1,87E+02	4,44E-02	4,36E+01
TOTAL ITALIAN SAN BENEDETTO WATER DIVISION	San Benedetto Mineral Water	TOTAL GLASS SUBDIVISION	Aquatic acidification	kg SO2 eq/year	2,05E+05	9,44E+04	2,00E+04	2,00E+03	8,94E+03	2,89E+03	5,53E+03	1,10E+04	3,39E+04	2,13E+04	9,79E+02	1,70E+03	7,53E+02	1,17E+03
SCORZE	San Benedetto Mineral Water	GLASS SUBDIVISION	Human toxicity	kg 1,4-DB eq/year	8,06E+06	3,60E+06	1,06E+06	8,72E+04	4,68E+05	1,57E+04	1,59E+05	8,06E+05	1,65E+05	1,40E+06	4,84E+04	1,74E+05	3,41E+04	4,00E+04
ATELLA	San Benedetto Mineral Water	GLASS SUBDIVISION	Human toxicity	kg 1,4-DB eq/year	4,41E+05	9,66E+04	5,87E+04	4,41E+03	2,06E+03	1,15E+03	2,81E+04	6,62E+04	5,29E+01	1,63E+05	0,00E+00	1,78E+04	2,01E+00	2,65E+03
TOTAL ITALIAN SAN BENEDETTO WATER DIVISION	San Benedetto Mineral Water	TOTAL GLASS SUBDIVISION	Human toxicity	kg 1,4-DB eq/year	8,50E+06	3,69E+06	1,12E+06	9,16E+04	4,71E+05	1,69E+04	1,87E+05	8,72E+05	1,65E+05	1,57E+06	4,84E+04	1,92E+05	3,41E+04	4,26E+04
SCORZE	San Benedetto Mineral Water	GLASS SUBDIVISION	Land occupation	m2org.arable/year	1,35E+06	4,33E+05	6,29E+04	3,35E+04	3,94E+05	1,09E+02	5,32E+03	2,11E+04	8,52E+03	3,77E+05	6,05E+03	6,30E+03	9,88E+02	3,90E+03
ATELLA	San Benedetto Mineral Water	GLASS SUBDIVISION	Land occupation	m2org.arable/year	6,77E+04	1,21E+04	2,22E+03	3,89E+03	1,07E+03	0,00E+00	1,06E+03	2,63E+03	2,74E+00	4,39E+04	0,00E+00	6,90E+02	5,83E-02	1,29E+02
TOTAL ITALIAN SAN BENEDETTO WATER DIVISION	San Benedetto Mineral Water	TOTAL GLASS SUBDIVISION	Land occupation	m2org.arable/year	1,42E+06	4,45E+05	6,51E+04	3,74E+04	3,95E+05	1,09E+02	6,38E+03	2,37E+04	8,52E+03	4,21E+05	6,05E+03	6,99E+03	9,88E+02	4,03E+03
SCORZE	San Benedetto Mineral Water	GLASS SUBDIVISION	Metal depletion	kg Fe eq/year	9,82E+05	4,16E+05	1,04E+05	1,32E+04	6,77E+04	2,50E+03	1,71E+04	1,10E+05	4,25E+04	1,64E+05	2,38E+04	9,18E+03	5,06E+03	7,25E+03
ATELLA	San Benedetto Mineral Water	GLASS SUBDIVISION	Metal depletion	kg Fe eq/year	5,15E+04	1,11E+04	5,66E+03	5,09E+02	2,62E+02	2,47E+02	2,68E+03	1,03E+04	1,37E+01	1,91E+04	0,00E+00	1,20E+03	2,99E-01	5,28E+02

						Raw material extraction and transformation				Production			Products delivery				Use phase	End of life
Site identification	Division identification	Subdivision identification	Environmental Impact Category	Impact unit	Total	Glass bottles	Caps	Labels	Other packaging	Natural gas	Electricity	Other production aspects	Ship delivery	Truck delivery	Train delivery	Other delivery aspects	Use	End of life
TOTAL ITALIAN SAN BENEDETTO WATER DIVISION	San Benedetto Mineral Water	TOTAL GLASS SUBDIVISION	Metal depletion	kg Fe eq/year	1,03E+06	4,27E+05	1,10E+05	1,37E+04	6,80E+04	2,75E+03	1,98E+04	1,20E+05	4,26E+04	1,83E+05	2,38E+04	1,04E+04	5,06E+03	7,78E+03
SCORZE	San Benedetto Mineral Water	GLASS SUBDIVISION	Fossil depletion	kg oil eq/year	9,40E+06	3,90E+06	7,12E+05	2,40E+05	5,72E+05	5,85E+05	4,88E+05	4,33E+05	5,27E+05	1,67E+06	5,33E+04	1,04E+05	5,52E+04	5,94E+04
ATELLA	San Benedetto Mineral Water	GLASS SUBDIVISION	Fossil depletion	kg oil eq/year	5,93E+05	1,06E+05	3,29E+04	4,46E+03	1,07E+04	1,21E+05	6,11E+04	4,73E+04	1,69E+02	1,94E+05	0,00E+00	1,35E+04	3,25E+00	1,85E+03
TOTAL ITALIAN SAN BENEDETTO WATER DIVISION	San Benedetto Mineral Water	TOTAL GLASS SUBDIVISION	Fossil depletion	kg oil eq/year	9,99E+06	4,00E+06	7,45E+05	2,45E+05	5,82E+05	7,06E+05	5,49E+05	4,81E+05	5,27E+05	1,87E+06	5,33E+04	1,17E+05	5,52E+04	6,12E+04

Table 45 ERD results- Environmental impacts – Organizational scale – San Benedetto Italian Mineral Water GLASS

Site identification	Division identification	Subdivision identification	Product identification	Format	Climate change	Ozone depletion	Terrestrial acidification	Terrestrial ecotoxicity	Water scarcity	Aquatic eutrophication	Aquatic ecotoxicity	Aquatic acidification	Human toxicity	Land occupation	Metal depletion	Fossil depletion
					kg CO2 eq	kg CFC-11 eq	kg SO2 eq	kg 1,4-DB eq	m3 eq	kg PO4 P-lim	kg TEG water	kg SO2 eq	kg 1,4-DB eq	m2org.arable	kg Fe eq	kg oil eq
SCORZE	SB Mineral Water	PET SUBDIVISION	COD1323	0,50	1,20E-01	1,01E-08	4,39E-04	1,31E-05	1,35E-03	1,57E-05	7,00E+00	4,79E-04	2,93E-02	2,72E-03	5,09E-03	4,52E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD1342	2,00	2,83E-01	3,05E-08	1,07E-03	4,16E-05	3,91E-03	4,10E-05	2,08E+01	1,17E-03	7,18E-02	9,26E-03	1,06E-02	1,04E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD1727	0,75	2,79E-01	2,62E-08	1,01E-03	3,33E-05	1,07E-03	3,73E-05	1,53E+01	1,10E-03	6,25E-02	7,02E-03	1,00E-02	1,11E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD1728	0,50	2,13E-01	1,77E-08	7,69E-04	2,04E-05	9,19E-04	2,70E-05	1,06E+01	8,39E-04	4,58E-02	4,51E-03	7,85E-03	8,43E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD1729	0,25	1,65E-01	1,18E-08	6,00E-04	1,37E-05	8,80E-04	1,91E-05	7,37E+00	6,54E-04	3,42E-02	3,01E-03	5,58E-03	6,75E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD1730	0,25	1,31E-01	8,96E-09	5,33E-04	1,00E-05	1,52E-01	1,81E-05	7,46E+00	5,81E-04	3,44E-02	2,25E-03	6,27E-03	5,24E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD1731	0,25	1,33E-01	8,76E-09	5,29E-04	1,01E-05	1,42E-03	1,82E-05	7,37E+00	5,76E-04	3,44E-02	2,15E-03	6,22E-03	5,21E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD1732	1,0	2,80E-01	2,49E-08	1,11E-03	3,12E-05	3,41E-03	3,93E-05	1,74E+01	1,21E-03	7,22E-02	6,78E-03	1,28E-02	1,10E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD1733	1,0	2,89E-01	2,42E-08	1,10E-03	3,05E-05	1,59E-01	3,98E-05	1,71E+01	1,20E-03	7,27E-02	6,41E-03	1,31E-02	1,09E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD1734	1,0	3,05E-01	2,80E-08	1,17E-03	4,04E-05	1,27E-01	4,16E-05	1,92E+01	1,28E-03	7,83E-02	8,09E-03	1,37E-02	1,17E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD1735	0,75	2,57E-01	2,11E-08	1,03E-03	2,62E-05	1,53E-01	3,60E-05	1,53E+01	1,12E-03	6,68E-02	5,70E-03	1,20E-02	1,02E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD1736	0,75	2,72E-01	2,17E-08	1,04E-03	2,91E-05	1,59E-01	3,73E-05	1,57E+01	1,13E-03	6,96E-02	5,90E-03	1,25E-02	1,04E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD1737	0,75	2,96E-01	2,53E-08	1,61E-03	2,88E-05	1,22E-01	3,95E-05	1,62E+01	1,75E-03	7,16E-02	5,50E-03	1,32E-02	1,11E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD1738	0,4	2,22E-01	2,18E-08	1,62E-03	2,22E-05	1,48E-02	2,86E-05	1,26E+01	1,77E-03	5,14E-02	4,23E-03	9,34E-03	8,54E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD1739	0,4	2,34E-01	2,29E-08	1,83E-03	2,10E-05	1,52E-01	2,95E-05	1,26E+01	1,99E-03	5,18E-02	3,99E-03	9,55E-03	8,78E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD1740	0,33	1,40E-01	1,03E-08	5,62E-04	1,18E-05	1,72E-03	1,85E-05	7,54E+00	6,13E-04	3,54E-02	2,24E-03	6,36E-03	5,66E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD1741	0,33	1,48E-01	1,08E-08	5,82E-04	1,32E-05	1,54E-03	1,92E-05	7,78E+00	6,34E-04	3,69E-02	2,35E-03	6,79E-03	5,78E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD1742	0,5	9,29E-02	9,07E-09	3,48E-04	1,15E-05	1,09E-03	1,24E-05	6,05E+00	3,81E-04	2,27E-02	2,74E-03	3,62E-03	3,61E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD1743	0,5	1,20E-01	1,02E-08	4,39E-04	1,37E-05	1,34E-03	1,58E-05	7,09E+00	4,79E-04	2,94E-02	2,81E-03	5,07E-03	4,51E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD1744	0,5	9,77E-02	9,24E-09	3,60E-04	1,14E-05	1,13E-03	1,25E-05	6,10E+00	3,94E-04	2,32E-02	2,67E-03	3,65E-03	3,85E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD1745	0,5	1,24E-01	1,03E-08	4,49E-04	1,37E-05	1,38E-03	1,59E-05	7,15E+00	4,90E-04	3,00E-02	2,83E-03	5,11E-03	4,73E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD1746	0,5	1,21E-01	1,17E-08	4,62E-04	1,66E-05	1,33E-03	1,62E-05	7,84E+00	5,06E-04	3,05E-02	3,61E-03	5,06E-03	4,75E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD1747	0,5	9,74E-02	9,20E-09	3,59E-04	1,14E-05	1,13E-03	1,24E-05	6,08E+00	3,93E-04	2,32E-02	2,64E-03	3,63E-03	3,84E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD1748	0,5	1,23E-01	1,01E-08	4,50E-04	1,26E-05	1,38E-03	1,58E-05	6,97E+00	4,91E-04	2,95E-02	2,68E-03	5,12E-03	4,68E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD1749	0,5	1,26E-01	1,11E-08	4,63E-04	1,53E-05	1,38E-03	1,61E-05	7,51E+00	5,07E-04	3,08E-02	3,12E-03	5,21E-03	4,87E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD1750	0,5	8,96E-02	8,38E-09	3,36E-04	9,64E-06	1,08E-03	1,21E-05	5,65E+00	3,67E-04	2,17E-02	2,41E-03	3,49E-03	3,49E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD1751	0,5	1,17E-01	9,67E-09	4,28E-04	1,21E-05	1,34E-03	1,54E-05	6,77E+00	4,67E-04	2,85E-02	2,55E-03	4,97E-03	4,40E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD1752	0,5	9,01E-02	8,52E-09	3,38E-04	9,85E-06	1,08E-03	1,21E-05	5,73E+00	3,69E-04	2,18E-02	2,48E-03	3,53E-03	3,50E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD1753	0,5	9,67E-02	8,95E-09	3,58E-04	1,02E-05	1,14E-03	1,24E-05	5,93E+00	3,91E-04	2,28E-02	2,51E-03	3,70E-03	3,81E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD1754	1,0	1,61E-01	1,74E-08	5,94E-04	2,34E-05	2,04E-03	2,15E-05	1,09E+01	6,51E-04	3,90E-02	4,55E-03	5,66E-03	5,67E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD1755	1,5	2,10E-01	2,30E-08	7,84E-04	3,28E-05	2,89E-03	2,95E-05	1,51E+01	8,59E-04	5,20E-02	6,19E-03	7,72E-03	7,78E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD1756	1,5	2,09E-01	2,30E-08	7,83E-04	3,26E-05	2,89E-03	2,95E-05	1,51E+01	8,58E-04	5,19E-02	6,17E-03	7,71E-03	7,77E-02

Site identification	Division identification	Subdivision identification	Product identification	Format	Climate change	Ozone depletion	Terrestrial acidification	Terrestrial ecotoxicity	Water scarcity	Aquatic eutrophication	Aquatic ecotoxicity	Aquatic acidification	Human toxicity	Land occupation	Metal depletion	Fossil depletion
					kg CO2 eq	kg CFC-11 eq	kg SO2 eq	kg 1,4-DB eq	m3 eq	kg PO4 P-lim	kg TEG water	kg SO2 eq	kg 1,4-DB eq	m2org.arable	kg Fe eq	kg oil eq
SCORZE	SB Mineral Water	PET SUBDIVISION	COD1757	2	2,72E-01	2,95E-08	1,02E-03	4,03E-05	3,84E-03	4,00E-05	2,03E+01	1,12E-03	6,90E-02	9,36E-03	1,02E-02	9,97E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD1758	2	2,72E-01	2,96E-08	1,03E-03	4,07E-05	3,85E-03	4,01E-05	2,04E+01	1,13E-03	6,93E-02	9,45E-03	1,03E-02	1,00E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD1759	2	2,65E-01	2,82E-08	1,00E-03	3,63E-05	3,83E-03	3,92E-05	1,95E+01	1,10E-03	6,66E-02	8,61E-03	1,00E-02	9,72E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD1760	2	2,67E-01	2,85E-08	1,01E-03	3,73E-05	3,84E-03	3,95E-05	1,97E+01	1,11E-03	6,73E-02	8,82E-03	1,01E-02	9,79E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD1761	1,5	2,99E-01	2,61E-08	1,11E-03	3,52E-05	3,60E-03	4,19E-05	1,87E+01	1,22E-03	7,54E-02	7,18E-03	1,33E-02	1,11E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD1762	1,5	3,00E-01	2,60E-08	1,11E-03	3,46E-05	3,61E-03	4,19E-05	1,86E+01	1,22E-03	7,53E-02	7,16E-03	1,33E-02	1,11E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD1763	1,5	3,03E-01	2,71E-08	1,13E-03	3,82E-05	3,60E-03	4,20E-05	1,91E+01	1,23E-03	7,67E-02	7,44E-03	1,33E-02	1,12E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD1764	1,5	2,92E-01	2,54E-08	1,09E-03	3,27E-05	3,58E-03	4,11E-05	1,83E+01	1,19E-03	7,34E-02	6,90E-03	1,29E-02	1,09E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD1765	1,5	2,93E-01	2,52E-08	1,09E-03	3,20E-05	3,59E-03	4,11E-05	1,82E+01	1,19E-03	7,33E-02	6,87E-03	1,29E-02	1,10E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD1766	1,5	2,91E-01	2,53E-08	1,09E-03	3,23E-05	3,57E-03	4,08E-05	1,81E+01	1,19E-03	7,30E-02	6,67E-03	1,28E-02	1,09E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD1777	1,5	2,06E-01	2,22E-08	7,75E-04	3,00E-05	2,88E-03	2,90E-05	1,46E+01	8,49E-04	5,05E-02	5,79E-03	7,61E-03	7,62E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD1778	1,5	2,06E-01	2,22E-08	7,77E-04	2,97E-05	2,88E-03	2,91E-05	1,46E+01	8,50E-04	5,05E-02	5,77E-03	7,66E-03	7,62E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD1779	0,5	1,13E-01	9,44E-09	4,23E-04	1,09E-05	1,33E-03	1,51E-05	6,58E+00	4,61E-04	2,77E-02	2,41E-03	4,89E-03	4,35E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD1784	0,5	1,23E-01	1,04E-08	4,48E-04	1,42E-05	1,35E-03	1,61E-05	7,22E+00	4,89E-04	3,02E-02	2,95E-03	5,13E-03	4,65E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD1785	0,5	1,14E-01	1,02E-08	4,39E-04	1,31E-05	1,53E-03	1,55E-05	7,09E+00	4,80E-04	2,88E-02	2,95E-03	4,80E-03	4,52E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD1786	0,5	1,18E-01	9,84E-09	4,33E-04	1,25E-05	1,34E-03	1,56E-05	6,88E+00	4,73E-04	2,88E-02	2,63E-03	5,00E-03	4,47E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD1787	2	2,62E-01	2,77E-08	9,89E-04	3,51E-05	3,83E-03	3,90E-05	1,93E+01	1,08E-03	6,60E-02	8,64E-03	9,90E-03	9,62E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD1788	2	2,65E-01	2,83E-08	1,00E-03	3,68E-05	3,83E-03	3,93E-05	1,96E+01	1,10E-03	6,70E-02	8,87E-03	1,00E-02	9,74E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD1790	0,5	1,15E-01	1,04E-08	4,42E-04	1,35E-05	1,53E-03	1,56E-05	7,18E+00	4,84E-04	2,90E-02	3,02E-03	4,83E-03	4,55E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD1791	0,5	1,15E-01	1,04E-08	4,42E-04	1,35E-05	1,53E-03	1,56E-05	7,18E+00	4,84E-04	2,90E-02	3,02E-03	4,83E-03	4,55E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6173	0,25	1,56E-01	1,36E-08	8,37E-04	1,80E-05	1,66E-03	2,07E-05	9,39E+00	9,15E-04	3,97E-02	3,46E-03	6,89E-03	6,16E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6175	0,33	1,74E-01	1,69E-08	6,80E-04	3,11E-05	1,78E-03	2,21E-05	1,13E+01	7,48E-04	4,64E-02	5,23E-03	7,55E-03	6,96E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6176	0,33	1,74E-01	1,58E-08	7,14E-04	2,71E-05	1,59E-03	2,20E-05	1,06E+01	7,84E-04	4,48E-02	4,49E-03	7,56E-03	6,77E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6177	0,4	2,13E-01	2,04E-08	1,32E-03	2,57E-05	2,11E-03	2,77E-05	1,27E+01	1,44E-03	5,21E-02	4,78E-03	9,08E-03	8,26E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6178	0,4	2,27E-01	2,25E-08	1,71E-03	2,27E-05	2,12E-03	2,89E-05	1,27E+01	1,86E-03	5,18E-02	4,06E-03	9,27E-03	8,69E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6179	0,4	2,48E-01	2,48E-08	2,32E-03	1,46E-05	1,95E-03	3,07E-05	1,22E+01	2,53E-03	5,02E-02	2,75E-03	9,73E-03	9,20E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6182	0,4	2,31E-01	2,27E-08	1,60E-03	2,58E-05	1,94E-03	2,93E-05	1,32E+01	1,75E-03	5,38E-02	4,79E-03	9,67E-03	8,75E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6183	0,4	2,34E-01	2,29E-08	1,83E-03	2,12E-05	1,93E-03	2,95E-05	1,26E+01	1,99E-03	5,17E-02	3,80E-03	9,50E-03	8,80E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6185	0,5	2,56E-01	2,60E-08	2,33E-03	1,51E-05	2,07E-03	3,12E-05	1,20E+01	2,30E-03	5,08E-02	2,54E-03	9,94E-03	9,56E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6186	0,5	2,76E-01	2,92E-08	2,71E-03	1,50E-05	2,11E-03	3,31E-05	1,27E+01	2,43E-03	5,24E-02	2,96E-03	1,05E-02	1,02E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6187	1,5	6,05E-01	7,27E-08	7,06E-03	3,30E-05	4,20E-03	7,14E-05	2,85E+01	5,62E-03	1,02E-01	7,70E-03	2,12E-02	2,12E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6188	0,75	2,49E-01	1,95E-08	1,19E-03	1,97E-05	3,07E-03	3,49E-05	1,38E+01	4,23E-03	6,32E-02	1,30E-03	1,14E-02	9,86E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6190	0,75	2,94E-01	2,50E-08	1,59E-03	2,84E-05	2,92E-03	3,93E-05	1,60E+01	5,40E-03	7,14E-02	1,73E-03	1,32E-02	1,10E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6191	0,75	3,42E-01	3,31E-08	2,41E-03	3,47E-05	2,99E-03	4,40E-05	1,85E+01	5,90E-03	7,76E-02	2,63E-03	1,43E-02	1,27E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6192	1,0	3,44E-01	3,47E-08	2,40E-03	3,17E-05	3,51E-03	4,51E-05	1,95E+01	6,19E-03	7,72E-02	2,62E-03	1,40E-02	1,32E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6193	1,0	3,38E-01	3,55E-08	1,32E-03	6,22E-05	3,52E-03	4,51E-05	2,35E+01	1,15E-02	8,99E-02	1,45E-03	1,45E-02	1,32E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6194	1,0	3,20E-01	3,16E-08	1,48E-03	4,49E-05	3,48E-03	4,30E-05	2,05E+01	8,82E-03	8,10E-02	1,62E-03	1,37E-02	1,25E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6195	1,0	3,37E-01	3,38E-08	2,12E-03	3,61E-05	3,50E-03	4,45E-05	1,98E+01	6,89E-03	7,84E-02	2,31E-03	1,39E-02	1,30E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6196	1,0	3,32E-01	3,08E-08	1,96E-03	3,06E-05	3,26E-03	4,37E-05	1,84E+01	5,80E-03	7,61E-02	2,14E-03	1,39E-02	1,24E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6197	1,0	3,47E-01	3,48E-08	1,31E-03	6,10E-05	3,31E-03	4,57E-05	2,32E+01	1,11E-02	9,05E-02	1,44E-03	1,50E-02	1,32E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6198	1,0	3,34E-01	3,17E-08	1,53E-03	4,50E-05	3,28E-03	4,42E-05	2,05E+01	8,61E-03	8,27E-02	1,67E-03	1,43E-02	1,26E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6199	1,0	3,57E-01	3,52E-08	2,12E-03	4,16E-05	3,31E-03	4,63E-05	2,08E+01	7,53E-03	8,28E-02	2,32E-03	1,48E-02	1,33E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6201	0,5	1,46E-01	1,77E-08	1,30E-03	1,58E-05	1,17E-03	1,76E-05	8,34E+00	2,81E-03	2,87E-02	1,42E-03	5,03E-03	5,38E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6202	0,5	1,67E-01	1,87E-08	1,39E-03	1,68E-05	1,46E-03	2,02E-05	9,27E+00	2,86E-03	3,43E-02	1,52E-03	6,15E-03	6,35E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6203	0,5	1,30E-01	1,29E-08	5,50E-04	1,92E-05	1,37E-03	1,67E-05	8,40E+00	3,48E-03	3,22E-02	6,03E-04	5,26E-03	5,16E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6204	0,5	1,93E-01	2,27E-08	1,98E-03	1,51E-05	1,47E-03	2,27E-05	9,89E+00	2,58E-03	3,58E-02	2,16E-03	6,79E-03	7,18E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6205	0,5	1,64E-01	1,94E-08	6,23E-04	3,91E-05	1,44E-03	2,03E-05	1,23E+01	6,60E-03	4,35E-02	6,91E-04	6,53E-03	6,44E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6206	0,5	9,03E-02	8,64E-09	3,38E-04	1,03E-05	1,08E-03	1,21E-05	5,78E+00	2,19E-03	2,17E-02	3,70E-04	3,51E-03	3,52E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6208	0,5	1,11E-01	1,38E-08	5,10E-04	2,33E-05	1,38E-03	1,71E-05	9,10E+00	4,12E-03	3,42E-02	5,61E-04	5,45E-03	5,33E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6207	0,5	1,34E-01	1,19E-08	4,47E-04	1,69E-05	1,14E-03	1,45E-05	7,44E+00	3,40E-03	2,74E-02	4,91E-04	4,94E-03	4,21E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6209	0,5	1,52E-01	1,69E-08	6,29E-04	3,04E-05	1,42E-03	1,90E-05	1,07E+01	5,25E-03	3,89E-02	6,94E-04	6,14E-03	5,95E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6210	0,5	2,06E-01	2,61E-08	1,54E-03	3,76E-05	1,55E-03	2,44E-05	1,34E+01	6,13E-03	4,65E-02	1,69E-03	7,58E-03	7,81E-02

Site identification	Division identification	Subdivision identification	Product identification	Format	Climate change	Ozone depletion	Terrestrial acidification	Terrestrial ecotoxicity	Water scarcity	Aquatic eutrophication	Aquatic ecotoxicity	Aquatic acidification	Human toxicity	Land occupation	Metal depletion	Fossil depletion
					kg CO2 eq	kg CFC-11 eq	kg SO2 eq	kg 1,4-DB eq	m3 eq	kg PO4 P-lim	kg TEG water	kg SO2 eq	kg 1,4-DB eq	m2org.arable	kg Fe eq	kg oil eq
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6212	0,5	1,88E-01	2,21E-08	1,76E-03	1,87E-05	1,46E-03	2,23E-05	1,02E+01	3,16E-03	3,68E-02	1,92E-03	6,74E-03	7,04E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6213	0,5	1,48E-01	1,52E-08	1,21E-03	9,63E-06	1,42E-03	1,82E-05	7,64E+00	1,75E-03	2,95E-02	1,32E-03	5,50E-03	5,65E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6214	0,5	2,07E-01	2,46E-08	2,40E-03	1,07E-05	1,48E-03	2,40E-05	9,73E+00	1,88E-03	3,51E-02	2,61E-03	7,05E-03	7,59E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6215	0,5	1,19E-01	1,06E-08	7,02E-04	7,79E-06	1,42E-03	1,55E-05	6,44E+00	1,41E-03	2,63E-02	7,64E-04	4,74E-03	4,70E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6216	0,5	1,20E-01	1,08E-08	7,04E-04	8,15E-06	1,45E-03	1,55E-05	6,51E+00	1,47E-03	2,66E-02	7,68E-04	4,77E-03	4,73E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6217	0,5	1,44E-01	1,57E-08	5,47E-04	2,86E-05	1,47E-03	1,82E-05	1,02E+01	4,95E-03	3,74E-02	6,03E-04	5,81E-03	5,71E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6218	0,5	1,33E-01	1,34E-08	5,98E-04	1,96E-05	1,50E-03	1,70E-05	8,55E+00	6,55E-04	3,27E-02	3,53E-03	5,34E-03	5,25E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6219	0,5	1,65E-01	1,84E-08	1,25E-03	1,98E-05	1,50E-03	2,01E-05	9,60E+00	1,36E-03	3,53E-02	3,34E-03	6,15E-03	6,29E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6220	0,5	2,16E-01	2,64E-08	2,33E-03	1,85E-05	2,18E-02	2,50E-05	1,11E+01	2,55E-03	3,92E-02	3,11E-03	7,44E-03	7,94E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6221	0,5	1,32E-01	1,13E-08	7,25E-04	9,51E-06	1,40E-03	1,64E-05	6,75E+00	7,90E-04	2,85E-02	1,50E-03	5,14E-03	4,97E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6223	0,5	1,45E-01	1,44E-08	5,29E-04	2,55E-05	1,42E-03	1,81E-05	9,46E+00	5,83E-04	3,65E-02	4,30E-03	5,87E-03	5,53E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6224	0,5	2,09E-01	1,92E-08	1,32E-03	1,97E-05	1,96E-03	2,65E-05	1,10E+01	1,44E-03	4,78E-02	3,05E-03	8,71E-03	8,00E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6225	0,5	1,41E-01	1,36E-08	5,60E-04	2,19E-05	1,41E-03	1,77E-05	8,83E+00	6,15E-04	3,46E-02	3,73E-03	5,69E-03	5,37E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6226	0,5	1,53E-01	1,59E-08	5,57E-04	2,97E-05	1,43E-03	1,90E-05	1,03E+01	6,15E-04	3,90E-02	4,96E-03	6,15E-03	5,82E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6227	0,5	2,35E-01	2,31E-08	1,67E-03	2,24E-05	2,05E-03	2,92E-05	1,23E+01	1,83E-03	5,20E-02	3,46E-03	9,55E-03	8,94E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6229	0,5	1,54E-01	1,61E-08	5,86E-04	2,93E-05	1,44E-03	1,91E-05	1,03E+01	6,46E-04	3,90E-02	4,91E-03	6,24E-03	5,85E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6230	0,5	1,77E-01	1,94E-08	1,26E-03	2,33E-05	1,47E-03	2,12E-05	1,02E+01	1,38E-03	3,82E-02	3,72E-03	6,63E-03	6,55E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6231	0,5	1,30E-01	1,20E-08	4,88E-04	1,79E-05	1,36E-03	1,69E-05	8,02E+00	5,35E-04	3,22E-02	3,15E-03	5,69E-03	4,87E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6232	0,5	2,58E-01	2,68E-08	2,13E-03	2,32E-05	2,08E-03	3,15E-05	1,31E+01	2,32E-03	5,43E-02	3,57E-03	1,02E-02	9,70E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6233	0,5	2,84E-01	3,09E-08	2,62E-03	2,40E-05	2,12E-03	3,40E-05	1,41E+01	2,86E-03	5,69E-02	3,68E-03	1,08E-02	1,05E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6234	0,5	1,41E-01	1,59E-08	1,35E-03	8,17E-06	1,20E-03	1,65E-05	7,01E+00	1,47E-03	2,52E-02	1,53E-03	4,63E-03	5,23E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6235	2	3,60E-01	4,51E-08	2,03E-03	6,63E-05	3,99E-03	4,88E-05	2,67E+01	2,23E-03	8,74E-02	1,28E-02	1,32E-02	1,31E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6236	2	3,73E-01	4,89E-08	1,40E-03	9,54E-05	4,02E-03	5,05E-05	3,12E+01	1,56E-03	1,01E-01	1,74E-02	1,40E-02	1,38E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6237	1,5	5,21E-01	6,43E-08	5,93E-03	3,77E-05	4,06E-03	6,33E-05	2,68E+01	6,47E-03	9,40E-02	6,49E-03	1,85E-02	1,89E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6238	1,5	3,36E-01	3,60E-08	1,41E-03	5,93E-05	3,80E-03	4,56E-05	2,37E+01	1,55E-03	8,75E-02	1,06E-02	1,43E-02	1,30E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6242	1,5	4,46E-01	5,28E-08	4,17E-03	4,44E-05	3,95E-03	5,60E-05	2,52E+01	4,55E-03	9,02E-02	7,59E-03	1,67E-02	1,65E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6243	1,5	4,24E-01	5,31E-08	1,63E-03	1,11E-04	3,96E-03	5,51E-05	3,38E+01	1,81E-03	1,17E-01	1,88E-02	1,75E-02	1,64E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6244	1,5	5,32E-01	7,35E-08	2,03E-03	1,69E-04	4,15E-03	6,66E-05	4,54E+01	2,27E-03	1,51E-01	2,79E-02	2,15E-02	2,04E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6245	1,5	3,72E-01	4,10E-08	2,67E-03	4,38E-05	3,84E-03	4,88E-05	2,27E+01	2,92E-03	8,35E-02	7,54E-03	1,48E-02	1,41E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6246	1,5	5,61E-01	7,03E-08	6,97E-03	3,09E-05	4,12E-03	6,71E-05	2,72E+01	7,60E-03	9,46E-02	5,39E-03	1,94E-02	2,01E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6247	1,5	5,86E-01	7,56E-08	6,76E-03	5,40E-05	4,17E-03	6,99E-05	3,12E+01	7,38E-03	1,07E-01	9,03E-03	2,05E-02	2,11E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6248	1,5	3,34E-01	3,59E-08	1,31E-03	6,14E-05	3,80E-03	4,54E-05	2,39E+01	1,45E-03	8,81E-02	1,09E-02	1,42E-02	1,30E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6249	1,5	3,96E-01	4,54E-08	2,86E-03	5,34E-05	3,88E-03	5,13E-05	2,49E+01	3,13E-03	8,97E-02	9,05E-03	1,56E-02	1,49E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6250	1,5	3,93E-01	4,45E-08	1,47E-03	8,72E-05	3,75E-03	5,15E-05	2,90E+01	1,62E-03	1,05E-01	1,48E-02	1,65E-02	1,47E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6251	1,5	3,70E-01	3,95E-08	1,37E-03	7,36E-05	3,72E-03	4,90E-05	2,62E+01	1,51E-03	9,71E-02	1,25E-02	1,57E-02	1,37E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6252	1,5	3,81E-01	4,16E-08	1,41E-03	7,94E-05	3,74E-03	5,01E-05	2,73E+01	1,56E-03	1,00E-01	1,34E-02	1,61E-02	1,42E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6253	1,5	3,70E-01	3,91E-08	1,67E-03	6,42E-05	3,71E-03	4,89E-05	2,49E+01	1,83E-03	9,32E-02	1,11E-02	1,56E-02	1,37E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6255	1,5	4,55E-01	5,56E-08	1,69E-03	1,19E-04	3,87E-03	5,80E-05	3,53E+01	1,88E-03	1,24E-01	1,97E-02	1,88E-02	1,69E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6256	1,5	5,05E-01	5,96E-08	4,93E-03	4,88E-05	3,91E-03	6,17E-05	2,71E+01	5,39E-03	9,79E-02	7,92E-03	1,86E-02	1,79E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6257	1,5	4,10E-01	4,55E-08	2,58E-03	6,26E-05	3,76E-03	5,27E-05	2,59E+01	2,82E-03	9,55E-02	1,01E-02	1,65E-02	1,49E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6259	1,5	5,21E-01	6,12E-08	5,84E-03	3,07E-05	3,92E-03	6,30E-05	2,52E+01	6,37E-03	9,18E-02	5,05E-03	1,87E-02	1,83E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6260	1,5	5,92E-01	7,28E-08	7,17E-03	3,57E-05	4,03E-03	7,01E-05	2,82E+01	7,81E-03	1,00E-01	5,77E-03	2,06E-02	2,07E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6261	1,5	6,12E-01	7,70E-08	6,87E-03	5,73E-05	4,07E-03	7,23E-05	3,18E+01	7,50E-03	1,11E-01	9,21E-03	2,16E-02	2,15E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6262	1,5	3,92E-01	4,19E-08	1,46E-03	7,59E-05	3,81E-03	5,19E-05	2,73E+01	1,61E-03	1,03E-01	1,42E-02	1,79E-02	1,44E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6263	1,5	3,06E-01	2,92E-08	1,93E-03	2,33E-05	3,73E-03	4,22E-05	1,77E+01	2,10E-03	6,94E-02	4,65E-03	1,27E-02	1,17E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6265	1,5	3,13E-01	3,12E-08	1,21E-03	4,86E-05	3,77E-03	4,33E-05	2,14E+01	1,32E-03	8,19E-02	9,92E-03	1,34E-02	1,22E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6266	1,5	4,49E-01	5,33E-08	3,99E-03	5,09E-05	3,97E-03	5,65E-05	2,62E+01	4,36E-03	9,35E-02	8,94E-03	1,69E-02	1,66E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6267	1,5	3,22E-01	2,97E-08	1,95E-03	2,51E-05	3,61E-03	4,36E-05	1,80E+01	2,12E-03	7,21E-02	4,65E-03	1,34E-02	1,19E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6269	1,5	3,30E-01	3,18E-08	1,22E-03	5,07E-05	3,65E-03	4,49E-05	2,18E+01	1,34E-03	8,48E-02	1,01E-02	1,42E-02	1,23E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6270	1,5	4,69E-01	5,42E-08	4,03E-03	5,42E-05	3,86E-03	5,84E-05	2,67E+01	4,40E-03	9,73E-02	9,01E-03	1,78E-02	1,68E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6271	1,5	2,64E-01	3,32E-08	9,85E-04	6,17E-05	2,99E-03	3,52E-05	2,09E+01	1,09E-03	6,89E-02	1,07E-02	9,69E-03	9,80E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6272	0,25	1,75E-01	1,40E-08	6,16E-04	2,13E-05	8,94E-04	2,02E-05	8,74E+00	6,74E-04	3,80E-02	4,14E-03	5,77E-03	7,18E-02

Site identification	Division identification	Subdivision identification	Product identification	Format	Climate change	Ozone depletion	Terrestrial acidification	Terrestrial ecotoxicity	Water scarcity	Aquatic eutrophication	Aquatic ecotoxicity	Aquatic acidification	Human toxicity	Land occupation	Metal depletion	Fossil depletion
					kg CO2 eq	kg CFC-11 eq	kg SO2 eq	kg 1,4-DB eq	m3 eq	kg PO4 P-lim	kg TEG water	kg SO2 eq	kg 1,4-DB eq	m2org.arable	kg Fe eq	kg oil eq
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6273	0,5	2,66E-01	2,77E-08	1,41E-03	3,87E-05	9,82E-04	3,24E-05	1,48E+01	1,55E-03	5,71E-02	7,25E-03	8,91E-03	1,04E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6276	0,33	1,60E-01	1,37E-08	9,05E-04	1,45E-05	1,75E-03	2,05E-05	8,58E+00	9,88E-04	3,82E-02	2,63E-03	6,91E-03	6,36E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6277	0,33	1,72E-01	1,52E-08	8,21E-04	2,24E-05	1,58E-03	2,17E-05	9,84E+00	8,99E-04	4,26E-02	3,75E-03	7,42E-03	6,66E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6278	1,5	4,13E-01	4,69E-08	1,53E-03	9,31E-05	3,82E-03	5,37E-05	3,04E+01	1,69E-03	1,10E-01	1,68E-02	1,72E-02	1,54E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6279	1,5	4,10E-01	4,70E-08	1,52E-03	9,37E-05	3,80E-03	5,34E-05	3,04E+01	1,68E-03	1,10E-01	1,68E-02	1,71E-02	1,53E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6293	0,5	2,13E-01	1,96E-08	1,14E-03	2,47E-05	2,01E-03	2,71E-05	1,18E+01	1,24E-03	5,10E-02	3,83E-03	9,01E-03	8,23E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6296	1,5	2,81E-01	2,60E-08	1,09E-03	3,38E-05	3,69E-03	3,98E-05	1,84E+01	1,19E-03	7,18E-02	6,63E-03	1,23E-02	1,10E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6297	1,5	3,43E-01	3,45E-08	1,27E-03	5,92E-05	3,67E-03	4,61E-05	2,33E+01	1,40E-03	8,87E-02	1,03E-02	1,47E-02	1,27E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6303	0,5	1,53E-01	1,60E-08	5,58E-04	2,98E-05	1,43E-03	1,90E-05	1,03E+01	6,15E-04	3,90E-02	4,97E-03	6,16E-03	5,83E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6304	0,5	2,91E-01	3,32E-08	2,12E-03	4,47E-05	2,14E-03	3,51E-05	1,72E+01	2,32E-03	6,63E-02	6,95E-03	1,14E-02	1,10E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD6305	0,5	2,22E-01	2,87E-08	1,84E-03	3,88E-05	1,73E-03	2,61E-05	1,41E+01	2,02E-03	4,85E-02	6,31E-03	8,03E-03	8,34E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD7099	0,4	2,60E-01	2,80E-08	1,83E-03	3,80E-05	1,98E-03	3,23E-05	1,58E+01	2,01E-03	6,10E-02	6,43E-03	1,05E-02	9,79E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD7165	0,75	3,59E-01	3,81E-08	2,85E-03	3,94E-05	3,24E-03	4,59E-05	2,01E+01	3,11E-03	8,07E-02	6,85E-03	1,46E-02	1,36E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD7422	1,5	3,07E-01	2,92E-08	1,93E-03	2,32E-05	3,74E-03	4,22E-05	1,77E+01	2,10E-03	6,95E-02	4,63E-03	1,27E-02	1,18E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD7423	1,5	3,22E-01	2,96E-08	1,93E-03	2,51E-05	3,61E-03	4,35E-05	1,80E+01	2,10E-03	7,20E-02	4,66E-03	1,34E-02	1,18E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD7550	1,5	5,86E-01	8,34E-08	2,23E-03	1,97E-04	4,26E-03	7,22E-05	5,10E+01	2,49E-03	1,67E-01	3,22E-02	2,34E-02	2,24E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD7583	0,5	2,06E-01	2,55E-08	2,26E-03	1,72E-05	1,45E-03	2,44E-05	1,07E+01	2,46E-03	3,77E-02	2,95E-03	7,26E-03	7,55E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD7802	0,25	1,53E-01	1,20E-08	7,97E-04	1,41E-05	1,46E-03	2,01E-05	8,55E+00	8,70E-04	3,78E-02	2,77E-03	6,79E-03	5,90E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD7868	1,5	3,01E-01	2,93E-08	1,16E-03	4,32E-05	3,74E-03	4,20E-05	2,03E+01	1,28E-03	7,78E-02	8,33E-03	1,29E-02	1,18E-01
SCORZE	SB Mineral Water	PET SUBDIVISION	COD7871	0,5	1,77E-01	1,91E-08	1,42E-03	1,81E-05	1,46E-03	2,11E-05	9,47E+00	1,55E-03	3,60E-02	2,90E-03	6,53E-03	6,50E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD7902	0,5	1,16E-01	8,91E-09	4,78E-04	8,25E-06	1,36E-03	1,50E-05	6,12E+00	5,20E-04	2,66E-02	1,39E-03	4,76E-03	4,44E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD7978	0,5	2,26E-01	2,69E-08	2,36E-03	1,99E-05	1,54E-03	2,59E-05	1,13E+01	2,58E-03	4,10E-02	3,16E-03	7,82E-03	8,10E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD7994	0,5	1,21E-01	1,08E-08	7,07E-04	8,20E-06	1,51E-03	1,56E-05	6,54E+00	7,70E-04	2,67E-02	1,48E-03	4,77E-03	4,76E-02
SCORZE	SB Mineral Water	PET SUBDIVISION	COD7995	0,5	1,31E-01	1,12E-08	7,20E-04	9,29E-06	1,39E-03	1,64E-05	6,70E+00	7,84E-04	2,84E-02	1,46E-03	5,12E-03	4,95E-02
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD1710	0,25	2,71E-01	3,51E-08	1,73E-03	7,48E-05	9,61E-05	4,18E-05	2,94E+01	1,87E-03	8,20E-02	1,32E-02	9,60E-03	8,58E-02
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD1711	0,25	2,81E-01	3,57E-08	1,75E-03	7,66E-05	1,31E-04	4,28E-05	2,98E+01	1,89E-03	8,42E-02	1,34E-02	1,01E-02	8,74E-02
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD1712	0,5	4,61E-01	6,11E-08	2,88E-03	1,28E-04	1,31E-04	7,18E-05	4,81E+01	3,12E-03	1,37E-01	2,32E-02	1,61E-02	1,48E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD1713	0,5	4,71E-01	6,19E-08	2,95E-03	1,30E-04	-1,68E-05	7,27E-05	4,84E+01	3,19E-03	1,38E-01	2,33E-02	1,64E-02	1,49E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD1714	0,75	7,72E-01	1,05E-07	4,79E-03	2,24E-04	3,67E-04	1,18E-04	7,93E+01	5,19E-03	2,28E-01	4,05E-02	2,73E-02	2,50E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD1715	0,75	7,86E-01	1,04E-07	4,98E-03	2,19E-04	1,83E-04	1,19E-04	7,85E+01	5,39E-03	2,27E-01	3,95E-02	2,77E-02	2,50E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD1716	1,0	8,18E-01	1,12E-07	5,27E-03	2,18E-04	-2,66E-04	1,27E-04	8,05E+01	5,71E-03	2,33E-01	4,20E-02	2,97E-02	2,64E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD1717	1,0	8,05E-01	1,07E-07	5,15E-03	2,06E-04	-3,82E-04	1,26E-04	7,78E+01	5,57E-03	2,27E-01	3,99E-02	2,94E-02	2,55E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD1718	0,5	1,48E-01	2,23E-08	7,58E-04	3,68E-05	-7,25E-04	2,41E-05	1,56E+01	8,29E-04	4,37E-02	6,24E-03	5,01E-03	4,95E-02
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD1719	0,5	1,53E-01	2,22E-08	7,57E-04	3,69E-05	-8,77E-04	2,46E-05	1,55E+01	8,27E-04	4,44E-02	6,11E-03	5,27E-03	4,94E-02
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD1720	0,75	2,22E-01	3,47E-08	1,11E-03	5,86E-05	-1,09E-03	3,64E-05	2,24E+01	1,22E-03	6,47E-02	1,09E-02	7,53E-03	7,50E-02
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD1721	0,75	2,21E-01	3,22E-08	1,07E-03	5,27E-05	-1,34E-03	3,60E-05	2,10E+01	1,17E-03	6,25E-02	9,66E-03	7,55E-03	7,05E-02
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD1722	0,75	2,82E-01	4,39E-08	1,32E-03	8,26E-05	-1,22E-03	4,28E-05	2,74E+01	1,45E-03	8,15E-02	1,49E-02	1,06E-02	9,40E-02
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD1724	1,0	2,68E-01	4,36E-08	1,28E-03	7,25E-05	-1,79E-03	4,50E-05	2,63E+01	1,41E-03	7,69E-02	1,31E-02	9,40E-03	9,12E-02
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD1725	1,0	2,53E-01	3,85E-08	1,19E-03	5,93E-05	-1,92E-03	4,31E-05	2,34E+01	1,30E-03	7,03E-02	1,07E-02	8,80E-03	8,15E-02
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD1726	1,0	2,73E-01	4,30E-08	1,27E-03	7,12E-05	-1,89E-03	4,52E-05	2,59E+01	1,39E-03	7,68E-02	1,29E-02	9,49E-03	9,03E-02
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6100	0,25	3,34E-01	4,59E-08	2,75E-03	8,59E-05	1,89E-04	4,80E-05	3,30E+01	2,99E-03	9,17E-02	1,43E-02	1,12E-02	1,07E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6101	0,25	3,19E-01	4,33E-08	2,53E-03	8,30E-05	1,64E-04	4,65E-05	3,21E+01	2,75E-03	8,92E-02	1,39E-02	1,08E-02	1,02E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6103	0,25	3,37E-01	4,68E-08	2,49E-03	9,59E-05	2,00E-04	4,85E-05	3,45E+01	2,71E-03	9,63E-02	1,61E-02	1,15E-02	1,09E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6104	0,25	3,61E-01	5,24E-08	2,06E-03	1,26E-04	2,54E-04	5,13E-05	3,94E+01	2,25E-03	1,11E-01	2,07E-02	1,27E-02	1,20E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6105	0,25	1,37E-01	2,17E-08	6,76E-04	4,90E-05	-2,84E-04	1,94E-05	1,59E+01	7,47E-04	4,39E-02	7,63E-03	4,90E-03	4,70E-02
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6106	0,25	3,42E-01	4,62E-08	2,74E-03	8,79E-05	2,18E-04	4,88E-05	3,33E+01	2,98E-03	9,36E-02	1,45E-02	1,16E-02	1,08E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6109	0,25	3,20E-01	4,24E-08	2,43E-03	8,32E-05	1,82E-04	4,66E-05	3,20E+01	2,64E-03	8,97E-02	1,38E-02	1,09E-02	1,01E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6111	0,25	3,55E-01	4,84E-08	2,91E-03	9,12E-05	2,41E-04	5,02E-05	3,42E+01	3,16E-03	9,63E-02	1,52E-02	1,20E-02	1,13E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6112	0,25	3,69E-01	5,26E-08	2,07E-03	1,27E-04	2,82E-04	5,21E-05	3,96E+01	2,26E-03	1,12E-01	2,08E-02	1,30E-02	1,21E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6113	0,25	1,38E-01	2,17E-08	6,76E-04	4,91E-05	-2,84E-04	1,94E-05	1,60E+01	7,47E-04	4,39E-02	7,62E-03	4,90E-03	4,70E-02
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6115	0,5	5,39E-01	7,43E-08	4,37E-03	1,36E-04	2,30E-04	7,93E-05	5,17E+01	4,74E-03	1,46E-01	2,36E-02	1,79E-02	1,74E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6116	0,5	4,73E-01	6,33E-08	3,31E-03	1,26E-04	1,24E-04	7,27E-05	4,82E+01	3,58E-03	1,36E-01	2,21E-02	1,60E-02	1,52E-01

Site identification	Division identification	Subdivision identification	Product identification	Format	Climate change	Ozone depletion	Terrestrial acidification	Terrestrial ecotoxicity	Water scarcity	Aquatic eutrophication	Aquatic ecotoxicity	Aquatic acidification	Human toxicity	Land occupation	Metal depletion	Fossil depletion
					kg CO2 eq	kg CFC-11 eq	kg SO2 eq	kg 1,4-DB eq	m3 eq	kg PO4 P-lim	kg TEG water	kg SO2 eq	kg 1,4-DB eq	m2org.arable	kg Fe eq	kg oil eq
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6117	0,5	5,40E-01	7,44E-08	4,28E-03	1,38E-04	2,44E-04	7,95E-05	5,20E+01	4,64E-03	1,47E-01	2,40E-02	1,80E-02	1,75E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6118	0,5	5,66E-01	7,89E-08	4,65E-03	1,44E-04	2,87E-04	8,22E-05	5,37E+01	5,05E-03	1,52E-01	2,49E-02	1,88E-02	1,84E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6119	0,5	5,43E-01	7,49E-08	4,38E-03	1,37E-04	2,48E-04	7,98E-05	5,20E+01	4,75E-03	1,47E-01	2,39E-02	1,80E-02	1,76E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6120	0,5	5,67E-01	7,83E-08	5,11E-03	1,30E-04	2,81E-04	8,21E-05	5,18E+01	5,55E-03	1,46E-01	2,27E-02	1,85E-02	1,83E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6121	0,5	5,39E-01	7,45E-08	3,67E-03	1,52E-04	2,83E-04	8,00E-05	5,40E+01	3,98E-03	1,55E-01	2,68E-02	1,93E-02	1,75E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6122	0,5	6,16E-01	9,07E-08	3,46E-03	2,14E-04	4,04E-04	8,82E-05	6,50E+01	3,78E-03	1,86E-01	3,63E-02	2,15E-02	2,06E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6124	0,5	2,08E-01	3,38E-08	9,85E-04	7,08E-05	-6,18E-04	3,06E-05	2,22E+01	1,09E-03	6,32E-02	1,12E-02	7,16E-03	7,22E-02
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6126	0,5	5,30E-01	7,09E-08	4,40E-03	1,23E-04	6,10E-05	7,82E-05	4,93E+01	4,77E-03	1,40E-01	2,18E-02	1,75E-02	1,68E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6127	0,5	5,49E-01	7,48E-08	4,31E-03	1,40E-04	9,73E-05	8,03E-05	5,22E+01	4,68E-03	1,49E-01	2,41E-02	1,83E-02	1,76E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6128	0,5	5,81E-01	8,02E-08	4,79E-03	1,45E-04	1,49E-04	8,35E-05	5,40E+01	5,20E-03	1,54E-01	2,49E-02	1,93E-02	1,86E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6129	0,5	5,55E-01	7,59E-08	4,38E-03	1,42E-04	1,08E-04	8,10E-05	5,27E+01	4,76E-03	1,50E-01	2,44E-02	1,85E-02	1,78E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6130	0,5	5,92E-01	8,15E-08	5,33E-03	1,35E-04	1,63E-04	8,45E-05	5,30E+01	5,78E-03	1,50E-01	2,36E-02	1,94E-02	1,89E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6131	0,5	1,88E-02	1,33E-09	4,10E-05	5,76E-07	3,31E-05	2,65E-06	3,72E+00	4,75E-05	2,46E-03	1,70E-04	2,03E-04	2,76E-03
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6132	0,5	6,10E-01	8,84E-08	3,41E-03	2,07E-04	2,33E-04	8,75E-05	6,37E+01	3,73E-03	1,83E-01	3,54E-02	2,13E-02	2,02E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6134	0,5	2,18E-01	3,44E-08	9,98E-04	7,30E-05	-7,63E-04	3,14E-05	2,26E+01	1,10E-03	6,51E-02	1,14E-02	7,57E-03	7,35E-02
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6136	0,75	8,30E-01	1,14E-07	5,52E-03	2,36E-04	4,76E-04	1,24E-04	8,30E+01	5,99E-03	2,39E-01	4,26E-02	2,95E-02	2,70E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6137	0,75	8,84E-01	1,22E-07	7,67E-03	2,10E-04	3,56E-04	1,29E-04	8,09E+01	8,32E-03	2,30E-01	3,75E-02	2,90E-02	2,86E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6138	0,75	9,49E-01	1,39E-07	5,42E-03	3,24E-04	6,69E-04	1,37E-04	9,89E+01	5,91E-03	2,84E-01	5,61E-02	3,30E-02	3,17E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6139	0,75	3,25E-01	5,43E-08	1,50E-03	1,16E-04	-1,08E-03	4,73E-05	3,37E+01	1,66E-03	9,75E-02	1,95E-02	1,12E-02	1,14E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6140	0,75	8,63E-01	1,19E-07	6,91E-03	2,20E-04	5,12E-04	1,27E-04	8,16E+01	7,49E-03	2,32E-01	3,91E-02	2,86E-02	2,80E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6141	0,75	8,80E-01	1,22E-07	7,12E-03	2,24E-04	5,07E-04	1,29E-04	8,28E+01	7,73E-03	2,36E-01	3,95E-02	2,94E-02	2,86E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6143	0,75	8,29E-01	1,12E-07	7,00E-03	1,95E-04	4,09E-04	1,23E-04	7,70E+01	7,59E-03	2,19E-01	3,52E-02	2,73E-02	2,67E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6144	0,75	9,95E-01	1,38E-07	9,28E-03	2,24E-04	4,75E-04	1,40E-04	8,61E+01	1,01E-02	2,46E-01	3,91E-02	3,24E-02	3,19E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6145	0,75	9,23E-01	1,27E-07	7,43E-03	2,31E-04	4,00E-04	1,33E-04	8,46E+01	8,06E-03	2,44E-01	4,13E-02	3,16E-02	2,96E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6146	0,75	9,21E-01	1,26E-07	8,05E-03	2,14E-04	3,59E-04	1,32E-04	8,22E+01	8,74E-03	2,36E-01	3,79E-02	3,03E-02	2,94E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6147	0,75	9,67E-01	1,40E-07	5,44E-03	3,27E-04	4,95E-04	1,39E-04	9,93E+01	5,93E-03	2,87E-01	5,63E-02	3,38E-02	3,19E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6148	0,75	3,54E-01	5,73E-08	1,56E-03	1,25E-04	-1,10E-03	5,02E-05	3,54E+01	1,74E-03	1,05E-01	2,07E-02	1,24E-02	1,20E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6149	0,75	8,79E-01	1,20E-07	6,94E-03	2,22E-04	3,00E-04	1,28E-04	8,19E+01	7,52E-03	2,35E-01	3,91E-02	2,94E-02	2,81E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6150	0,75	8,92E-01	1,22E-07	7,14E-03	2,23E-04	3,27E-04	1,30E-04	8,25E+01	7,75E-03	2,37E-01	3,93E-02	3,00E-02	2,85E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6152	0,75	8,53E-01	1,14E-07	7,08E-03	2,01E-04	2,45E-04	1,25E-04	7,82E+01	7,67E-03	2,24E-01	3,55E-02	2,83E-02	2,71E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6153	0,75	8,38E-01	1,12E-07	6,84E-03	1,99E-04	2,20E-04	1,24E-04	7,74E+01	7,41E-03	2,22E-01	3,52E-02	2,78E-02	2,66E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6154	1,0	9,05E-01	1,25E-07	8,46E-03	1,85E-04	-2,23E-04	1,34E-04	7,84E+01	9,17E-03	2,23E-01	3,52E-02	2,90E-02	2,91E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6155	1,0	9,17E-01	1,30E-07	6,34E-03	2,56E-04	-1,34E-04	1,37E-04	8,89E+01	6,89E-03	2,56E-01	4,73E-02	3,17E-02	3,01E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6157	1,0	3,44E-01	5,95E-08	1,56E-03	1,21E-04	-1,74E-03	5,32E-05	3,55E+01	1,73E-03	1,03E-01	2,01E-02	1,20E-02	1,17E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6158	1,0	7,60E-01	1,02E-07	5,40E-03	1,87E-04	-3,87E-04	1,20E-04	7,40E+01	5,83E-03	2,11E-01	3,57E-02	2,53E-02	2,44E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6159	1,0	9,10E-01	1,28E-07	7,51E-03	2,19E-04	-1,96E-04	1,35E-04	8,33E+01	8,15E-03	2,37E-01	4,06E-02	2,98E-02	2,95E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6162	1,0	8,79E-01	1,22E-07	7,28E-03	2,06E-04	-2,50E-04	1,32E-04	8,05E+01	7,89E-03	2,29E-01	3,86E-02	2,88E-02	2,84E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6163	1,0	8,95E-01	1,25E-07	7,37E-03	2,13E-04	2,29E-05	1,34E-04	8,20E+01	7,99E-03	2,34E-01	3,96E-02	2,93E-02	2,90E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6164	1,0	9,35E-01	1,30E-07	7,68E-03	2,22E-04	-2,45E-04	1,38E-04	8,41E+01	8,33E-03	2,42E-01	4,08E-02	3,08E-02	3,00E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6166	1,0	1,00E+00	1,40E-07	9,16E-03	2,19E-04	-1,45E-04	1,44E-04	8,58E+01	9,95E-03	2,46E-01	4,02E-02	3,24E-02	3,21E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6167	1,0	9,78E-01	1,36E-07	8,24E-03	2,29E-04	-1,51E-04	1,42E-04	8,65E+01	8,95E-03	2,50E-01	4,26E-02	3,28E-02	3,14E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6169	1,0	3,55E-01	5,93E-08	1,57E-03	1,21E-04	-1,81E-03	5,42E-05	3,54E+01	1,74E-03	1,04E-01	1,99E-02	1,25E-02	1,17E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6171	1,0	8,67E-01	1,17E-07	7,27E-03	1,91E-04	-3,66E-04	1,31E-04	7,75E+01	7,88E-03	2,22E-01	3,59E-02	2,84E-02	2,75E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD6172	1,0	9,09E-01	1,25E-07	7,39E-03	2,14E-04	-2,88E-04	1,35E-04	8,22E+01	8,02E-03	2,36E-01	3,96E-02	3,00E-02	2,91E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD7051	0,25	3,36E-01	4,77E-08	1,97E-03	1,12E-04	2,08E-04	4,87E-05	3,68E+01	2,15E-03	1,03E-01	1,86E-02	1,18E-02	1,11E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD7100	0,75	9,78E-01	1,37E-07	9,24E-03	2,22E-04	6,49E-04	1,38E-04	8,57E+01	1,00E-02	2,43E-01	3,90E-02	3,16E-02	3,17E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD7109	0,25	2,75E-01	3,48E-08	1,72E-03	7,61E-05	1,08E-04	4,20E-05	2,95E+01	1,86E-03	8,28E-02	1,27E-02	9,58E-03	8,54E-02
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD7242	1,0	1,05E+00	1,48E-07	1,01E-02	2,21E-04	-7,05E-05	1,49E-04	8,76E+01	1,10E-02	2,51E-01	4,05E-02	3,37E-02	3,37E-01
SCORZE	SB Mineral Water	GLASS SUBDIVISION	COD7451	0,5	5,98E-01	8,31E-08	5,75E-03	1,30E-04	3,28E-04	8,51E-05	5,28E+01	6,24E-03	1,49E-01	2,26E-02	1,93E-02	1,93E-01
POPOLI	SB Mineral Water	PET SUBDIVISION	COD2127	0,5	2,84E-01	2,26E-08	1,11E-03	3,23E-05	3,19E-03	3,83E-05	1,69E+01	1,21E-03	7,21E-02	4,85E-03	1,21E-02	1,07E-01
POPOLI	SB Mineral Water	PET SUBDIVISION	COD2129	1	2,99E-01	2,36E-08	1,14E-03	3,54E-05	3,24E-03	3,97E-05	1,75E+01	1,24E-03	7,52E-02	5,14E-03	1,27E-02	1,09E-01
POPOLI	SB Mineral Water	PET SUBDIVISION	COD3440	0,5	1,10E-01	8,27E-09	3,75E-04	9,86E-06	1,14E-03	1,25E-05	5,80E+00	4,10E-04	2,21E-02	1,56E-03	3,40E-03	4,07E-02

Site identification	Division identification	Subdivision identification	Product identification	Format	Climate change	Ozone depletion	Terrestrial acidification	Terrestrial ecotoxicity	Water scarcity	Aquatic eutrophication	Aquatic ecotoxicity	Aquatic acidification	Human toxicity	Land occupation	Metal depletion	Fossil depletion
					kg CO2 eq	kg CFC-11 eq	kg SO2 eq	kg 1,4-DB eq	m3 eq	kg PO4 P-lim	kg TEG water	kg SO2 eq	kg 1,4-DB eq	m2org.arable	kg Fe eq	kg oil eq
POPOLI	SB Mineral Water	PET SUBDIVISION	COD3441	0,5	1,45E-01	1,01E-08	4,94E-04	1,24E-05	1,45E-03	1,66E-05	7,16E+00	5,39E-04	3,06E-02	1,67E-03	4,95E-03	5,31E-02
POPOLI	SB Mineral Water	PET SUBDIVISION	COD3442	0,5	1,49E-01	1,05E-08	5,12E-04	1,36E-05	1,46E-03	1,70E-05	7,41E+00	5,59E-04	3,15E-02	1,84E-03	5,09E-03	5,41E-02
POPOLI	SB Mineral Water	PET SUBDIVISION	COD3445	0,5	9,19E-02	8,21E-09	3,49E-04	1,01E-05	1,08E-03	1,23E-05	5,78E+00	3,81E-04	2,17E-02	1,62E-03	3,39E-03	3,36E-02
POPOLI	SB Mineral Water	PET SUBDIVISION	COD3446	0,5	1,41E-01	1,03E-08	4,90E-04	1,31E-05	1,42E-03	1,67E-05	7,26E+00	5,35E-04	3,05E-02	1,77E-03	5,02E-03	5,12E-02
POPOLI	SB Mineral Water	PET SUBDIVISION	COD3447	0,5	1,46E-01	1,11E-08	5,22E-04	1,53E-05	1,42E-03	1,72E-05	7,68E+00	5,71E-04	3,18E-02	2,09E-03	5,18E-03	5,25E-02
POPOLI	SB Mineral Water	PET SUBDIVISION	COD3449	0,5	1,23E-01	7,85E-09	4,16E-04	8,22E-06	1,31E-03	1,50E-05	6,00E+00	4,53E-04	2,63E-02	1,09E-03	4,44E-03	4,41E-02
POPOLI	SB Mineral Water	PET SUBDIVISION	COD3450	1,5	2,41E-01	2,24E-08	9,34E-04	2,78E-05	3,13E-03	3,40E-05	1,61E+01	1,02E-03	5,83E-02	4,74E-03	9,17E-03	8,70E-02
POPOLI	SB Mineral Water	PET SUBDIVISION	COD3451	1,5	3,51E-01	2,89E-08	1,29E-03	3,50E-05	3,88E-03	4,47E-05	2,01E+01	1,41E-03	8,11E-02	5,34E-03	1,30E-02	1,26E-01
POPOLI	SB Mineral Water	PET SUBDIVISION	COD3452	1,5	3,72E-01	3,22E-08	1,38E-03	4,41E-05	3,93E-03	4,69E-05	2,19E+01	1,51E-03	8,70E-02	6,67E-03	1,38E-02	1,32E-01
POPOLI	SB Mineral Water	PET SUBDIVISION	COD3453	1,5	2,42E-01	2,27E-08	9,42E-04	2,85E-05	3,14E-03	3,40E-05	1,62E+01	1,03E-03	5,83E-02	4,83E-03	9,20E-03	8,73E-02
POPOLI	SB Mineral Water	PET SUBDIVISION	COD3454	2	2,99E-01	2,89E-08	1,16E-03	3,77E-05	4,01E-03	4,28E-05	2,08E+01	1,27E-03	7,31E-02	6,49E-03	1,14E-02	1,07E-01
POPOLI	SB Mineral Water	PET SUBDIVISION	COD3455	2	3,02E-01	2,95E-08	1,17E-03	3,95E-05	4,02E-03	4,31E-05	2,12E+01	1,28E-03	7,39E-02	6,81E-03	1,15E-02	1,08E-01
VIGGIANELLO	SB Mineral Water	PET SUBDIVISION	COD2200	2	3,04E-01	3,05E-08	1,15E-03	5,08E-05	4,08E-03	4,30E-05	2,24E+01	1,26E-03	7,75E-02	8,54E-03	1,28E-02	1,13E-01
VIGGIANELLO	SB Mineral Water	PET SUBDIVISION	COD2205	0,5	9,57E-02	8,70E-09	3,58E-04	1,50E-05	1,18E-03	1,28E-05	6,52E+00	3,92E-04	2,40E-02	2,51E-03	3,94E-03	3,66E-02
VIGGIANELLO	SB Mineral Water	PET SUBDIVISION	COD2207	1,5	2,34E-01	2,24E-08	8,91E-04	3,64E-05	3,17E-03	3,31E-05	1,68E+01	9,77E-04	5,96E-02	6,03E-03	9,96E-03	8,79E-02
VIGGIANELLO	SB Mineral Water	PET SUBDIVISION	COD2215	2	3,05E-01	3,08E-08	1,16E-03	5,17E-05	4,08E-03	4,29E-05	2,25E+01	1,27E-03	7,79E-02	8,52E-03	1,28E-02	1,14E-01
VIGGIANELLO	SB Mineral Water	PET SUBDIVISION	COD2216	2	3,07E-01	3,11E-08	1,16E-03	5,25E-05	4,08E-03	4,31E-05	2,27E+01	1,28E-03	7,84E-02	8,65E-03	1,29E-02	1,14E-01
VIGGIANELLO	SB Mineral Water	PET SUBDIVISION	COD2217	2	2,98E-01	2,94E-08	1,13E-03	4,77E-05	4,06E-03	4,21E-05	2,18E+01	1,24E-03	7,56E-02	7,90E-03	1,25E-02	1,11E-01
VIGGIANELLO	SB Mineral Water	PET SUBDIVISION	COD2218	2	2,70E-01	2,84E-08	9,86E-04	4,49E-05	3,65E-03	3,66E-05	2,01E+01	1,08E-03	6,60E-02	7,27E-03	1,03E-02	9,70E-02
VIGGIANELLO	SB Mineral Water	PET SUBDIVISION	COD2220	1,0	1,51E-01	1,66E-08	5,31E-04	2,88E-05	1,80E-03	1,90E-05	1,13E+01	5,84E-04	3,64E-02	4,51E-03	5,30E-03	5,34E-02
VIGGIANELLO	SB Mineral Water	PET SUBDIVISION	COD2221	2	2,69E-01	2,81E-08	9,81E-04	4,41E-05	3,64E-03	3,64E-05	2,00E+01	1,08E-03	6,55E-02	7,14E-03	1,03E-02	9,64E-02
DONATO	SB Mineral Water	PET SUBDIVISION	COD2267	0,5	9,76E-02	8,49E-09	3,72E-04	8,80E-06	1,22E-03	1,27E-05	5,90E+00	4,04E-04	2,26E-02	1,58E-03	3,64E-03	3,61E-02
DONATO	SB Mineral Water	PET SUBDIVISION	COD2268	0,5	1,31E-01	9,69E-09	4,65E-04	1,20E-05	1,48E-03	1,68E-05	7,02E+00	5,04E-04	3,07E-02	1,77E-03	5,31E-03	4,48E-02
DONATO	SB Mineral Water	PET SUBDIVISION	COD2278	1,5	2,92E-01	2,70E-08	1,13E-03	3,17E-05	3,64E-03	3,87E-05	1,85E+01	1,22E-03	7,00E-02	5,22E-03	1,12E-02	1,07E-01
DONATO	SB Mineral Water	PET SUBDIVISION	COD2279	1,5	3,14E-01	2,72E-08	1,15E-03	3,35E-05	3,72E-03	4,07E-05	1,87E+01	1,25E-03	7,37E-02	5,15E-03	1,22E-02	1,09E-01
DONATO	SB Mineral Water	PET SUBDIVISION	COD2299	2	3,09E-01	2,85E-08	1,20E-03	2,43E-05	4,40E-03	4,26E-05	1,98E+01	1,30E-03	7,07E-02	4,89E-03	1,14E-02	1,10E-01
ATELLA	SB Mineral Water	PET SUBDIVISION	COD3204	1,0	3,00E-01	2,73E-08	1,18E-03	3,79E-05	3,33E-03	3,96E-05	1,85E+01	1,28E-03	7,50E-02	5,61E-03	1,19E-02	1,12E-01
ATELLA	SB Mineral Water	PET SUBDIVISION	COD3209	1,0	3,17E-01	2,88E-08	1,21E-03	4,29E-05	3,38E-03	4,14E-05	1,94E+01	1,33E-03	7,90E-02	6,15E-03	1,26E-02	1,15E-01
ATELLA	SB Mineral Water	GLASS SUBDIVISION	COD3207	0,75	2,33E-01	2,91E-08	1,06E-03	5,19E-05	1,59E-03	2,78E-05	2,12E+01	1,16E-03	5,83E-02	8,33E-03	6,70E-03	7,70E-02
ATELLA	SB Mineral Water	GLASS SUBDIVISION	COD3208	1,0	3,00E-01	3,89E-08	1,28E-03	7,28E-05	2,05E-03	3,52E-05	2,65E+01	1,41E-03	7,37E-02	1,14E-02	8,59E-03	1,00E-01
ATELLA	SB Mineral Water	GLASS SUBDIVISION	COD3210	1,0	3,30E-01	4,28E-08	1,37E-03	8,52E-05	2,12E-03	3,82E-05	2,88E+01	1,50E-03	8,18E-02	1,31E-02	9,76E-03	1,09E-01
ATELLA	SB Mineral Water	GLASS SUBDIVISION	COD3211	0,75	2,55E-01	3,19E-08	1,12E-03	6,04E-05	1,64E-03	3,01E-05	2,28E+01	1,23E-03	6,41E-02	9,50E-03	7,55E-03	8,29E-02

Table 46 ERD results- Environmental impacts – Product scale – San Benedetto Italian Mineral Water PET + Glass

3.2.1.4. Life Cycle Interpretation

The application of MLCA model permits to assess resource consumptions and environmental impact for all assessment scales consistently with OLCA and LCA methodologies. In fact, it allows to aggregate the results at different level of analysis (see figure below) allowing identifying environmental hotspots and potential improvement strategies. In this way, the ERD interface is supportive both inventory level and impact assessment level.

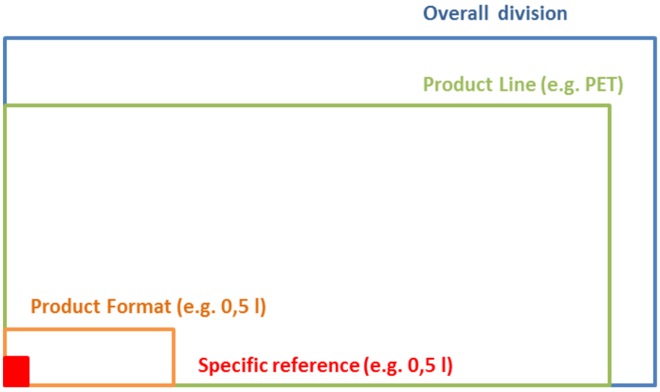


Figure 114 Different level of analysis of MLCA results.

The life cycle results can be interpreted in order to obtain fundamental information to improve life cycle management performance of the organization:

- Life cycle interpretation – Organizational scale;
- Life cycle interpretation – Product portfolio analysis;
- Life cycle interpretation – Product scale;
- Life cycle interpretation – Process scale;
- Tracking environmental impacts over the time.

The model has been developed also compatibly with the European Product Environmental Footprint Category Rules (PEFCR) and the Organisation Environmental Footprint (OEF) the new two tool of the European Commission for the assessment of environmental impacts of products and organizations.

3.2.1.4.1. Life Cycle interpretation – Organizational scale

The results returned by MLCA SimaPro model and manage by the ERD interface permits to assess the total environmental impacts on all impact categories selected for the total Italian San Benedetto Water Division. The environmental impact categories considered are according to OCLA and LCA profile descripted in the chapter 2. The profile contains all impact categories considered relevant for the water bottle sector in line with the specific European Product Environmental Footprint Category Rules (PEFCR): climate change, water scarcity and fossil depletion. In the case of this test the organizational scale is associated to the global Italian San Benedetto Water Division and to the two Sub Division related to PET product and GLASS products. In the table 47 has possible to see the summary of the life cycle environmental impacts of the global Italian San Benedetto Water Division. This result is a very novelty, has been cited by UNEP (2017) as first experience of OLCA in the world. Now the organization know the real impacts of its whole life cycle processes.

Site identification	Environmental Impact Category	Impact unit	Total
TOTAL ITALIAN SB WATER DIVISION	Climate change	kg CO2 eq/year	2,91E+08
TOTAL ITALIAN SB WATER DIVISION	Ozone depletion	kg CFC-11 eq/year	2,92E+01
TOTAL ITALIAN SB WATER DIVISION	Terrestrial acidification	kg SO2 eq/year	1,25E+06
TOTAL ITALIAN SB WATER DIVISION	Terrestrial ecotoxicity	kg 1,4-DB eq/year	4,07E+04
TOTAL ITALIAN SB WATER DIVISION	Water scarcity	m3 eq/year	4,27E+06
TOTAL ITALIAN SB WATER DIVISION	Aquatic eutrophication	kg PO4 P-lim/year	3,98E+04
TOTAL ITALIAN SB WATER DIVISION	Aquatic ecotoxicity	kg TEG water/year	1,97E+10
TOTAL ITALIAN SB WATER DIVISION	Aquatic acidification	kg SO2 eq/year	1,36E+06
TOTAL ITALIAN SB WATER DIVISION	Human toxicity	kg 1,4-DB eq/year	7,15E+07
TOTAL ITALIAN SB WATER DIVISION	Land occupation	m2org.arable/year	7,89E+06
TOTAL ITALIAN SB WATER DIVISION	Metal depletion	kg Fe eq/year	1,14E+07
TOTAL ITALIAN SB WATER DIVISION	Fossil depletion	kg oil eq/year	1,07E+08

Table 47 OLCA environmental impact results – San Benedetto Italian Mineral Water Division 2016.

The organization can explore the contribution of the two Sub Divisions (PET and GLASS) in order to start to understand where act to reduce environmental impacts (figure below).

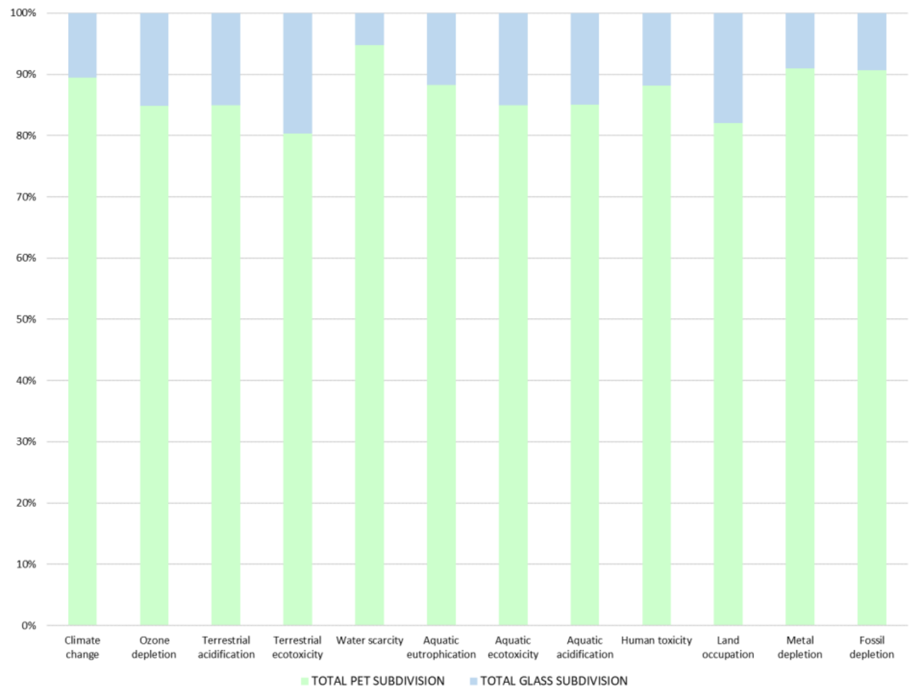


Figure 115 OLCA environmental impact results – Sub division contributions analysis – San Benedetto Italian Mineral Water Division 2016.

The contribution of the PET water Sub Division is in average of 87% while the contribution of the GLASS water Sub Division of 13%. The contribution to the total environmental impacts of San Benedetto Italian Mineral Water Division can be analysed also in function of the specific production site. Al production site produce PET water product while only Scorzè and Atella production sites produce GLASS water products. As shown in the figure below, the different productive sites show average contributions on the different impact categories of: 75% Scorzè site (VE), 12% Popoli site (PE), 9% Viggianello site (PZ), 4% Donato site (BI) and 1% Atella site (PZ). These results support the initial choice to start the application test of OES2 from the site of Scorzè (VE).

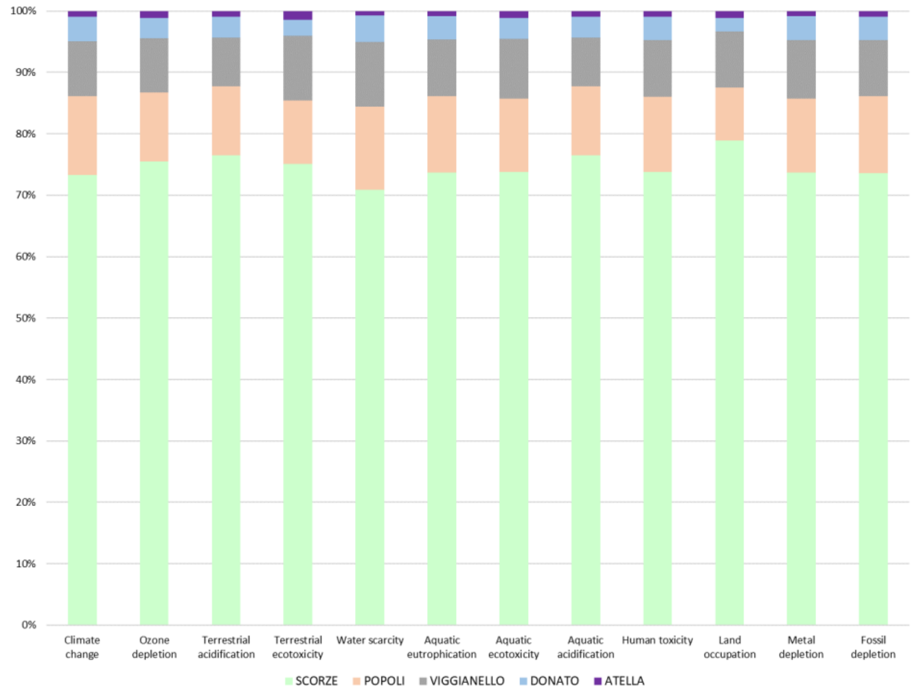


Figure 116 OLCA environmental impact results – Site contributions analysis – San Benedetto Italian Mineral Water Division 2016.

Focusing on the San Benedetto Italian PET Mineral Water Sub Division, that is the most strategic Sub Division, the total environmental impacts are shown in the following table. The strategic importance of PET Sub Division is related to the highest contribution to the environmental impacts and to the ecodesign and ecoefficiency projects that in the case of PET are most numerous respect to the GLASS Sub Division (e.g. lightening projects are directly implemented by San Benedetto on PET bottles and caps being San Benedetto the producer of these packaging components). The figure 117 shows that the different productive sites show average contributions on the different impact categories of: 70% Scorzè site (VE), 15% Popoli site (PE), 10% Viggianello site (PZ), 4% Donato site (BI) and 1% Atella site (PZ).

Site identification	Environmental Impact Category	Impact unit	Total
TOTAL PET SUBDIVISION	Climate change	kg CO2 eq/year	2,60E+08
TOTAL PET SUBDIVISION	Ozone depletion	kg CFC-11 eq/year	2,48E+01
TOTAL PET SUBDIVISION	Terrestrial acidification	kg SO2 eq/year	1,06E+06
TOTAL PET SUBDIVISION	Terrestrial ecotoxicity	kg 1,4-DB eq/year	3,27E+04
TOTAL PET SUBDIVISION	Water scarcity	m3 eq/year	4,05E+06
TOTAL PET SUBDIVISION	Aquatic eutrophication	kg PO4 P-lim/year	3,51E+04
TOTAL PET SUBDIVISION	Aquatic ecotoxicity	kg TEG water/year	1,67E+10
TOTAL PET SUBDIVISION	Aquatic acidification	kg SO2 eq/year	1,16E+06
TOTAL PET SUBDIVISION	Human toxicity	kg 1,4-DB eq/year	6,30E+07
TOTAL PET SUBDIVISION	Land occupation	m2org.arable/year	6,47E+06
TOTAL PET SUBDIVISION	Metal depletion	kg Fe eq/year	1,04E+07
TOTAL PET SUBDIVISION	Fossil depletion	kg oil eq/year	9,72E+07

Table 48 OLCA environmental impact results – San Benedetto Italian PET Mineral Water Division 2016.

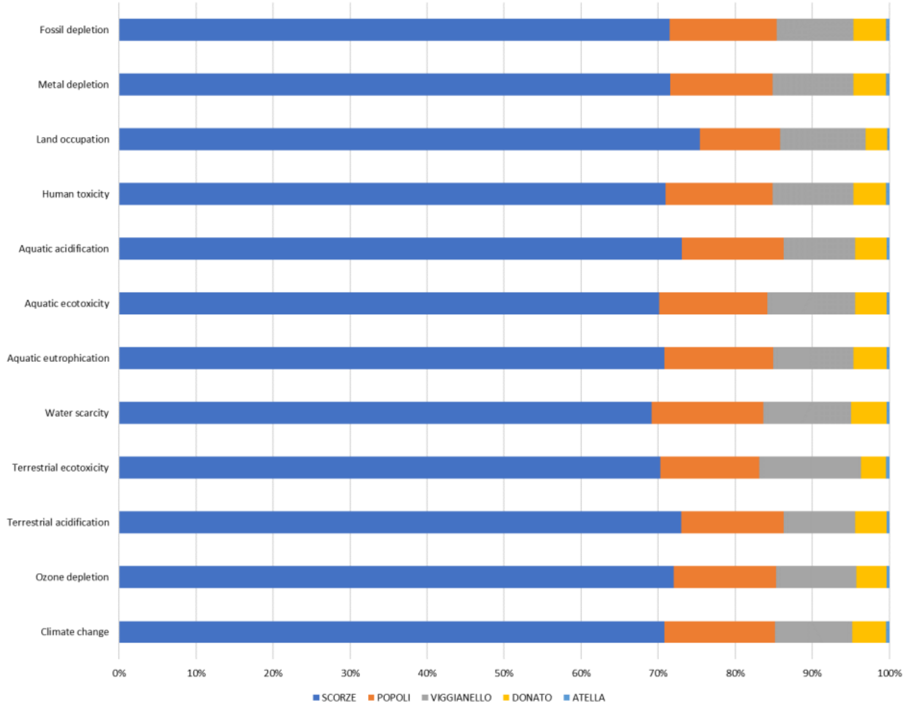


Figure 117 OLCA environmental impact results – Site contributions analysis – San Benedetto Italian PET Mineral Water Division 2016.

The different life cycle stages show average contributions on the different impact categories of: 48% raw material extraction and transformation, 15% production, 29% product delivery, 3% use phase and 5% end of life (See figure below).

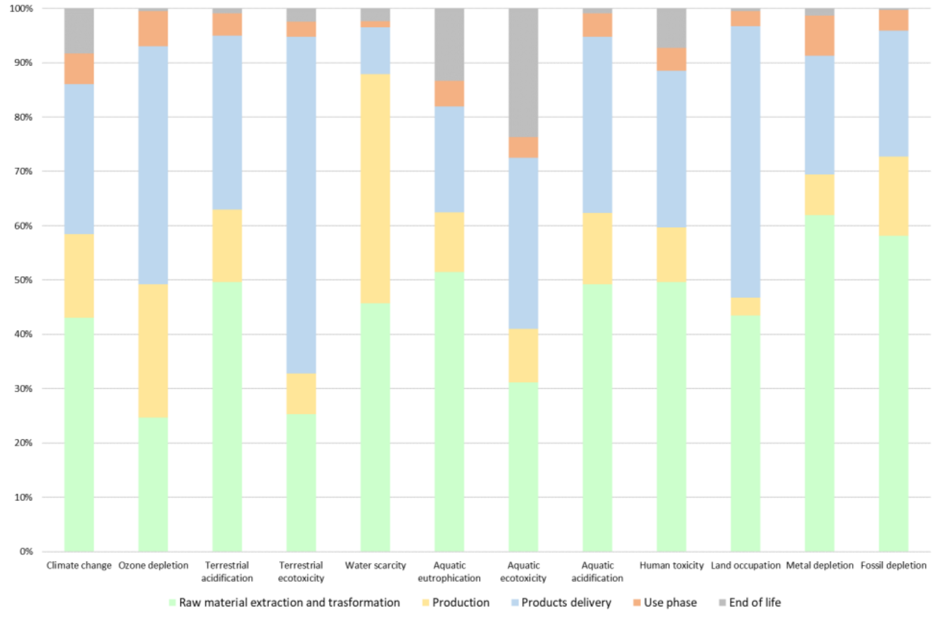


Figure 118 OLCA environmental impact results – Life cycle stages analysis – San Benedetto Italian PET Mineral Water Sub Division 2016.

The contribution analysis at level of life cycle processes is very important in order to identify the most relevant processes that have to manage in order to improve the environmental performance. For example, focusing on climate change impact category, the most relevant contributions are associated to: PET granulate production (about 32%), electricity production for bottling processes and bottle production processes (about 13%) and truck transport for product delivery (about 17%). The analysis at life cycle processes level, is important to identify the hotspots in order to assess strategic levers to manage and reduce environmental impacts. In this case, the most strategic levers to reduce environmental burdens are: the bottle weight reduction, the use of RPET, the reduction of energy consumptions and the reduction of impact generates from delivery transports (e.g. reduction of distances or transport means substitution).

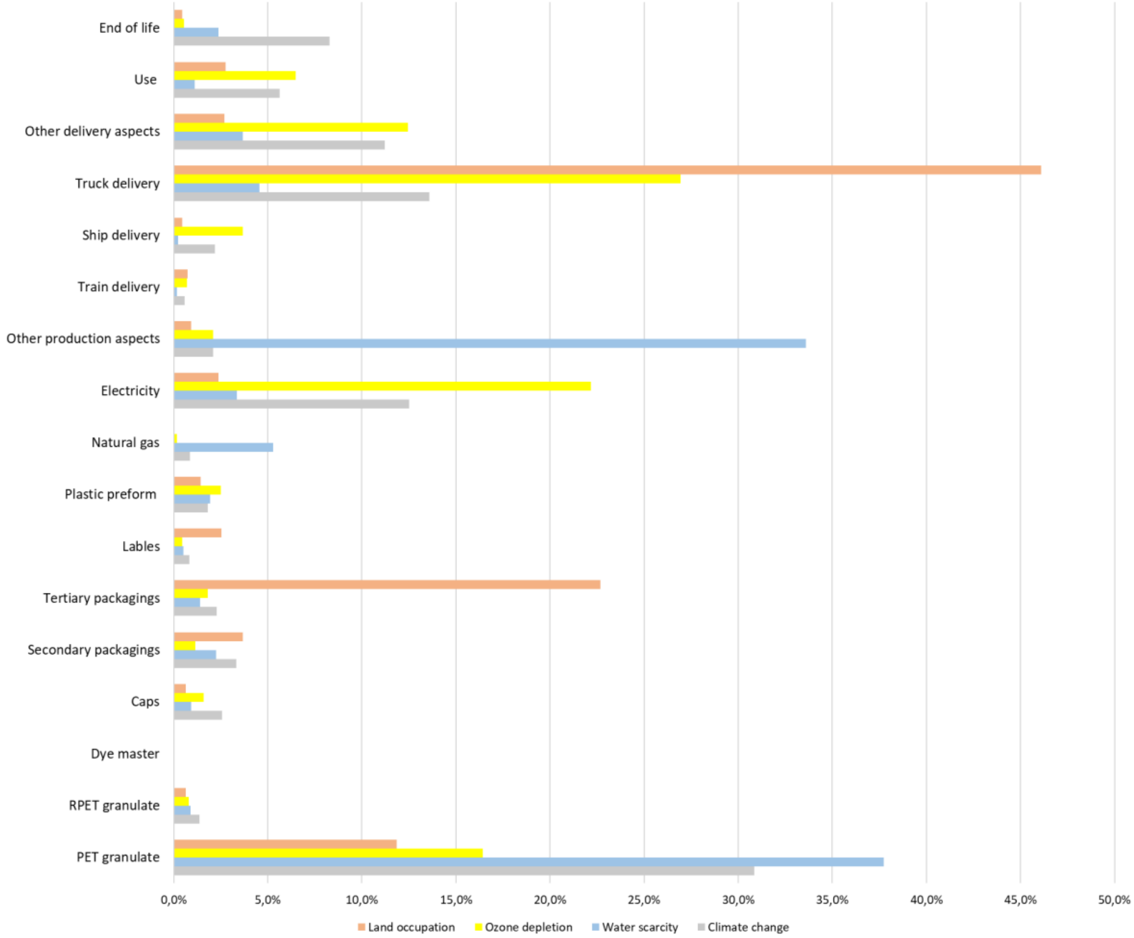


Figure 119 OLCA environmental impact results – Process contributions analysis – San Benedetto Italian PET Mineral Water Division 2016.

The following figure shows the contribution analysis in terms of resource consumptions generates by the different productive sites. In order to assess the environmental impacts is important also to consider the inventory analysis results. In the following figure have been shown the contributions of the different productive sites to the total relevant inventory flow that are related to the consumption of materials and energy, and to the generation of wastes. For example, the results show that about the 70% of PET has been consumed during 2016 from the Scorzè production site while regarding to the caps consumption the contribution has been equal to 76%. In terms of total mass of products delivered the contribution of Scorzè has been equal to 64% and the average distances travelled with truck from products delivered from Scorzè results the 20% lower than the distance travelled in the case of Viggianello and about the double of the value in the case of Donato site.

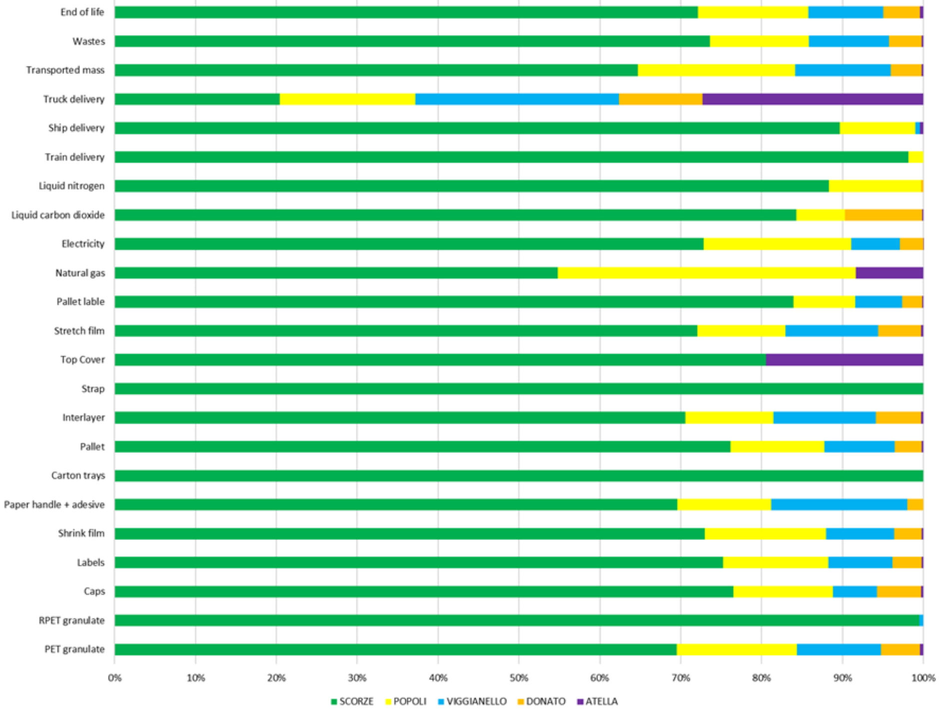


Figure 120 OLCA inventory resource consumptions results – Site contributions analysis – San Benedetto Italian PET Mineral Water Division 2016.

3.2.1.4.2. Life cycle interpretation – Product portfolio analysis

Focusing on the Scorzè site, the product portfolio relative to PET Mineral Water can be studied in order to identify the contributions of the different products and hotpots. The first analysis can be conducted at level of different product categories, in the following figure has been shown an example realized by dividing products in function of their formats. On the average the 0,5L format, 1,0L, 1,5 L and 2,0L show contributions respectively of: 40%, 4%, 29% and 25%. The analysis can be performed also directly at product level finding the contribution of every single products to the total environmental impact of the site or of the Division in function of the assessment needs. Figure 122 represents an aggregation of results for all the different PET product codes that has a relative contribution over the 2% of the overall climate changes impacts. The representation allows understanding on which references the company should focus to reduce climate changes impacts.

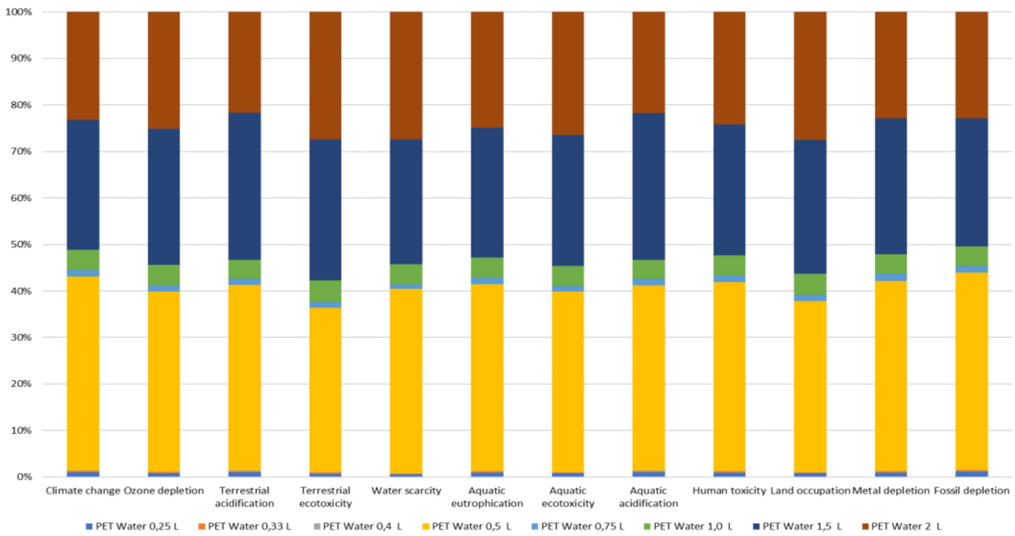


Figure 121 OLCA environmental impact results – Product categories contributions analysis – San Benedetto Italian Mineral Water Division 2016.

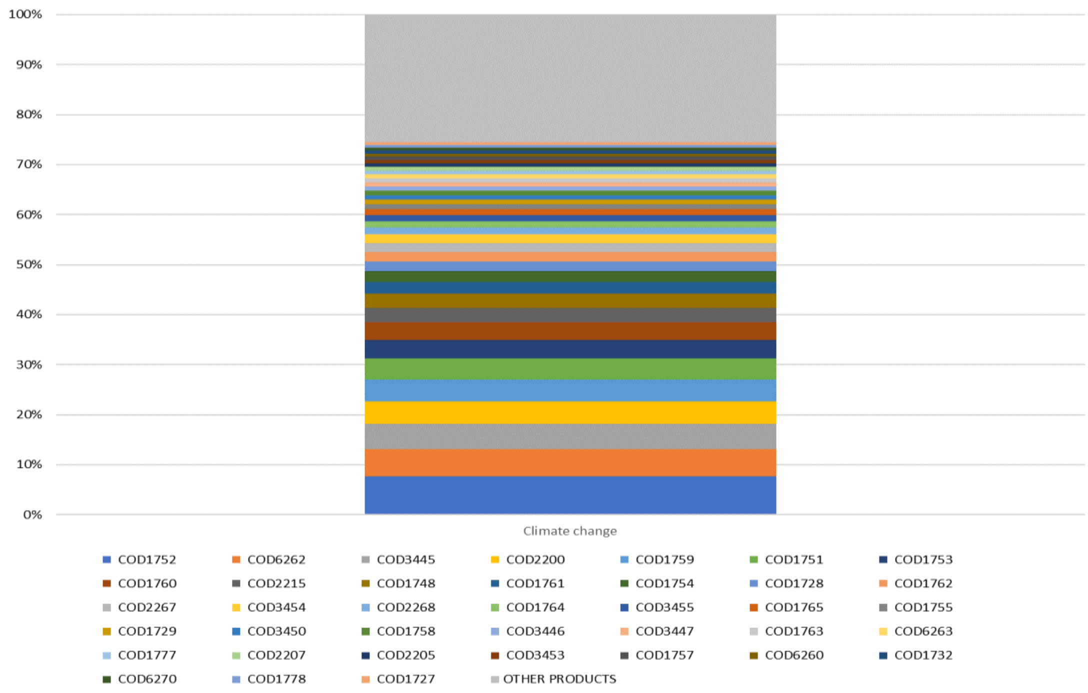


Figure 122 OLCA environmental impact results – Product contributions analysis – San Benedetto Italian PET Mineral Water Division 2016.

In the following table, has been shown an example of screening analysis of the impacts on climate change of the product portfolio. Interesting information can be acquired observing the results trend in function of the format, hotspot emerging at level of 0,25L; 0,33L; 0,40L and 0,75L; and comparing the average values with the extremes values of the range for each format. In function of the range amplitude and the position of the average value it is possible to identify potential hotspots. For example, in the case of 0,25L format, the average value is moved to the upper range value and therefore the majority of the production is realized not using the best design solution available.

Format	Climate change impact		
	Average value	Minimum range value	Maximum range value
Litres/bottle	g CO2eq/bottle	g CO2eq/bottle	g CO2eq/bottle
0,25	164,8	130,1	175,4
0,33	161,3	139,6	174,4
0,40	233,1	213,1	259,8
0,50	106,1	89,6	291,1
0,75	293	249,2	359,0
1,00	160,8	151,1	356,8
1,50	309,1	205,5	611,9
2,00	266,5	262,0	373,3

Table 49 OLCA environmental impact results – San Benedetto Italian PET Mineral Water Division 2016.

Specific focus can be conducted on all products categories. For examples in the figure 123, has been analysed the product category 2L considering all the San Benedetto PET Italian Mineral Water Division. The results permit to compare the environmental performance, in this case regarding the climate change category, of products of the same category realized in different production site. In this case, excluding the most two higher results, that are related to two products realized in Scorzè and delivered abroad (higher distribution), in average the products of format 2,0L produced in the sites of Scorzè and Viggianello show lower GHG emissions.

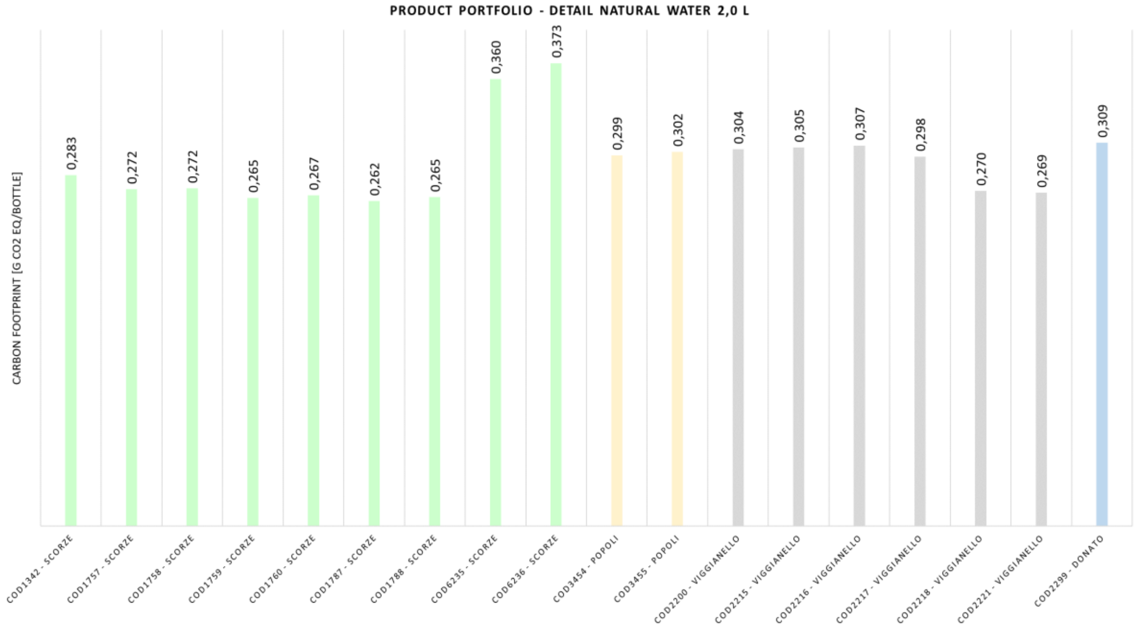


Figure 123 LCA environmental impact results – Product comparison – San Benedetto Italian PET Mineral Water 2,0L Product Category 2016.

Finally, the following figure permits instead to assess how different products contribute to the inventory resource consumptions in order to identify the products with the largest contribution. The assessment of material and energy consumptions and of the quantity of wastes generated along al the life cycle of the organization is very important to manage the environmental impacts.

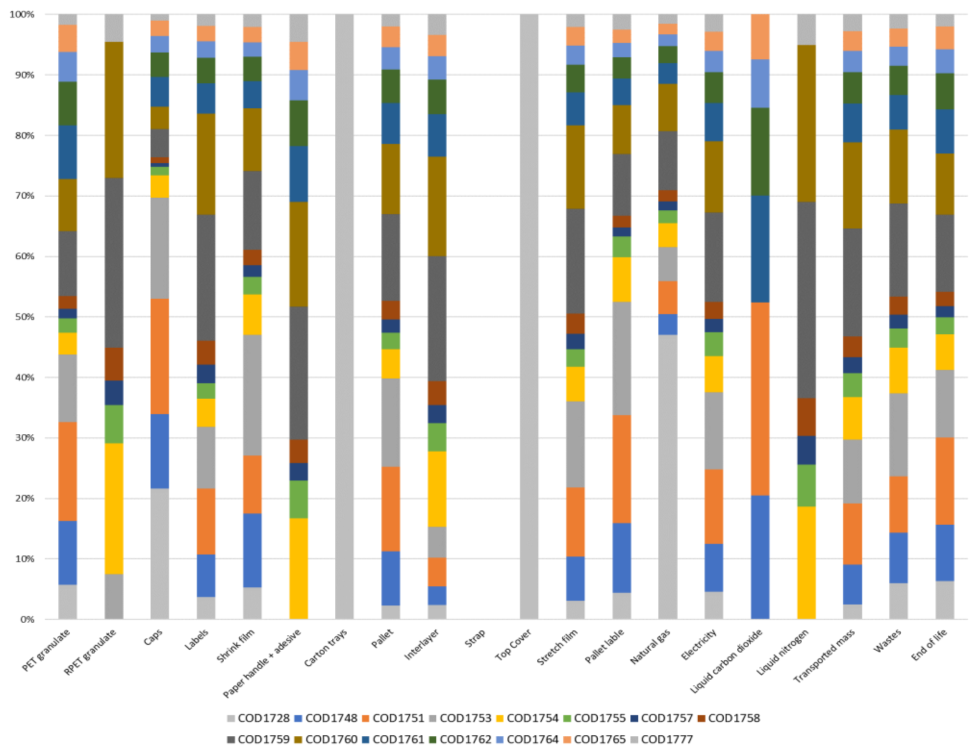


Figure 124 OLCA inventory resource consumptions results – Product contributions analysis – San Benedetto Italian PET Mineral Water Division 2016.

3.2.1.4.3. Life cycle interpretation – Product scale

The analysis can be performed also at product level, according to LCA framework, in order to identify specific performance of interesting products or to compare different products.

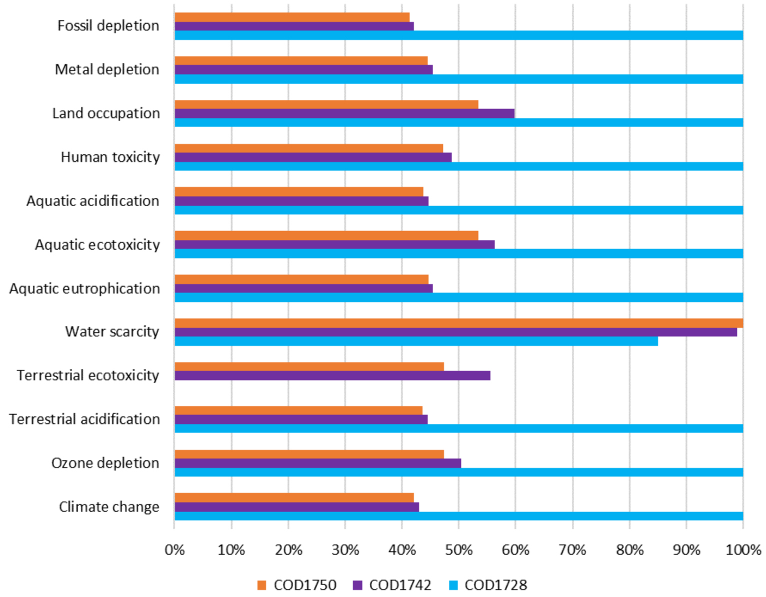


Figure 125 LCA environmental impact results – Products comparison – San Benedetto PET 0,5L products.

In the previously figure have been compared three different products in term of carbon footprint performance. The product code 1728, is a 0,5L natural water product bottled with a special aseptic process and show consequentially the most higher impact. The product cod 1742 is the standard 0,5L natural water product while the best performance is associate to the product code 1750 that is the 0,5L natural water product of the EcoGreen Family. In addition to global impacts, the MLCA model has been able to perform a life cycle stage analysis at product level as shown in the figure below.

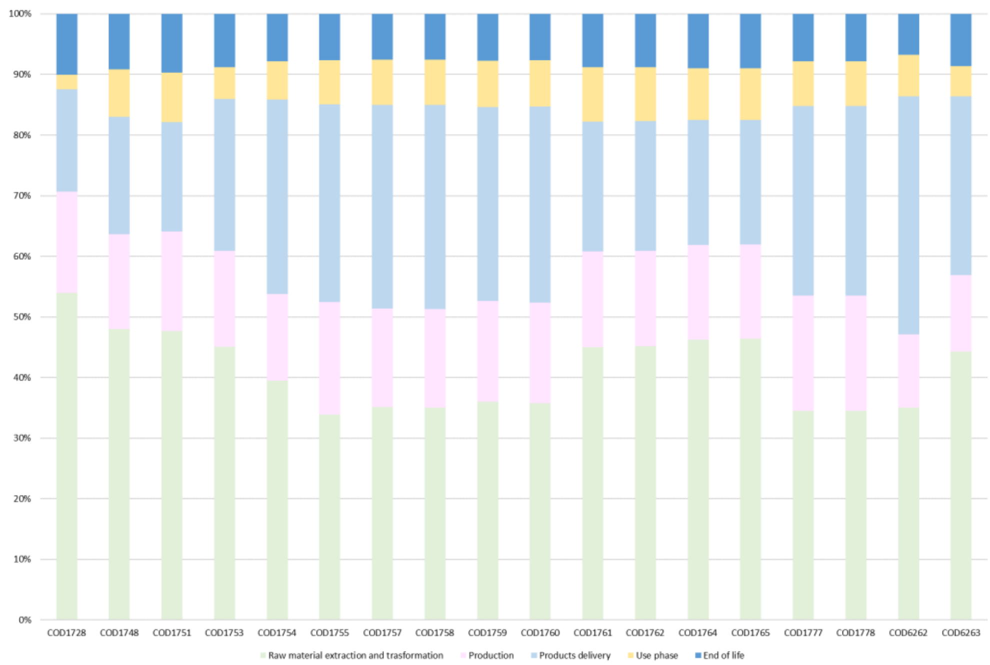


Figure 126 LCA environmental impact results – Life cycle stages analysis – San Benedetto PET products.

3.2.1.4.4. Life cycle interpretation – Process scale

The high level of detail of the MLCA model is able to identify differences at level of production processes of San Benedetto S.p.A. The example choice is related to the production of the same product code with two different bottling lines (L58 and L52). The bottling line L58 thanks the introduction of a new technology can apply to the product prestressed plastic film instead of film stretch permitting to reduce the consumption of film and the reduction of energy consumption (the prestressed film does not require thermal shrinking). In the following table are briefly shown the results where the bottling line L58 permits to realize product unit with a carbon footprint lower of -2,6% respect to the product units of the same product code realized by the bottling line L52. This example demonstrates the high sensibility of the MLCA model also at process scale and how can be useful this approach to identify hotspot and improvement opportunity at process level that is one of the level where the organization can more invest.

Aspect	Measure units	L52	L58	Delta (%)
Plastic film consumption	g/bottle	1,110	0,435	-61%
Electricity consumption	kWh/bottle	0,00489	0,00379	-22%
Product Carbon Footprint	g CO2 eq/bottle	129,6	126,3	-2,6%

Table 50 Process sensibility of the MLCA model.

3.2.1.4.5. Tracking environmental impacts – Over the time

The analysis is performed cyclically, according with time period defined by the organization. In this case the organization has defined a time period of 1 financial year. All the analysis previously descripted can be conducted over the time to monitor the trend of environmental impacts and the trend of inventory consumptions. Focusing on Scorzè production site, where the implementation has started and where data were available from 2013, the figure below report the environmental impact on climate change impact category generated in the year 2013, 2014, 2015 and 2016 from all San Benedetto Mineral Water Scorze site.

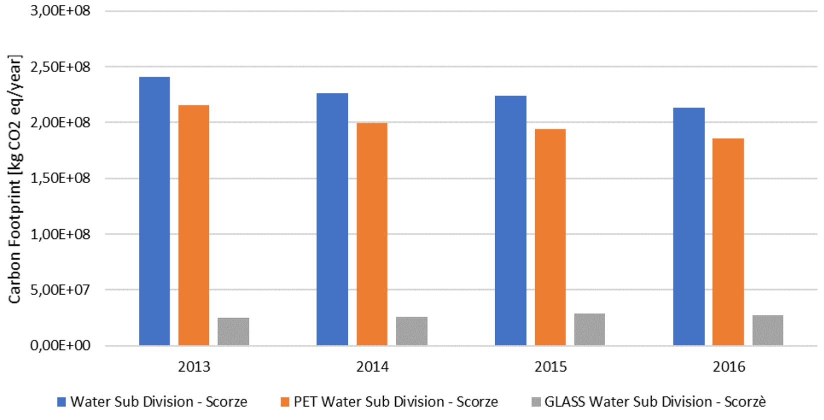


Figure 127 OLCA environmental impact results – Climate Change impact category – Over the time – San Benedetto Mineral Water Scorze site. From 2013 to 2016.

The results show that globally the emissions have decreased of -11% from 2013 to 2016. In the specific case of the PET Sub Division and the GLASS Sub Division the emissions are respectively decreased of -14% and increased of 11%. Another example can be, the tracking of the GHG emissions at level of the EcoGreen product line.

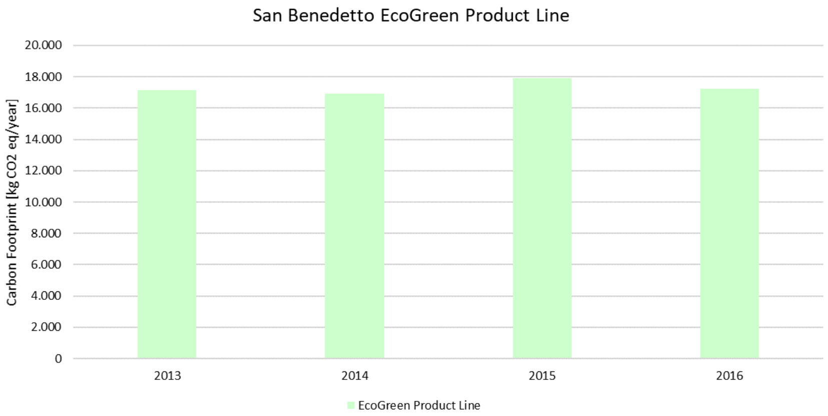


Figure 128 LCA environmental impact results – Climate Change impact category – Over the time – San Benedetto EcoGreen Product Line. From 2013 to 2016.

In the case the EcoGreen product line has maintained constant its global GHG emissions. It is important underline that these results do not reflected the performance, in fact the analysis of the performance, according to ISO 14031, must be conducted using OPIs. Thus, type of analysis of the life cycle performance in OES2 is performed using Eco-EKA. In this way, in the following paragraph has been descripted the environmental performance evaluation of life cycle performance and the application of Eco-EKA.

3.2.1.4.6. Environmental impacts – Burdens shifting issues

The application of OLCA, expanding the application scope of LCA to organization, determines the birth of new methodological aspects. In the paragraph 3.4.1.2 of this chapter, the concept of Organizational Ecodesign has been introduced, where San Benedetto has modified its organizational structure, acquiring a new production site and transferring to it some production processes in order to reducing environmental impacts. This is a positive example, but the organizations could potentially make wrong decisions. In fact, when a new site is acquired, and the production partially transferred, especially in the case of multinationals organizations, it is important to pay attention to the “base environmental impact load” intrinsically determined by the choice of the country where located the new production site. In fact, the GHG emission of electricity mix of the country, the WSI of the country are aspects that automatically, with the same performance in terms of resources consumptions (in this example electricity and water) imply different level of environmental impacts generated by the organization. Focusing on the case where the organization reallocates the products portfolio in the different sites, transferring production processes between the sites, it is clear that some products can improve their environmental performance, other products could worst their environment performance and overall the organization could see a worsening of its environmental performance. In this case the new concept of organizational burdens shifting (Type III) has been introduced where the organization promoting the improvement of a part of products (green products of the portfolio) using LCA methodology, generates the worsening of the environmental performance at organizational scale (Manzardo & Loss et al., 2017). The use of OLCA permits to avoid this issue and the example provides in the paragraph 3.4.1.2 shows as the organization, avoiding this issue, can exploits the assessments conducted at organizational scale to improve its environmental performance and the performance of its products.

3.3. TEST 2: Application of OES2 method to criticalities on environmental management area (3)

This test has the objective to assess the capacity of OES2 method to face the gaps on life cycle management related to criticalities on environmental performance evaluation.

Critical Areas	Identified gaps
3. Performance evaluation & performance tracking	10. Lack of OPIs for environmental performance evaluation related to life cycle management at product and organizational level
	11. Difficulties in performance tracking and in OPI trends analysis

Table 51 Identified gaps on performance evaluation and performance tracking assessment, faced by OES2 method in the test 2.

In order to face these gaps OES2 method applies:

- One EMTs: the EPE methodology (ISO 14031)
- One STEMs: the Eco – EKA developed according to ISO 14031.

According to ISO14031 methodology when an organization adopts a life cycle management approach, it must be select an appropriate set of Operative Performance Indicators (OPIs) in order to evaluate the performance. The use of OPIs to assess environmental impacts and resource consumptions is fundamental in order to evaluate correctly the performance. In fact, as evidenced in the previously paragraph, the tracking of environmental impacts, not indexed considering a reference flow, do not permits the assessment of the trend of the environmental performance. In order to give evidence of this aspect, in the present paragraph have been proposed results for the same two examples (performance tracking of Scorzè site and performance tracking of EcoGreen product line). These choice is also taken according with organizational goals in terms of performance evaluation, that are listed following:

- To monitor the environmental performance of the Sub Division San Benedetto PET Mineral Water (Scorzè site) at level of environmental impacts (especially on climate change) and of resource consumptions;
- To monitor the environmental performance of the EcoGreen product family at level of environmental impacts (especially on climate change) and of resource consumption.

The focus on climate change impact category is related to the strategical framework adopted in terms of external communication by the organization. In fact, according with some authors such as Weidema et al., 2005 the communication on carbon footprint is positively receipted by consumers. How can be observed in this case the organization have two performance evaluation goals, one for the organizational level (for the biggest production site and where data were available from 2013 with homogeneous characteristics) and one for the product level (the San Benedetto product line thought for environmental aware consumers).

3.3.1. EPE of Life Cycle Performance – Organizational scale

According to the procedure shown in chapter 2, the Eco-EKA assesses the relevance of different aspects in order to calculate OPIs only for aspects with contribution higher than cut-off. The monitoring of the life cycle performance of Scorzè site for the production of all products related to the Sub Division San Benedetto PET Mineral Water requires the following performance be assessed:

- Sub Division performance: at environmental impacts level (EOPIs) and at resource consumptions level (IOPIs) must be assessed;
- Product Portfolio performance: according to the procedure that controls the relevant assessor of Eco-EKA, in order to understand the performance of the Sub Division scale it is important

to assess the performance of the assessment scale below and therefore the scale of product portfolio;

- Life cycle stages and process performance: according to the same procedure, the relevant life cycle aspects in terms of life cycle stages and flows must be considered;
- Finally, the relevant SOPIs (indicators that supports the understanding of OPIs), in function organization experience have been assessed.

3.3.1.1. Application of the procedure of relevance assessing

In this case, relevance assessing step, have been set the following cut-off: product portfolio (1%); life cycle stages and processes (3%).

At product portfolio level have been resulted relevant the following products:

- 0,25 L product category (6 product codes);
- 0,50 L product category (64 product codes);
- 1,0 L product category (12 product codes);
- 1,5 L product category (47 product codes);
- 2,0 L product category (9 product codes).

While the other product (0,33 L, 0,40 L, 0,75 L) not resulting individually relevant have been aggregated in the category "Other products" (22 product codes) because the cumulative relevance is not neglectable. The use of product category is according with the results shown in the previously paragraph. In this case, about of 75% on produced volume is assessed with the product categories 0,25L; 0,5L; 1L; 1,5L and 2L while the 25% is associated to other products. Therefore, the application of the relevance assessor of Eco-EKA permits to filter and aggregate results stored in ERD in order to simplify the performance tracking.

At level of life cycle stages, all are considered relevant: raw material extraction and transformation (43%), production (15%); Products delivery (28%), use phase (6%) and end of life (8%). While at level of life cycle processes the processes that are relevant are reported in the following figure:

	Life cycle process	% contribution to GHG emissions	
Raw material extraction and transformation	PET granulate consumption	31%	Relevant
	RPET granulate consumption	1%	Not relevant, but considered relevant*
	Caps production	4%	Relevant
	Secondary packaging consumptions	4%	Relevant
	Tertiary packaging consumptions	3%	Relevant
Production	Electricity consumption	12%	Relevant
Products delivery	Train delivery	1%	Not relevant, but considered relevant *
	Ship delivery	3%	Relevant
	Truck delivery	13%	Relevant
End of life	End of life (waste generation)	8%	Relevant

Table 52 List of life cycle processes with relevant contributions on the environmental performance of the Sub Division.

Not relevant, but considered relevant *: The RPET and the train transport have been considered relevant even if the contributions are lower than 3% because they are respectively substitutes of PET and Truck transport and therefore are indirectly relevant.

3.3.1.2. Selection of EOPIs and IOPIs

The OPIs used by Eco-EKA have been selected according to ISO 14031. Two types of OPIs have been considered, according to approach presented in the chapter 2: EOPIs, that are OPIs related to

environmental impacts and IOPIs, that are OPIs related to inventory resource consumptions. This choice permits to make the evaluation of the life cycle performance, consistently also with LCA and OLCA framework where are performed the life cycle inventory (LCI) analysis and the life cycle impact analysis (LCIA).
As reference flow has been choice a value of 1000 litres of San Benedetto Mineral Water. According with the relevance analysis, the EOPIs shown in the following table have been defined.

Focus	EOPI	Measure unit
San Benedetto PET Mineal Water Sub Division (Scorzè site)	Total GHG emissions	kg CO2 eq/1000 litres
	GHG emission for raw material extraction and transformation	kg CO2 eq/1000 litres
	GHG emission for production	kg CO2 eq/1000 litres
	GHG emission for product delivery	kg CO2 eq/1000 litres
	GHG emission for use phase	kg CO2 eq/1000 litres
	GHG emission for end of life	kg CO2 eq/1000 litres
Product Portfolio	GHG emissions of Products 0,25L	kg CO2 eq/1000 litres
	GHG emissions of Products 0,50L	kg CO2 eq/1000 litres
	GHG emissions of Products 1,0L	kg CO2 eq/1000 litres
	GHG emissions of Products 1,5L	kg CO2 eq/1000 litres
	GHG emissions of Products 2,0L	kg CO2 eq/1000 litres
	GHG emissions of Other products	kg CO2 eq/1000 litres

Table 53 EOPIs defined to perform the environmental performance evaluation of life cycle performance of San Benedetto PET Mineral Water Sub Division (Scorzè site)

Equivalent EOPIs have been defined for the other environmental impact categories, consistently with the results stored in ERD and returned by MLCA SimaPro model. The Eco EKA permits automatically to select the environmental category to visualize by the analyser interface, in function of the needs of the user. In order to monitor the resource consumptions and to support the evaluation of the trend of EOPIs, the following IOPIs have been defined:

Focus	IOPI	Measure unit
San Benedetto PET Mineal Water Sub Division (Scorzè site)	Total plastic consumption for bottle production	kg/1000 litres
	Total PET consumption for bottle production	kg/1000 litres
	Total RPET consumption for bottle production	kg/1000 litres
	Mass of caps	kg/1000 litres
	Mass of secondary packaging	kg/1000 litres
	Mass of tertiary packaging	kg/1000 litres
	Electricity consumption	kWh/1000 litres
	Average distance travelled by train	km
	Average distance travelled by train	km
	Average distance travelled by train	km
	Mass of waste produced by end of life	kg/1000 litres
Product Portfolio (for every product category)	Total plastic consumption for bottle production	kg/1000 litres
	Total PET consumption for bottle production	kg/1000 litres
	Total RPET consumption for bottle production	kg/1000 litres
	Mass of caps	kg/1000 litres
	Mass of secondary packaging	kg/1000 litres
	Mass of tertiary packaging	kg/1000 litres
	Electricity consumption	kWh/1000 litres
	Average distance travelled by train	km
	Average distance travelled by train	km
	Average distance travelled by train	km
	Mass of waste produced by end of life	kg/1000 litres

Table 54 IOPIs defined to perform the environmental performance evaluation of life cycle performance of San Benedetto PET Mineral Water Sub Division (Scorzè site)

According to Eco-EKA structure developed in chapter 2, the calculation of EOPIs and SOPIs has been automatized using excel programming language. Consistently with the architecture of results stored in ERD interface at inventory level (ERD – IA) and Environmental impact level (ERD – EIA) the calculator inserted in ECO-EKA calculate all EOPIs and IOPIs according to relevance assessing.

3.3.1.3. Selection of SOPIs

The introduction of SOPIs are very important to support the evaluation of the EOPIs and IOPs trends. In fact, some aspects related to product portfolio changes can influence significantly the performance. In the case of the present analysis, on the base of practical experience of the organization, the SOPIs listed in the following table have been defined and monitored.

Focus	SOPI	Measure unit
San Benedetto PET Mineal Water Sub Division (Scorzè site)	Average format	Litres/bottle
Product categories (0,25L + 0,5L + 1L + 1,5L + 2L)	Average format	Litres/bottle
Other products	Average format	Litres/bottle
Aseptic production	Incidence on total volumes produced of aseptic products	%
Raw materials extraction and transformation	Emission factor of PET	kg CO2 eq/kg
	Emission factor of RPET	kg CO2 eq/kg
Production	Emission factor of electricity	kg CO2 eq/kWh

Table 55 SOPIs defined to perform the environmental performance evaluation of life cycle performance of San Benedetto PET Mineral Water Sub Division (Scorzè site)

The average format is a key characteristic of the products portfolio and depends from market demands. The reduction of average format is a opposite force that generates increase of resource consumptions and of environmental impacts. When the average format decreases the organization must implemented more improvements in order to cancel this opposite force and get positive performance. Also in the case of the increase of incidence of products produced with aseptic technologies, an increase of them generates an increase of resource consumptions and environmental impacts. Finally, the emission factors of PET and RPET are very important to monitor and understand the performance. In fact, also with the same plastic consumptions, the environmental performance could be very different in function of the emission factors. In fact, the emission factor of RPET that is on average 4 times lower than the value of PET permits to rapidly decrease the environmental impacts. The same concept can be applied to electricity, where the introduction of trigeneration unit in the 2016 has permits to increase of about 16% the GHG emissions related to electricity consumption in the productive site of Scorzè.

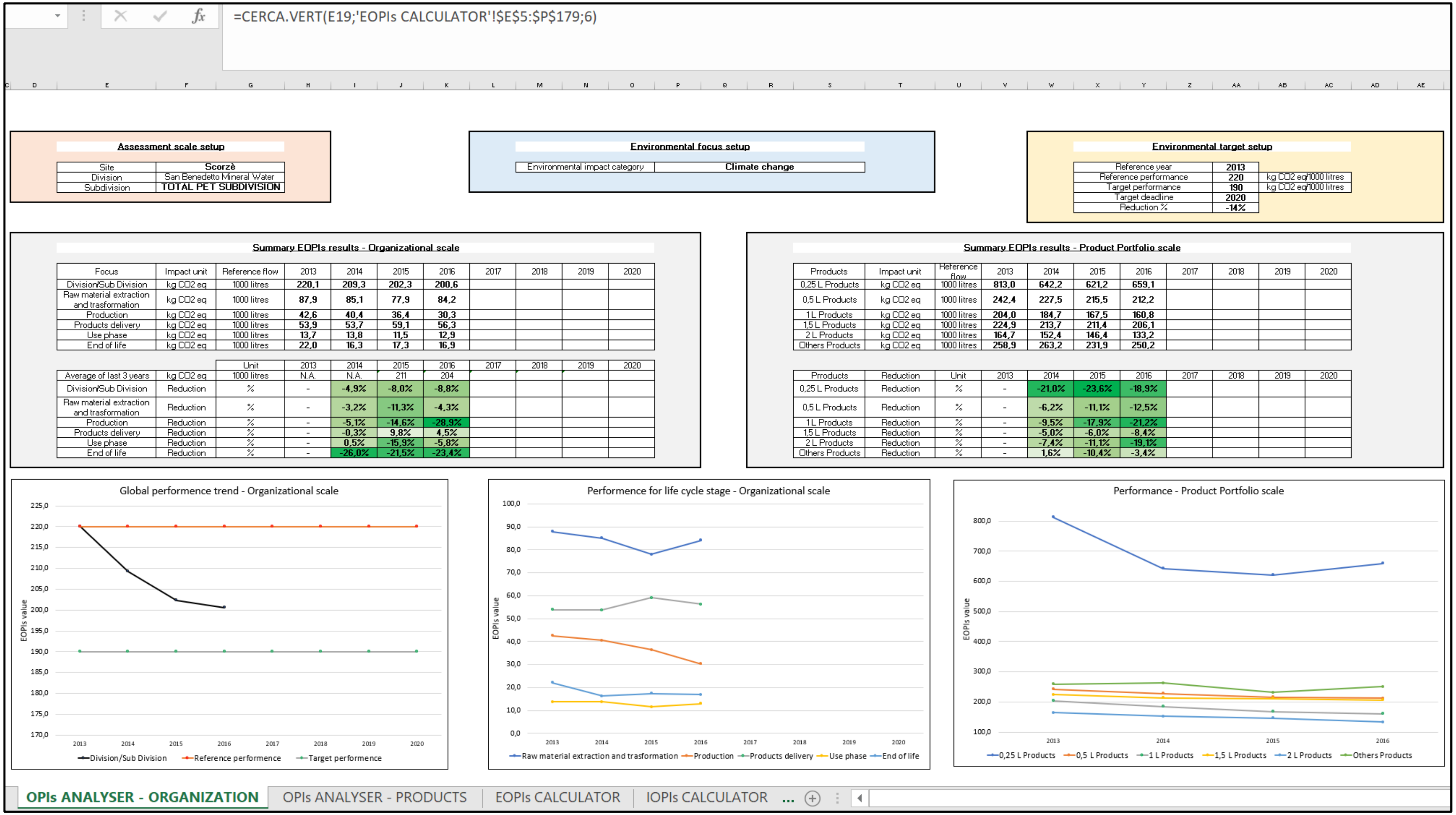
3.3.1.4. Set Baseline and Targets

According with ISO 14031, has been defined a baseline and a target. As a baseline has been choice for the organization the performance of year 2013 (220 kg CO2 eq/ 1000 litres) and as a target the performance that corresponds to a reduction of 14% of the baseline performance (190 kg CO2 eq/1000 litres). The deadline to achieve the target is 2020 year.

The Eco-EKA has been developed in order to monitor life cycle environmental performance in the case of all impact categories. In the present test results are shown for climate change category because San Benedetto has since 2013 at industrial strategy and a communication strategy at corporate and product level for the reduction of GHG emissions. This choice is according with other authors such as Zvezdov et al. (2016) that recognize the relevance to mitigate GHG emissions. However, actually for internal strategic use the organization monitor other impact categories, and in the future will evaluate the possibility to communicate externally other environmental performance to stakeholders.

3.3.1.5. Life cycle performance evaluation with Eco – EKA – Organizational scale

The following figures shown the two assessment areas of Eco-EKA (Eco - Environmental KPI Analyzer). The analyser of Eco – EKA permits to evaluate and visualize in a smart dashboard all EOPIs, IOPs and SOPIs defined far all the assessment years. In the figure 129 has been shown the results of performance evaluation at level of EOPIs. In the part of left have been shown the results of EOPIs for the Sub Division scale. The performance respect to the 2013 in the 2016 has improve of -8,2% passing from (220 kg/CO2/kg to 202 kg CO2 kg). This value is different from the -14% obtained by OLCA results without indexed the life cycle performance but observing only absolute values. Focusing on performance trend it is possible to notice that in the last year the performance is slightly improved respect to the year 2015. Also in this case the absolute results obtained by OLCA shown a decrease of -5% but when the performance is indexed, a lower improvement has been observed. This example confirms the need to use ISO 14031 in order to assess life cycle environmental performance obtained by OLCA and LCA because many factors could influence the performance and the ISO 14031 provides the correct framework to assess all relevant aspects. Going on with the trend analysis it is possible to notice that passing from 2015 to 2016 the raw material extraction and transformation life cycle stage that has shown an increasing that can be explain observing the IOPIs relate RPET use that shows a decrease. Furthermore, the SOPI related to RPET emission factor shows a relevant increase due to the fact that RPET has been purchases from suppliers located in countries with an electricity mix with high carbon footprint (kg CO2 eq/kWh) (e.g. Poland). These two aspects determine a worsening of environmental performance at level of life cycle stage related to raw materials. The production stage shows a good improve of environmental performance thanks to a reduction of electricity consumptions (see at level of IOPIs) and a reduction of emission factor associated to electricity (see at level SOPIs) due to the introduction of the new trigeneration unit. The life cycle stage related to product delivery shows an improvement of the performance due to the reduction of average distance travelled by truck (see IOPIs). The variations associated to use phase and end of life are not relevant passing from 2015 to 2016. Therefore, globally we assist to a compensation phenom that produces a small improvement (-0,8%). The analysis of EOPIs of the products portfolio permits to evaluate the trend for the different product categories. In this case it is possible to notice while the product categories 1L and 2L show a good improvement, the product categories 0,5L and 1,5L show improvement less large. However, at level of 0,25L and the category “other product” a worsening of performance has been noticed from 2015 to 2016. This worsening is due to the increase of plastic consumption (IOPIs) due to the reduction of the of average format (SOPIs).



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Assessment scale setup

Site	**Scorzè**
Division	San Benedetto Mineral Water
Subdivision	**TOTAL PET SUBDIVISION**

Environmental focus setup

Environmental impact category	**Climate change**

Environmental target setup

Reference year	**2013**	
Reference performance	**220**	kg CO2 eq/1000 litres
Target performance	**190**	kg CO2 eq/1000 litres
Target deadline	**2020**	
Reduction %	**-14%**	

Summary EOPIs results - Organizational scale

Focus	Impact unit	Reference flow	2013	2014	2015	2016	2017	2018	2019	2020
Division/Sub Division	kg CO2 eq	1000 litres	**220,1**	**209,3**	**202,3**	**200,6**				
Raw material extraction and trasformation	kg CO2 eq	1000 litres	**87,9**	**85,1**	**77,9**	**84,2**				
Production	kg CO2 eq	1000 litres	**42,6**	**40,4**	**36,4**	**30,3**				
Products delivery	kg CO2 eq	1000 litres	**53,9**	**53,7**	**59,1**	**56,3**				
Use phase	kg CO2 eq	1000 litres	**13,7**	**13,8**	**11,5**	**12,9**				
End of life	kg CO2 eq	1000 litres	**22,0**	**16,3**	**17,3**	**16,9**				

		Unit	2013	2014	2015	2016	2017	2018	2019	2020
Average of last 3 years	kg CO2 eq	1000 litres	N.A.	N.A.	211	204				
Division/Sub Division	Reduction	%	-	**-4,9%**	**-8,0%**	**-8,8%**				
Raw material extraction and trasformation	Reduction	%	-	**-3,2%**	**-11,3%**	**-4,3%**				
Production	Reduction	%	-	**-5,1%**	**-14,6%**	**-28,9%**				
Products delivery	Reduction	%	-	**-0,3%**	**9,8%**	**4,5%**				
Use phase	Reduction	%	-	**0,5%**	**-15,9%**	**-5,8%**				
End of life	Reduction	%	-	**-26,0%**	**-21,5%**	**-23,4%**				

Summary EOPIs results - Product Portfolio scale

Prroducts	Impact unit	Reference flow	2013	2014	2015	2016	2017	2018	2019	2020
0,25 L Products	kg CO2 eq	1000 litres	**813,0**	**642,2**	**621,2**	**659,1**				
0,5 L Products	kg CO2 eq	1000 litres	**242,4**	**227,5**	**215,5**	**212,2**				
1 L Products	kg CO2 eq	1000 litres	**204,0**	**184,7**	**167,5**	**160,8**				
1,5 L Products	kg CO2 eq	1000 litres	**224,9**	**213,7**	**211,4**	**206,1**				
2 L Products	kg CO2 eq	1000 litres	**164,7**	**152,4**	**146,4**	**133,2**				
Others Products	kg CO2 eq	1000 litres	**258,9**	**263,2**	**231,9**	**250,2**				

Prroducts	Reduction	Unit	2013	2014	2015	2016	2017	2018	2019	2020
0,25 L Products	Reduction	%	-	**-21,0%**	**-23,6%**	**-18,9%**				
0,5 L Products	Reduction	%	-	**-6,2%**	**-11,1%**	**-12,5%**				
1 L Products	Reduction	%	-	**-9,5%**	**-17,9%**	**-21,2%**				
1,5 L Products	Reduction	%	-	**-5,0%**	**-6,0%**	**-8,4%**				
2 L Products	Reduction	%	-	**-7,4%**	**-11,1%**	**-19,1%**				
Others Products	Reduction	%	-	**1,6%**	**-10,4%**	**-3,4%**				

Figure 129 Life Cycle Environmental Performance results returned by Eco -EKA at environmental impact evaluation level. San Benedetto PET Mineral Water Sub Division (Scorzè site).

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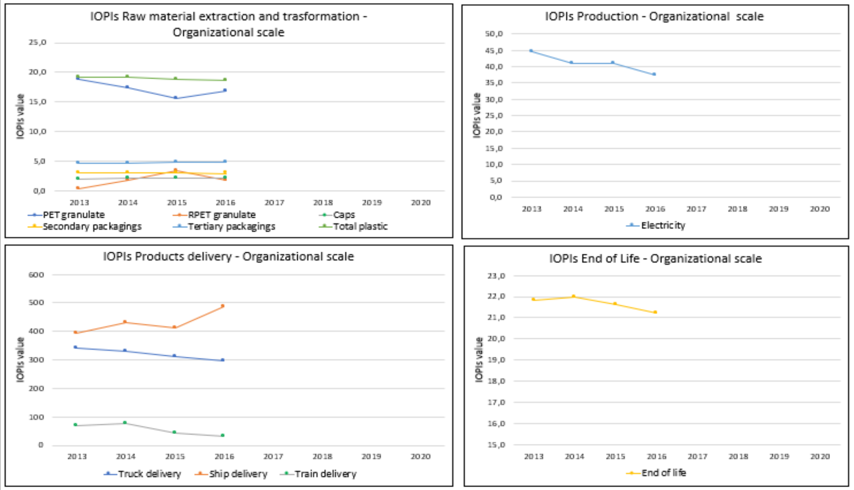
Summary IOPIs results - Division/Sub Division scale

Focus	Unit	Reference flow	2013	2014	2015	2016	2017	2018	2019	2020
PET granulate	kg	1000 litres	18,8	17,4	15,6	16,8				
RPET granulate	kg	1000 litres	0,3	1,7	3,3	1,8				
Total plastic	kg	1000 litres	19,1	19,2	18,9	18,6				
Caps	kg	1000 litres	2,0	2,1	2,1	2,1				
Secondary packagings	kg	1000 litres	3,0	3,1	2,9	2,9				
Tertiary packagings	kg	1000 litres	4,7	4,7	4,7	4,7				
Electricity	kWh	1000 litres	44,5	40,9	41,1	37,5				
Train delivery	km	1000 litres	68	77	42	32				
Ship delivery	km	1000 litres	392	432	411	488				
Truck delivery	km	1000 litres	342	331	312	297				
End of life	kg	1000 litres	21,8	22,0	21,6	21,2				



Summary SOPIs results

Focus	Unit	2013	2014	2015	2016	2017	2018	2019	2020
Average format total	litre/bottle	0,91	0,90	0,86	0,85				
Average format products category up 1%	litre/bottle	0,92	0,92	0,86	0,86				
Average other products	litre/bottle	0,89	0,82	0,90	0,80				
Aseptin incidence	%	1,8%	2,1%	2,4%	2,3%				
Emission factor PET	kg CO2 eq/kg	3,50	3,47	3,47	3,49				
Emission factor RPET	kg CO2 eq/kg	0,61	0,80	0,65	0,89				
Emission factor Electricity	kg CO2 eq/kWh	0,63	0,63	0,63	0,53				

	Unit	2013	2014	2015	2016	2017	2018	2019	2020
Average format total	%	-	-1,1%	-5,2%	-6,7%				
Average format products category up 1%	%	-	0,4%	-6,6%	-5,8%				
Average other products	%	-	-7,2%	1,1%	-9,5%				
Delta of aseptin incidence	%	-	0,3%	0,2%	0,0%				
Emission factor PET	%	-	-0,9%	-0,9%	-0,3%				
Emission factor RPET	%	-	31,1%	6,6%	45,9%				
Emission factor Electricity	%	-	0,0%	0,0%	-15,5%				

Summary IOPIs results - Product Portfolio scale

	Focus	Unit	Reference flow	2013	2014	2015	2016	2017	2018	2019	2020
PET granulate	0,25 L Products	kg	1000 litres	66,6	57,8	57,2	57,6				
	0,5 L Products	kg	1000 litres	22,1	22,0	20,1	19,7				
	1 L Products	kg	1000 litres	19,2	19,5	15,5	14,1				
	1,5 L Products	kg	1000 litres	19,1	18,3	13,7	18,0				
	2 L Products	kg	1000 litres	13,8	9,8	9,5	8,9				
	Others Products	kg	1000 litres	40,6	40,3	40,4	41,2				
RPET granulate	0,25 L Products	kg	1000 litres	0,0	0,0	0,0	0,0				
	0,5 L Products	kg	1000 litres	0,0	0,0	1,0	1,0				
	1 L Products	kg	1000 litres	3,7	3,6	5,0	5,4				
	1,5 L Products	kg	1000 litres	0,0	1,0	5,3	0,8				
	2 L Products	kg	1000 litres	0,2	4,2	4,1	3,7				
	Others Products	kg	1000 litres	0,0	0,0	0,0	0,0				
Total plastic	0,25 L Products	kg	1000 litres	66,6	57,8	57,2	57,6				
	0,5 L Products	kg	1000 litres	22,1	22,0	21,1	20,7				
	1 L Products	kg	1000 litres	22,9	23,1	20,5	19,5				
	1,5 L Products	kg	1000 litres	19,1	19,3	19,0	18,8				
	2 L Products	kg	1000 litres	14,0	14,0	13,5	12,5				
	Others Products	kg	1000 litres	40,6	40,3	40,4	41,2				
Caps	0,25 L Products	kg	1000 litres	31,8	33,0	32,5	32,9				
	0,5 L Products	kg	1000 litres	3,4	3,4	3,4	3,4				
	1 L Products	kg	1000 litres	1,6	1,6	1,3	1,2				
	1,5 L Products	kg	1000 litres	1,3	1,3	1,3	1,2				
	2 L Products	kg	1000 litres	0,7	0,7	0,7	0,5				
	Others Products	kg	1000 litres	7,8	7,6	6,2	5,9				
Secondary packagings	0,25 L Products	kg	1000 litres	19,3	19,9	17,8	17,4				
	0,5 L Products	kg	1000 litres	3,9	4,1	3,9	3,9				
	1 L Products	kg	1000 litres	3,4	3,3	2,9	2,7				
	1,5 L Products	kg	1000 litres	2,4	2,4	2,2	2,1				
	2 L Products	kg	1000 litres	2,1	2,1	2,0	2,0				
	Others Products	kg	1000 litres	6,5	6,3	6,3	6,0				
Tertiary packagings	0,25 L Products	kg	1000 litres	6,1	6,0	5,8	5,8				
	0,5 L Products	kg	1000 litres	5,2	5,1	5,1	5,1				
	1 L Products	kg	1000 litres	5,0	5,0	5,0	4,8				
	1,5 L Products	kg	1000 litres	4,8	4,8	5,0	4,8				
	2 L Products	kg	1000 litres	3,9	3,9	3,9	4,0				
	Others Products	kg	1000 litres	5,4	5,4	5,6	5,6				
Electricity	0,25 L Products	kWh	1000 litres	177,9	163,5	164,6	150,1				
	0,5 L Products	kWh	1000 litres	89,0	81,7	82,3	75,1				
	1 L Products	kWh	1000 litres	44,5	40,9	41,1	37,5				
	1,5 L Products	kWh	1000 litres	29,7	27,2	27,4	25,0				
	2 L Products	kWh	1000 litres	22,2	20,4	20,6	18,8				
	Others Products	kWh	1000 litres	55,5	51,0	51,3	46,8				
Train delivery	0,25 L Products	kg	1000 litres	119	24	147	156				
	0,5 L Products	kg	1000 litres	33	57	34	25				
	1 L Products	kg	1000 litres	72	56	80	86				
	1,5 L Products	kg	1000 litres	56	93	53	50				
	2 L Products	kg	1000 litres	124	108	28	4				
	Others Products	kg	1000 litres	13	203	36	31				
Ship delivery	0,25 L Products	kg	1000 litres	936	17	162	551				
	0,5 L Products	kg	1000 litres	504	312	263	330				
	1 L Products	kg	1000 litres	787	311	93	97				
	1,5 L Products	kg	1000 litres	536	997	965	1115				
	2 L Products	kg	1000 litres	15	20	15	18				
	Others Products	kg	1000 litres	810	423	470	776				
Truck delivery	0,25 L Products	kg	1000 litres	322	253	322	310				
	0,5 L Products	kg	1000 litres	267	299	257	251				
	1 L Products	kg	1000 litres	337	442	335	323				
	1,5 L Products	kg	1000 litres	418	405	392	372				
	2 L Products	kg	1000 litres	336	15	124	262				
	Others Products	kg	1000 litres	737	354	463	444				
End of life	0,25 L Products	kg	1000 litres	69,9	61,2	89,7	90,5				
	0,5 L Products	kg	1000 litres	23,7	23,6	24,4	24,1				
	1 L Products	kg	1000 litres	24,1	24,4	21,8	20,7				
	1,5 L Products	kg	1000 litres	19,7	20,0	20,3	20,0				
	2 L Products	kg	1000 litres	21,8	21,6	14,2	13,0				
	Others Products	kg	1000 litres	59,9	60,3	46,6	47,0				

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Figure 130 Life Cycle Environmental Performance results returned by Eco -EKA at inventory evaluation level. San Benedetto PET Mineral Water Sub Division (Scorzè site).

3.3.1.6. Life Cycle Performance of the San Benedetto Italian Mineral Water Division

Although San Benedetto has started with the performance tracking of the life cycle environmental performance from the Scorze site where data were available since 2013. The organization have extended the approach to all Italian site, before including the Vigginello site in the 2015 and after, in the 2016, including the other sites (Donato, Popoli, Atella). In the present paragraph are reported the environmental performance on climate change of the whole division, where the 2016 constitutes the first year of assessment and from the next year the performance will be feed to Eco-EKA considering all the division.

Production site	Measure unit	2013	2014	2015	2016
Scorzè (VE)	kg CO2 eq/1000 litres	220,1	209,3	202,3	200,6
Popoli (PE)	kg CO2 eq/1000 litres	-	-	-	184,0
Viggianello (PZ)	kg CO2 eq/1000 litres	-	-	154,0	156,0
Donato (BI)	kg CO2 eq/1000 litres	-	-	-	213,0
Atella (PZ)	kg CO2 eq/1000 litres	-	-	-	305,0
Total Italian Division	kg CO2 eq/1000 litres	-	-	-	**0,194**

Table 56 Results of the environmental impacts on climate change, first year of assessment of the whole San Benedetto Italian Mineral Water Division.

3.3.2. EPE of Life Cycle Performance – Product scale

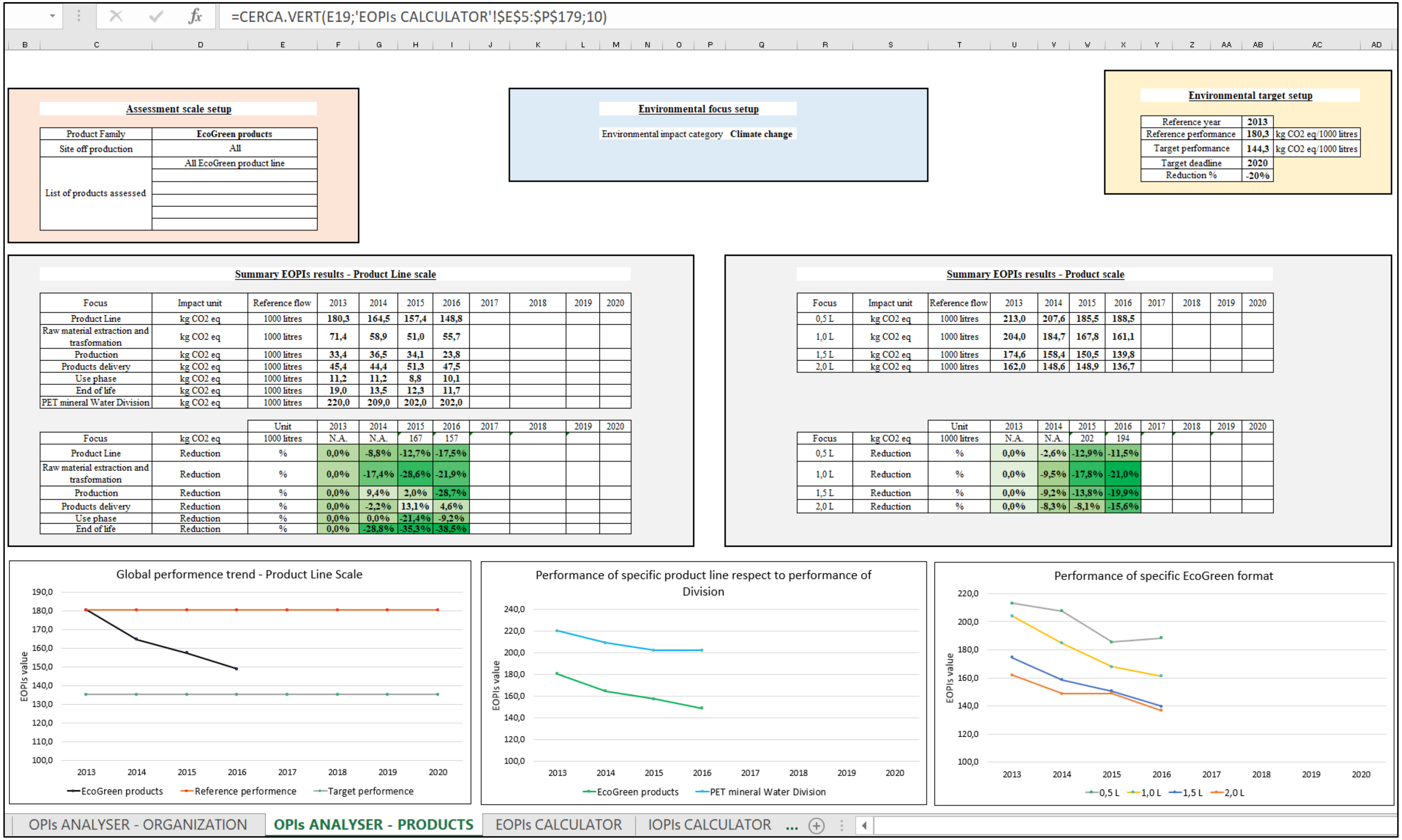
The same procedure has been applied also to the EcoGreen products line (for the description of EcoGreen products line see paragraph 3.7.2.1). The same approach in EOPIs definition has been used defining EOPIs for the evaluation of the environmental performance of the whole products line and for the evaluation of the single product formats. Also at level of the definition of IOPIs and SOPIs the approach used has been coherent with the one previously descripted.

3.3.2.1. Set Baseline and Targets

According with ISO 14031, has been defined a baseline and a target. As a baseline has been choice for the EcoGreen product line the performance of year 2013 (180,3 kg CO2 eq/ 1000 litres) and as a target a performance better to a performance that corresponds to a reduction of 20% of the baseline performance (144,3 kg CO2 eq/1000 litres). The deadline to achieve the target is 2020 year.

3.3.2.2. Life cycle performance evaluation with Eco – EKA – Product scale

A specific smart dashboard is present in the Eco-EKA for the performance evaluation and the performance tracking of products. The following two figures show the results respectively at level of environmental impacts (EOPIs) and of inventory consumptions (IOPIs). The performance respect to the 2013 in the 2016 has improved of -17,6% passing from (180 kg/CO2/kg to 148 kg CO2 kg). Focusing on the product formats, the format of 1L is the one that has been improved more (-21%) while the other formants respectively have reached the following improvements of the performance: -11,5% (0,5L); -19,9% (1,5L) and -15,6% (2L). These improvements have been mainly due to aspects that can be observed in the inventory dashboard part: average weight reduction of about -15%; increasing of RPET utilization from 16% to 33%, cap average weight reduction of about -18%, reduction of emission from energy consumption of about -19%, reduction of shrink film consumption of about - 20% and finally the reduction of kilometric distances travelled by truck of about -10%.



Assessment scale setup

Product Family	**EcoGreen products**
Site off production	All
List of products assessed	All EcoGreen product line

Environmental focus setup

Environmental impact category **Climate change**

Environmental target setup

Reference year	**2013**	
Reference performance	**180,3**	kg CO2 eq/1000 litres
Target performance	**144,3**	kg CO2 eq/1000 litres
Target deadline	**2020**	
Reduction %	**-20%**	

Summary EOPIs results - Product Line scale

Focus	Impact unit	Reference flow	2013	2014	2015	2016	2017	2018	2019	2020
Product Line	kg CO2 eq	1000 litres	**180,3**	**164,5**	**157,4**	**148,8**				
Raw material extraction and trasformation	kg CO2 eq	1000 litres	**71,4**	**58,9**	**51,0**	**55,7**				
Production	kg CO2 eq	1000 litres	**33,4**	**36,5**	**34,1**	**23,8**				
Products delivery	kg CO2 eq	1000 litres	**45,4**	**44,4**	**51,3**	**47,5**				
Use phase	kg CO2 eq	1000 litres	**11,2**	**11,2**	**8,8**	**10,1**				
End of life	kg CO2 eq	1000 litres	**19,0**	**13,5**	**12,3**	**11,7**				
PET mineral Water Division	kg CO2 eq	1000 litres	**220,0**	**209,0**	**202,0**	**202,0**				

		Unit	2013	2014	2015	2016	2017	2018	2019	2020
Focus	kg CO2 eq	1000 litres	N.A.	N.A.	167	157				
Product Line	Reduction	%	**0,0%**	**-8,8%**	**-12,7%**	**-17,5%**				
Raw material extraction and trasformation	Reduction	%	**0,0%**	**-17,4%**	**-28,6%**	**-21,9%**				
Production	Reduction	%	**0,0%**	**9,4%**	**2,0%**	**-28,7%**				
Products delivery	Reduction	%	**0,0%**	**-2,2%**	**13,1%**	**4,6%**				
Use phase	Reduction	%	**0,0%**	**0,0%**	**-21,4%**	**-9,2%**				
End of life	Reduction	%	**0,0%**	**-28,8%**	**-35,3%**	**-38,5%**				

Summary EOPIs results - Product scale

Focus	Impact unit	Reference flow	2013	2014	2015	2016	2017	2018	2019	2020
0,5 L	kg CO2 eq	1000 litres	**213,0**	**207,6**	**185,5**	**188,5**				
1,0 L	kg CO2 eq	1000 litres	**204,0**	**184,7**	**167,8**	**161,1**				
1,5 L	kg CO2 eq	1000 litres	**174,6**	**158,4**	**150,5**	**139,8**				
2,0 L	kg CO2 eq	1000 litres	**162,0**	**148,6**	**148,9**	**136,7**				

		Unit	2013	2014	2015	2016	2017	2018	2019	2020
Focus	kg CO2 eq	1000 litres	N.A.	N.A.	202	194				
0,5 L	Reduction	%	**0,0%**	**-2,6%**	**-12,9%**	**-11,5%**				
1,0 L	Reduction	%	**0,0%**	**-9,5%**	**-17,8%**	**-21,0%**				
1,5 L	Reduction	%	**0,0%**	**-9,2%**	**-13,8%**	**-19,9%**				
2,0 L	Reduction	%	**0,0%**	**-8,3%**	**-8,1%**	**-15,6%**				

Figure 131 Life Cycle Environmental Performance results returned by Eco -EKA at environmental impact evaluation level. EcoGreen product line.

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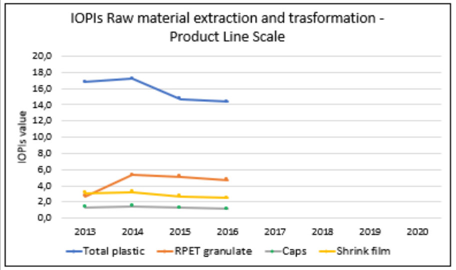
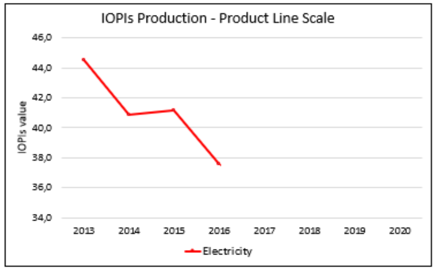
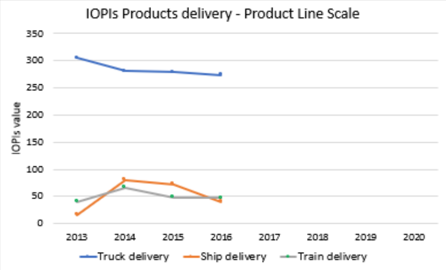
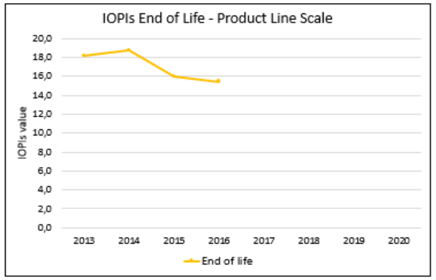
Summary IOPIs results

Focus		Unit	Reference flow	2013	2014	2015	2016	2017	2018	2019	2020
Total plastic	All EcoGreen Line	kg	1000 litres	16,8	17,2	14,7	14,3				
RPET granulate	All EcoGreen Line	%	1000 litres	16%	31%	35%	33%				
	All EcoGreen Line	kg	1000 litres	2,7	5,3	5,1	4,7				
Caps	All EcoGreen Line	kg	1000 litres	1,36	1,49	1,25	1,12				
Shrink film	All EcoGreen Line	kg	1000 litres	3,08	3,23	2,70	2,45				
Electricity	All EcoGreen Line	kWh	1000 litres	44,5	40,9	41,1	37,5				
Train delivery	All EcoGreen Line	km	1000 litres	40	66	48	47				
Ship delivery	All EcoGreen Line	km	1000 litres	16	80	72	40				
Truck delivery	All EcoGreen Line	km	1000 litres	305	281	279	274				
End of life	All EcoGreen Line	kg	1000 litres	18,2	18,7	15,9	15,5				









Summary IOPIs results

	Focus	Unit	Reference flow	2013	2014	2015	2016	2017	2018	2019	2020
Total plastic	0,5 L	kg	1000 litres	9,5	9,5	8,7	8,7				
	1,0 L	kg	1000 litres	18,0	18,0	14,5	14,5				
	1,5 L	kg	1000 litres	22,8	22,8	19,8	18,8				
	2,0 L	kg	1000 litres	28,0	28,0	27,9	25,3				
PET granulate	0,5 L	kg	1000 litres	9,5	9,5	7,8	7,8				
	1,0 L	kg	1000 litres	12,6	9,0	7,3	7,3				
	1,5 L	kg	1000 litres	20,5	16,0	13,9	13,2				
	2,0 L	kg	1000 litres	25,2	19,6	19,5	17,7				
RPET granulate	0,5 L	kg	1000 litres	0,0	0,0	0,9	0,9				
	1,0 L	kg	1000 litres	5,4	9,0	7,3	7,3				
	1,5 L	kg	1000 litres	2,3	6,8	5,9	5,6				
	2,0 L	kg	1000 litres	2,8	8,4	8,4	7,6				
% RPET	0,5 L	%	1000 litres	0%	0%	10%	10%				
	1,0 L	%	1000 litres	30%	50%	50%	50%				
	1,5 L	%	1000 litres	10%	30%	30%	30%				
	2,0 L	%	1000 litres	10%	30%	30%	30%				
Caps	0,5 L	kg	1000 litres	1,4	1,4	1,4	1,4				
	1,0 L	kg	1000 litres	1,4	1,4	1,0	0,9				
	1,5 L	kg	1000 litres	1,4	1,4	1,0	0,9				
	2,0 L	kg	1000 litres	1,4	1,4	1,4	1,0				
Shrink film	0,5 L	kg	1000 litres	2,1	2,0	1,8	1,7				
	1,0 L	kg	1000 litres	3,4	3,4	2,8	2,5				
	1,5 L	kg	1000 litres	4,0	4,0	3,2	2,9				
	2,0 L	kg	1000 litres	4,1	4,1	3,6	3,5				
Electricity	0,5 L	kWh	1000 litres	89,0	81,7	82,3	75,1				
	1,0 L	kWh	1000 litres	44,5	39,9	40,1	36,5				
	1,5 L	kWh	1000 litres	29,7	27,2	27,4	25,0				
	2,0 L	kWh	1000 litres	22,2	20,4	20,6	18,8				
Train delivery	0,5 L	km	1000 litres	21,8	20,0	2,5	0,4				
	1,0 L	km	1000 litres	76,6	123,8	95,2	102,8				
	1,5 L	km	1000 litres	6,9	4,1	0,6	0,7				
	2,0 L	km	1000 litres	1,9	18,3	12,2	0,0				
Ship delivery	0,5 L	km	1000 litres	0,5	422,0	352,4	195,0				
	1,0 L	km	1000 litres	34,9	14,6	9,8	10,6				
	1,5 L	km	1000 litres	1,1	0,1	0,0	0,0				
	2,0 L	km	1000 litres	0,0	0,1	0,1	0,1				
Truck delivery	0,5 L	km	1000 litres	235,0	224,4	216,3	226,0				
	1,0 L	km	1000 litres	315,3	277,5	291,4	283,8				
	1,5 L	km	1000 litres	318,8	316,9	294,8	285,5				
	2,0 L	km	1000 litres	306,1	274,4	278,5	285,9				
End of life	0,5 L	kg	1000 litres	10,9	10,9	10,1	10,1				
	1,0 L	kg	1000 litres	19,4	19,4	15,5	15,4				
	1,5 L	kg	1000 litres	24,2	24,2	20,9	19,7				
	2,0 L	kg	1000 litres	29,4	29,4	29,3	26,3				

Summary SOPIs results

Focus	Unit	2013	2014	2015	2016	2017	2018	2019	2020
Average format	litre/bottle	1,206	1,087	1,084	1,157				
Preforms produced by suppliers	%	38%			42%				
Emission factor PET	kg CO2 eq/kg	3,50	3,47	3,47	3,49				
Emission factor RPET	kg CO2 eq/kg	0,61	0,80	0,65	0,89				
Emission factor Electricity	kg CO2 eq/kWh	0,63	0,63	0,63	0,53				

		2013	2014	2015	2016	2017	2018	2019	2020
Reduction % respected reference performence	%	0,0%	-9,9%	-10,1%	-4,1%				
Emission factor PET	%	-	-0,9%	-0,9%	-0,3%				
Emission factor RPET	%	-	31,1%	6,6%	45,9%				
Emission factor Electricity	%	-	0,0%	0,0%	-15,5%				

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Figure 132 Life Cycle Environmental Performance results returned by Eco -EKA at inventory evaluation level. EcoGreen product line.

3.4. TEST 3: Application of OES2 method to criticalities on environmental management areas (4) & (5) – Part EcoDesign

This test has the objective to assess the capacity of OES2 method to face the gaps on life cycle management related to criticalities on ecodesign and the assessment of the environmental performance of new projects and investments.

Life Cycle Management Critical Areas	Identified gaps
4. Ecoinnovation	12. Difficulties in implementation of practical ecodesign processes and new eco-friendly alternative solutions comparison
5. Strategic decision making	14. Difficulties in the assessment of environmental performance of investments

Table 57 Identified gaps on ecoefficiency – Ecodesign part, faced by OES2 method in the test 3.

In order to face these gaps OES2 method applies:

- One EMTs: ISO/TR 14062 for ecodesign
- One STEM: Eco-DSD (Eco Design Simulation Dashboard).

According to ISO14062 methodology when an organization wants to develop new design solutions (e.g. new products, investments in new process technologies) must assessed the improvement of life cycle environmental performance of the new solutions. In this context San Benedetto has started to use ecodesign to assess and support decision making processes regarding the development of new products and of already existing products and regarding innovation at process and organizational level. This choice is very strategical in order to assess preventively the effects of decisions related to development projects on the life cycle environmental performance. In this way the organization can assess if the development projects support the achievement of environmental goals established according to the environmental strategical framework defined by the organization (for this aspect see test 6 on ESSM). Furthermore, a specific procedure has been developed in order to manage the application of ecodesign to development projects and investments assessment. In the following figure has been shown, with reference to climate change environmental impact category, the contribution of the different processes with a decision making influence perspective.

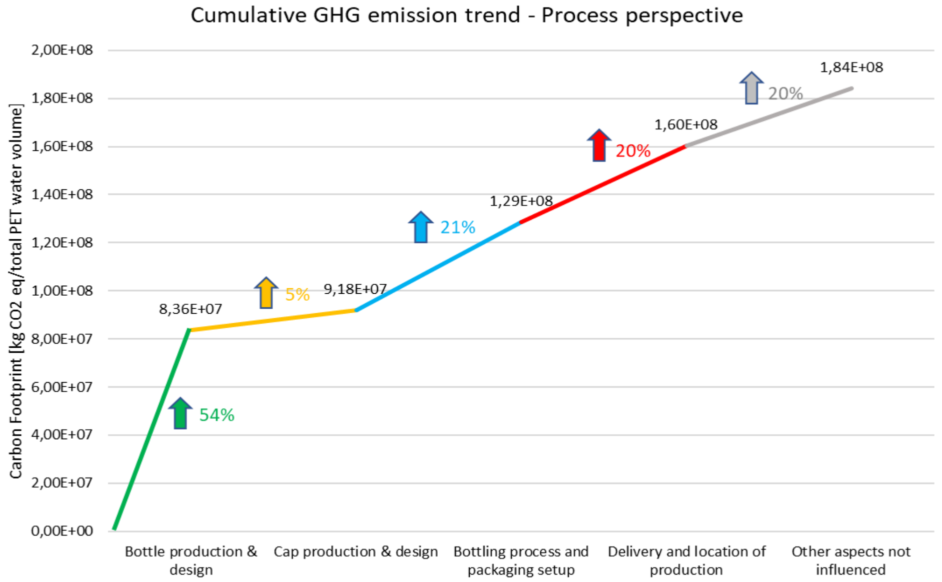


Figure 133 Cumulative GHG emission of the different processes with a decision making perspective. San Benedetto PET Mineral Water Sub Division (Scorzè site) 2016.

In this case it is possible to notice that:

- Decision making processes related to bottle design and production influenced the 54% of the total GHG emissions;

- Decision making processes related to cap design and production influenced the 5% of the total GHG emissions;
- Decision making processes related to bottling processes and product packaging setup influenced the 21% of the total GHG emissions;
- Decision making processes related to the localization of the production and the products delivery influenced the 20% of the total GHG emissions;
- Finally, a part of the impacts is related to life cycle processes that cannot be influenced by organization (e.g. use phase and cooling processes at store points).

This information is very important in order to know the potential influence of the different decision making areas. In the following paragraphs have been shown the results returned by the application of ecodesign and Eco-DSD.

3.4.1. Ecodesign application

The ecodesign component of OES2 method has been tested by the organization on a large amount of design projects from 2014 to 2016. About 30 projects have been assessed: 14 product ecodesign projects, 14 process ecodesign projects and 2 organizational ecodesign projects. In fact, according the multiscale approach of OES2 methods, the ecodesign projects have been distinguished in three different typologies:

- Product ecodesign projects: they concern the development of new products or of already existing products;
- Process ecodesign projects: they concern the investments on new process technologies (e.g. new machineries or new components for upgrading the already existing process technologies);
- Organizational ecodesign projects: they concern investments and changes at organizational level (e.g. new production sites acquisition, delocalization of production). The concept organizational ecodesign has been presented at SETAC conference (Loss et al., 2016). In fact, with the introduction of OLCA methodology that expands the scope of LCA to the whole organization or to divisions (sub-set of organization through the consolidation method) in this PhD thesis the concept of ecodesign normally applied to products and processes have been extended to the organization scale (Loss et al., 2016).

The application of ecodesign has been conducted according to ISO/TR14062 and results have been used for the “conceptual design” and for the “detailed design” stages. The assessments of environmental performance have been conducted according to LCA (ISO 14040-44) and OLCA (ISO/TS 14072) framework and using the EcoDesign Simulation Dashboard (Eco-DSD) (for details see chapter 3). The Eco-DSD has been introduce by OES2 method as a work space to speed up the assessment of ecodesign projects and to permit a smart communication of the results to top management in order to support the decision making process. In the following paragraph these results have been shown:

- Product ecodesign project: lighting of bottle and cap of 0,5L San Benedetto Still Mineral Water products;
- Organizational ecodesign project: the acquisition of a new production site of Viggianello in the south of Italy;
- Process ecodesign project: the design of a new bottling line.

For policy and confidentiality reasons of the organization the economic results have been not shown. This aspect does not invalidate the objective of the application that focus on show as OES2 method is supportive to face identified scientific gaps related to life cycle environmental management.

3.4.1.1. Product ecodesign

3.4.1.1.1. <u>Goal and scope</u>

The goal of the project is the weight reduction of the plastic bottles containers with format 0,5L used for products San Benedetto Still Mineral Water and the weight reduction of the plastic mass of caps used to pack mineral still water. In the following table have been shown the starting design parameters and the parameters related to the two design alternatives assessed.

	Bottle weight [g/bottle]	Cap weight [g/cap]
Starting design	8,7	1,36
First ecodesign alternative	8,2	0,90
Second design alternative	7,8	0,90

Table 58 Starting design and new ecodesign alternatives assessed.

In the starting design the cap has a diameter of 28 mm (D28) while in the case of ecodesign alternatives the cap has a diameter of 26 mm (D26). The goal of ecodesign assessment is to evaluate the environmental performance in terms of reduction of GHG emissions of new design alternatives. The assessment is intended to assist the organization to identify the potential environmental and economic savings related to new design alternatives assessed.

The Functional Unit (FU) was identified as the total number of bottles that were packed in one year with the bottle and the cap characterized by the starting design parameters. Therefore, the functional unit is set equal to 427.000.000 of bottles.

The **system boundaries** include all pertinent processes to the ecodesign project that are indented as all the processes that undergoes a variation as effect of the ecodesign project. The life cycle processes are:

- PET and RPET plastic consumption for bottle production including also the transport from the suppliers;
- HDPE plastic consumption for cap production including also the transport from the suppliers;
- Masterbatch consumption for cap production including also the transport from the suppliers;
- Electricity consumption for bottle and cap production. In fact, a specific statistical model has been elaborated to assess the reduction of electricity consumption as effect of weight reduction both in the case of bottle production and cap production;
- Cardboard boxes consumption for cap transport;
- Pallet consumption for cap transport;
- Transport process of the caps from the production site located in Paese (TV) to the bottling site located in Scorze (VE). In fact, the lightening of caps permits to increase the number of caps contained by a box from 6500 caps to 9000 caps;
- End of life wastes. The bottle weight reduction and the cap weight reduction permit to reduce the waste generated in end of life stage.

The environmental impacts of climate change have been assessed using the IPCC 2013 GWP 100a v 1.00 (IPCC, 2016). A cut off of 5% has been used.

The ecodesign assessment has been performed using the Eco-DSD.

3.4.1.1.2. Inventory analysis, impact assessment and results interpretation

The inventory data has been feed by the EID interface to “Simulation Data Logger” component of Eco-DSD establishing programmed links in excel language while the design specifications for the two alternatives (e.g. bottle weights and cap weights) have been inserted manually from designers as also the electricity consumption that have required the development of a statistical model. According with the theoretical framework defined in chapter 2, Eco-DSD has been developed using the programming language of Excel. The screenshots of the tool have been shown in order to show the software architecture of Eco-DSD that has been built following the methodological framework developed and descripted in the chapter 2. These screenshots have been shown only for the first test inasmuch the Eco-DSD structure is standard and do not change never. Therefore, for the other tests has been shown only the part of Eco-DSD (“performance comparator”) where are shown the results of the eco design assessment. The major part of the contents has been translated in English, but the notes was left in Italian. In fact, being a tool operatively used from engineers and eco designers the tool has been developed in Italian.

Life cycle aspects	Parameters	Measure unit	Starting Design value	Alternative 1 Design value	Alternative 2 Design value	Specification on the automatic data source	Notes
PRODUCTIVE ASPECTS	**Functional unit**	**bottles/year**	**427.000.000**	**427.000.000**	**427.000.000**		
ENERGY	KPI pressa 23	kWh/1000pz	1,23	0,92	0,92	EID/Energy consumptions mapping/Paese/2016	viene considerata solo energia elettrica diretta
	KPI pressa 24	kWh/1000pz	1,25	0,91	0,91	EID/Energy consumptions mapping/Paese/2016	viene considerata solo energia elettrica diretta
	KPI pressa 26	kWh/1000pz	0,99	0,73	0,73	EID/Energy consumptions mapping/Paese/2016	viene considerata solo energia elettrica diretta
	Consumo energetico produzione tappi	kWh	481.007	311.710	311.710	Calculated automatically	
	Consumo energetico produzione bottiglia	kWh	4.118.715	4.001.092	3.906.993	Calculated automatically	
	KPI SIPA 4	kWh/1000pz	10,23	9,95	9,73	Elaborazione da modello statistico sviluppato per le macchine monostadio rep 80	viene considerata solo energia elettrica diretta
	KPI SIPA 6	kWh/1000pz	9,42	9,15	8,93	Elaborazione da modello statistico sviluppato per le macchine monostadio rep 80	viene considerata solo energia elettrica diretta
	KPI SIPA 9	kWh/1000pz	9,67	9,40	9,18	Elaborazione da modello statistico sviluppato per le macchine monostadio rep 80	viene considerata solo energia elettrica diretta
	KPI SIPA 31	kWh/1000pz	9,35	9,08	8,86	Elaborazione da modello statistico sviluppato per le macchine monostadio rep 80	viene considerata solo energia elettrica diretta
RAW MATERIALS	Bottle weight (cod SAP 20042378)	g	8,70	8,20	7,80	Design specification - inserted by user	
	percentuale R-PET	%	10%	10%	10%	EID/PET bottles production processes mapping/Scorze/2016	
	Consumo di PET	kg	3.373.745	3.179.851	3.024.737	Calculated	
	Consumo di R-PET	kg	374.861	353.317	336.082	Calculated	
	Cap weight	g	1,35	0,90	0,90	Design specification - inserted by user	
	peso HDPE tappo rosa	gr/pz	1,346	0,898	0,898	Design specification - inserted by user	cod HDPE 10030009
	peso MASTER tappo rosa	gr/pz	0,003	0,002	0,002	Design specification - inserted by user	cod MASTERBATCH 10030160 e 10030299
	Consumo di HDPE	kg	583.409	388.493	388.493	Calculated automatically	
	Consumo di MASTERBATCH	kg	1.467	1.030	1.030	Calculated automatically	
	Consumo di SCATOLE PER TAPPI	kg	22.078	15.945	15.945	si stima che il riutilizzo di una scatola sia di tre volte	
	Consumo di PALLETS	kg	1.587	1.146	1.146	si stima che il riutilizzo di un pallet sia di 20 volte	
AUXILIARY MATERIALS	Scatola per tappi	kg	1,0	1,0	1,0	Peso scatola per tappi	
	Numero PF medio ponderato per pallet	pz	1383	1383	1383	EID/Products bills mapping/Scorze/2016	
	Avarage number of caps for singe cardboard boxe	pz	6500	9000	9000	Design specification - inserted by user	
	Peso di un pallet di tappi	kg	179	169	169	Calculated automatically	
	Pallet	kg	23,0	23,0	23,0	peso pallet	
UPSTREAM RAW MATERIALS TRANSPORTS	Distanza fornitore-Scorzè R-PET camion	km	1098	1098	1098	EID/Supply chain transports mapping/Scorze/2016	
	Distanza fornitore-Scorzè PET camion	km	83	83	83	EID/Supply chain transports mapping/Scorze/2016	
	Distanza fornitore-Scorzè PET nave	km	20130	20130	20130	EID/Supply chain transports mapping/Scorze/2016	
	Distanza fornitore-Paese HDPE camion	km	668,02	668,02	668,02	EID/Supply chain transports mapping/Paese/2016	
	Distanza fornitore-Paese HDPE nave	km	92,77	92,77	92,77	EID/Supply chain transports mapping/Paese/2016	
	Distanza fornitori- Paese MASTERBATCH camion	km	162,88	162,88	162,88	EID/Supply chain transports mapping/Paese/2016	media ponderata dei km dei fornitori per i cod master impiegati
	Distanza fornitore-Paese SCATOLA TAPPI camion	km	35	35	35	EID/Supply chain transports mapping/Paese/2016	
	Distanza fornitore-Scorzè PALLET camion	km	245	245	245	EID/Supply chain transports mapping/Paese/2016	
	Massa di tappi trasportata da Paese a Scorzè	kg	605.189	404.561	404.561	Calculated automatically	
	Massa di tappi trasportata in un camion	kg	5.923	5.564	5.564	Calculated automatically	
	Distanza Paese-Scorzè	km	13,5	13,5	13,5	EID/Supply chain transports mapping/Scorze/2016	
	Massa di PET e R-PET contenuta in un camion	kg	22.500	22.500	22.500	Calculated automatically	
	Massa di HDPE contenuta in un camion	kg	27.500	27.500	27.500	Calculated automatically	
	Massa scatola per tappi contenuta in un camion	kg	5.500	5.500	5.500	Calculated automatically	
	Massa di pallets per camion	kg	16.100	16.100	16.100	Calculated automatically	
	Numero di camion di PET e R-PET	-	167	157	149	Calculated automatically	
	Numero di camion di HDPE	-	21	14	14	Calculated automatically	
	Numero di camion di tappi	-	102	73	73	Calculated automatically	
	Numero di camion per pallets nuovi	-	0,10	0,07	0,07	Calculated automatically	
	Numero di camion di scatole per tappi	-	4,0	2,9	2,9	Calculated automatically	
DELIVERY TRANSPORTS	Distanza media ponderata distribuzione prodotto finito camion	km	246,78	246,78	246,78	EID/Delivery transports mapping/Scorze/2016	
	Distanza media ponderata distribuzione prodotto finito nave	km	217,79	217,79	217,79	EID/Delivery transports mapping/Scorze/2016	
	Distanza media ponderata distribuzione prodotto finito treno	km	19,04	19,04	19,04	EID/Delivery transports mapping/Scorze/2016	
	Peso Prodotto Finito (una bottiglia)	kg	0,5397	0,5387	0,5383	EID/Products bills mapping/Scorze/2016	si considera il peso da DB a meno di bottiglia e tappo che vengono inseriti manualmente
	Peso Prodotto Finito (un pallet)	kg	746,38	745,05	744,50	Calculated automatically	
	Massa di prodotto finito trasportata in un camion	kg	24.631	24.587	24.569	Calculated automatically	viene considerato un autotreno completo (33 pallet)

PERFORMANCE COMPARATOR | IMPACTS CALCULATOR | INVENTORY CALCULATOR | **SIMULATION DATA LOGGER**

Figure 134 Eco-DSD Simulation Data Logger component

E33 =SOMMA('SIMULATION DATA LOGGER'!E36:E37)

PROJECT NAME	Bottle + cap weight reduction - Mineral Still Water 0,5L Products									
DESIGN ALTERNATIVES		Udm	Starting design		Alternative 1			Alternative 2		
		↓	Bottle 0,5L (8,7 g) + Cap D28 (1,36 g)	Notes	Bottle 0,5L (8,2 g) + Cap D28 (0,90 g)	Notes	Variation (Δ) Alternative 1 - Alternative 0	Bottle 0,5L (7,8 g) + Cap D28 (0,90 g)	Notes	Variation (Δ) Alternative 2 - Alternative 0
Life cyle aspects	Functional unit	bottles/year	427.000.000	Production budget	427.000.000	Production budget	Production budget	427.000.000	Production budget	
Energy consumptions	Electricity medium voltage	kWh	4.533.723	Il consumo energetico dovuto alla produzione tappi è pari al KPI medio ponderato delle presse per l'unità funzionale. Il consumo energetico delle SIPA è calcolato a partire dal KPI ponderato delle 4 macchine (calcolato a partire dal modello statistico elaborato per le macchine monoestadio) che producono la bottiglia, rapportato all'unità funzionale.	4.312.802	Il consumo energetico dovuto alla produzione tappi è pari al KPI calcolato sulla base del modello statistico per la pressa 26. Il consumo energetico delle SIPA è calcolato a partire dal KPI ponderato delle 4 macchine (calcolato a partire dal modello statistico elaborato per le macchine monoestadio) che producono la bottiglia, rapportato all'unità funzionale.	-220.920,84	4.218.703	Il consumo energetico dovuto alla produzione tappi è pari al KPI calcolato sulla base del modello statistico per la pressa 26. Il consumo energetico delle SIPA è calcolato a partire dal KPI ponderato delle 4 macchine (calcolato a partire dal modello statistico elaborato per le macchine monoestadio) che producono la bottiglia, rapportato all'unità funzionale.	-315.019,8
Raw materials consumptions	PET consumption	kg	3.373.745	Rappresenta la componente di PET delle bottiglie da 0,5L (peso 8,70 gr) soffiate dalle SIPA 4-6-9-31 (con relativi scarti) e poi imbottigliate nelle linee 51-52 (con relativi scarti)	3.179.851	Rappresenta la componente di PET delle bottiglie da 0,5L (peso 8,20 gr) soffiate dalle SIPA 4-6-9-31 (con relativi scarti) e poi imbottigliate nelle linee 51-52	-193.893,37	3.024.737	Rappresenta la componente di PET delle bottiglie da 0,5L (peso 7,80 gr) soffiate dalle SIPA 4-6-9-31 (con relativi scarti) e poi imbottigliate nelle linee 51-52 (con	-349.008,1
	RPET consumption	kg	374.861	Rappresenta la componente di R-PET delle bottiglie da 0,5L (peso 8,70 gr) soffiate dalle SIPA 4-6-9-31 (con relativi scarti) e poi imbottigliate nelle linee 51-52 (con relativi scarti)	353.317	Rappresenta la componente di R-PET delle bottiglie da 0,5L (peso 8,20 gr) soffiate dalle SIPA 4-6-9-31 (con relativi scarti) e poi imbottigliate nelle linee 51-52	-21.543,71	336.082	Rappresenta la componente di R-PET delle bottiglie da 0,5L (peso 7,80 gr) soffiate dalle SIPA 4-6-9-31 (con relativi scarti) e poi imbottigliate nelle linee 51-52 (con	-38.778,7
	HDPE consumption	kg	583.409	Rappresenta la componente di HDPE dei tappi D28 3P (peso 1,30 gr) prodotti dalle presse 23-24-26 (con relativi scarti) e poi impiegati nelle linee 51-52 (con relativi scarti)	388.493	Rappresenta la componente di HDPE dei tappi D26 3P (peso media 0,90 gr) prodotte dalla pressa 26 (con relativi scarti) e poi impiegati nelle linee 51-52 (con	-194.915,66	388.493	Rappresenta la componente di HDPE dei tappi D26 3P (peso media 0,90 gr) prodotte dalla pressa 23 e 24 (con relativi scarti) e poi impiegati nelle linee 51-52 (con	-194.915,7
	Masterbatch consumption	kg	1.467	Rappresenta la componente di MASTERBATCH dei tappi D28 3P (peso 1,30 gr) prodotte dalle presse 23-24-26 (con relativi scarti) e poi impiegati nelle linee 51-52 (con relativi scarti)	1.030	Rappresenta la componente di MASTERBATCH dei tappi D28 3P (peso 1,30 gr) prodotti dalla pressa 26 (con relativi scarti) e poi impiegati nelle linee 51-52 (con relativi scarti)	-436,65	1.030	Rappresenta la componente di MASTERBATCH dei tappi D28 3P (peso 1,30 gr) prodotti dalla pressa 26 (con relativi scarti) e poi impiegati nelle linee 51-52 (con relativi scarti)	-436,6
Auxiliary materials consumptions	Cardboard boxes for caps consumption	kg	22.078	Si stima che in una scatola ci stiano circa 6500 tappi, e che il fattore di riutilizzo di una scatola sia pari a 3 volte	15.945	Si stima che in una scatola ci stiano circa 9000 tappi, e che il fattore di riutilizzo di una scatola sia pari a 3 volte	-6.132,79	15.945	Si stima che in una scatola ci stiano circa 9000 tappi, e che il fattore di riutilizzo di una scatola sia pari a 3 volte	-6.132,8
	Wood pallet consumption	kg	1.587	Pallet tappi: Viene stimato che in un pallet ci stiano 16 scatole (4 strati da 4 scatole), e che il fattore di riutilizzo del pallet sia di circa 20 volte	1.146	Pallet tappi: Viene stimato che in un pallet ci stiano 16 scatole (4 strati da 4 scatole), e che il fattore di riutilizzo del pallet sia di circa 20 volte	-440,79	1.146	Pallet tappi: Viene stimato che in un pallet ci stiano 16 scatole (4 strati da 4 scatole), e che il fattore di riutilizzo del pallet sia di circa 20 volte	-440,8
Upstream raw materials transports	PET transport - truck	kg*km	280.358.179	Il trasporto dal fornitore fino allo stabilimento di Scorzè viene calcolato come prodotto tra la massa di PET (comprensiva di scarto) e i km medi ponderati in camion e in nave dai fornitori a Scorzè.	264.245.640	Il trasporto dal fornitore fino allo stabilimento di Scorzè viene calcolato come prodotto tra la massa di PET (comprensiva di scarto) e i km medi ponderati in camion e in nave dai fornitori a Scorzè.	-16.112.539,00	251.355.608	Il trasporto dal fornitore fino allo stabilimento di Scorzè viene calcolato come prodotto tra la massa di PET (comprensiva di scarto) e i km medi ponderati in camion e in nave dai fornitori a Scorzè.	-29.002.570,2
	PET transport - ship	kg*km	67.913.479.371		64.010.405.844		-3.903.073.527,07	60.887.947.022		-7.025.532.348,7
	RPET transport - truck	kg*km	411.536.845	Si considera il prodotto tra la massa di R-PET consumata e la distanza media ponderata dei fornitori allo stabilimento di Scorzè.	387.941.854	Si considera il prodotto tra la massa di R-PET consumata e la distanza media ponderata dei fornitori allo stabilimento di Scorzè.	-23.594.991,07	369.017.861	Si considera il prodotto tra la massa di R-PET consumata e la distanza media ponderata dei fornitori allo stabilimento di Scorzè.	-42.518.983,9
	RPET transport - ship	kg*km	0		0		0,00	0		0,0
	HDPE transport - truck	kg*km	389.728.884	Il trasporto dal fornitore fino allo stabilimento di Pessano viene calcolato come prodotto tra la massa di HDPE e i km medi ponderati in camion e in nave dei fornitori	259.521.324	Il trasporto dal fornitore fino allo stabilimento di Pessano viene calcolato come prodotto tra la massa di HDPE e i km medi ponderati in camion e in nave dei fornitori	-130.207.560,20	259.521.324	Il trasporto dal fornitore fino allo stabilimento di Pessano viene calcolato come prodotto tra la massa di HDPE e i km medi ponderati in camion e in nave dei fornitori	-130.207.560,3
	HDPE transport - ship	kg*km	54.122.854		36.040.528		-18.082.325,83	36.040.528		-18.082.325,9
	Masterbatch transport - truck	kg*km	238.934	Si considera la massa di MASTERBATCH consumata e i km medi ponderati dei fornitori	167.815	Si considera la massa di MASTERBATCH consumata e i km medi ponderati dei fornitori	-71.119,19	167.815	Si considera la massa di MASTERBATCH consumata e i km medi ponderati dei fornitori	-71.119,2
	Cardboard boxes for caps transport - truck	kg*km	772.731	Si considera il consumo di scatole per la distanza dal relativo fornitore	558.084	Si considera il consumo di scatole per la distanza dal relativo fornitore	-214.647,61	558.084	Si considera il consumo di scatole per la distanza dal relativo fornitore	-214.647,6
	Wood pallet transport - truck	kg*km	388.780	Si considera la massa consumata di pallet per la distanza dal relativo fornitore	280.786	Si considera la massa consumata di pallet per la distanza dal relativo fornitore	-107.994,50	280.786	Si considera la massa consumata di pallet per la distanza dal relativo fornitore	-107.994,6
	Caps transport from Paese to Scorze	kg*km	8.170.056	La massa trasportata è pari alla massa dei tappi (compresa di scarto linee) con le relative scatole e con i relativi pallets	5.461.572	La massa trasportata è pari alla massa dei tappi (compresa di scarto linee) con le relative scatole e con i relativi pallets	-2.708.483,24	5.461.572	La massa trasportata è pari alla massa dei tappi (compresa di scarto linee) con le relative scatole e con i relativi pallets	-2.708.483,2
Delivery transports	Product delivery transport - truck	kg*km	56.870.225.216	Risulta dalla massa trasportata in un camion (considerando 33 pallet in un autotreno) per i km medi ponderati in camion, treno e nave.	56.769.063.236	Risulta dalla massa trasportata in un camion (considerando 33 pallet in un autotreno) per i km medi ponderati in camion, treno e nave.	-101.161.980,40	56.726.912.496	Risulta dalla massa trasportata in un camion (considerando 33 pallet in un autotreno) per i km medi ponderati in camion, treno e nave.	-143.312.720,6
	Product delivery transport - ship	kg*km	50.189.426.121		50.100.148.142		-89.277.979,25	50.062.948.985		-126.477.135,9
	Product delivery transport - train	kg*km	4.388.492.552		4.380.686.211		-7.806.340,36	4.377.433.569		-11.058.982,2
Wastes	Product End of Life	kg	4.291.667	Si considera la massa della bottiglia e dei tappi, post consumo.	3.885.700	Si considera la massa della bottiglia e dei tappi, post consumo.	-405.967,30	3.714.900	Si considera la massa della bottiglia e dei tappi, post consumo.	-576.767,4
	Plastic waste (Production site)	kg	42.180	Vengono considerati gli scarti delle presse (per HDPE e MASTER), quelli delle macchine SIPA e delle linee di imbottigliamento (sia per PET, R-PET, HDPE e MASTERBATCH)	37.310	Vengono considerati gli scarti delle presse (per HDPE e MASTER), quelli delle macchine SIPA e delle linee di imbottigliamento (sia per PET, R-PET, HDPE e MASTERBATCH)	-4.870,02	35.747	Vengono considerati gli scarti delle presse (per HDPE e MASTER), quelli delle macchine SIPA e delle linee di imbottigliamento (sia per PET, R-PET, HDPE e MASTERBATCH)	-6.433,4
	Paper waste (Production site)	kg	22.078	Pari alla massa delle scatole per tappi	15.945	Pari alla massa delle scatole per tappi	-6.132,79	15.945	Pari alla massa delle scatole per tappi	-6.132,8
	Wood waste (Production site)	kg	1.587	Pari alla massa dei pallets	1.146	Pari alla massa dei pallets	-440,79	1.146	Pari alla massa dei pallets	-440,8

PERFORMANCE COMPARATOR | IMPACTS CALCULATOR | INVENTORY CALCULATOR | SIMULATION DATA LOGGER

Figure 135 Eco-DSD Inventory Calculator component

			Starting design			Alternative 1				Alternative 2			
	Life cycle aspects	Measure unit	Inventory data calculated	Emission factor (kg CO2 eq/ udm)	Unit cost (€/udm)	Inventory data calculated	Consumption variation (Alternative 1 - Starting design)	Emission factor (kg CO2 eq/ udm)	Unit cost (€/udm)	Inventory data calculated	Consumption variation (Alternative 1 - Starting design)	Emission factor (kg CO2 eq/ udm)	Unit cost (€/udm)
ENERGY	Electricity medium voltage - Scorze	kWh	4599723	0,52579	Confidential data	4312802	-286921	0,52579	Confidential data	4218703	-381020	0,52579	Confidential data
	Metano	Sm3	0	2,83614		0	0	2,83614		0	0	2,83614	
RAW MATERIALS	PET consumption	kg	3373745	3,28009		3179851	-193893	3,28009		3024737	-349008	3,28009	
	RPET consumption	kg	374861	0,81372		353317	-21544	0,81372		336082	-38779	0,81372	
	HDPE consumption	kg	583409	2,10300		388493	-194916	2,10300		388493	-194916	2,10300	
	Masterbatch consumption	kg	1467	2,28215		1030	-437	2,28215		1030	-437	2,28215	
	Shrink film consumption	kg	0	2,23131		0	0	2,23131		0	0	2,23131	
	Stretch film consumption	kg	0	1,97550		0	0	1,97550		0	0	1,97550	
	0	0	0	0,00000		0	0	0,00000		0	0	0,00000	
	0	0	0	0,00000		0	0	0,00000		0	0	0,00000	
	0	0	0	0,00000		0	0	0,00000		0	0	0,00000	
CHEMICALS	0	0	0	0,00000		0	0	0,00000		0	0	0,00000	
	0	0	0	0,00000		0	0	0,00000		0	0	0,00000	
	0	0	0	0,00000		0	0	0,00000		0	0	0,00000	
	0	0	0	0,00000		0	0	0,00000		0	0	0,00000	
AUXILIARY MATERIALS	Cardboard Octabin for preforms transport	kg	0	1,33418		0	0	1,33418		0	0	1,33418	
	Cardboard boxes for caps consumption	kg	22078	1,33418		15945	-6133	1,33418		15945	-6133	1,33418	
	Wood pallet consumption	kg	1587	0,02431		1146	-441	0,02431		1146	-441	0,02431	
UPSTREAM RAW MATERIALS TRANSPORTS	PET transport - truck	kg*km	280358179	0,00017		264245640	-16112539	0,00017		251355608	-29002570	0,00017	
	PET transport - ship	kg*km	67913479371	0,00001		64010405844	-3903073527	0,00001		60887947022	-7025532349	0,00001	
	RPET transport - truck	kg*km	411596845	0,00017		387941854	-23654991	0,00017		369017861	-42578984	0,00017	
	RPET transport - ship	kg*km	0	0,00001		0	0	0,00001		0	0	0,00001	
	HDPE transport - truck	kg*km	389728884	0,00017		259521324	-130207560	0,00017		259521324	-130207560	0,00017	
	HDPE transport - ship	kg*km	54122854	0,00001		36040528	-18082326	0,00001		36040528	-18082326	0,00001	
	Masterbatch transport - truck	kg*km	238934	0,00017		167815	-71119	0,00017		167815	-71119	0,00017	
	Trasporto film termoretraibile camion	kg*km	0	0,00017		0	0	0,00017		0	0	0,00017	
	Trasporto film estensibile camion	kg*km	0	0,00017		0	0	0,00017		0	0	0,00017	
	Trasporto octabin per preforme camion	kg*km	0	0,00017		0	0	0,00017		0	0	0,00017	
	Cardoboard boxes for caps transport - truck	kg*km	772731	0,00017		558084	-214648	0,00017		558084	-214648	0,00017	
	Wood pallet transport - truck	kg*km	388780	0,00017		280786	-107995	0,00017		280786	-107995	0,00017	
	Caps transport from Paese to Scorze	kg*km	8170056	0,00017		5461572	-2708483	0,00017		5461572	-2708483	0,00017	
DELIVERY TRANSPORTS	Product delivery transport - truck	kg*km	56870225216	0,00008		56769063296	-101161920	0,00008		56726912496	-143312721	0,00008	
	Product delivery transport - ship	kg*km	50189426121	0,00001		50100148142	-89277978	0,00001		50062948985	-126477136	0,00001	
	Product delivery transport - train	kg*km	4388492552	0,00005		4380686211	-7806340	0,00005		4377433569	-11058982	0,00005	
WASTES	Product End of Life	kg	4291667	0,75100		3885700	-405967	0,75100		3714900	-576767	0,75100	
	Plastic waste (Production site)	kg	42180	0,07450		37310	-4871	0,07450		35747	-6433	0,07450	
	Paper waste (Production site)	kg	22078	0,02710		15945	-6133	0,02710		15945	-6133	0,02710	
	Wood waste (Production site)	kg	1587	0,05510		1146	-441	0,05510		1146	-441	0,05510	
	0	0	0	0,00000		0	0	0,00000		0	0	0,00000	
	0	0	0	0,00000		0	0	0,00000		0	0	0,00000	

PERFORMANCE COMPARATOR | IMPACTS CALCULATOR | INVENTORY CALCULATOR | SIMULATION DATA LOGGER

Figure 136 Eco-DSD Impacts Calculator component part 1

	ENVIRONMENTAL IMPACT CALCULATOR					ECONOMIC SAVING CALCULATION				
	Starting design	Alternative 1		Alternative 2		Starting design	Alternative 1		Alternative 2	
Life cyle aspects	Starting desing Environmental impact	Alternative 1 Environmental impact	Alternativa 1 Environmental impact saved	Alternative 2 Environmental impact	Alternativa 2 Environmental impact saved	Starting design Economic cost	Alternative 1 Economic cost	Alternative 1 Economic saving	Alternative 2 Economic cost	Alternative 2 Economic saving
ENERGY	2.418.488	2.267.628	150.860	2.218.152	200.336					
	0	0	0	0	0					
RAW MATERIALS	11.066.186	10.430.198	635.988	9.921.408	1.144.778					
	305.031	287.501	17.531	273.477	31.555					
	1.226.909	817.002	409.908	817.002	409.908					
	3.348	2.351	996	2.351	996					
	0	0	0	0	0					
	0	0	0	0	0					
	0	0	0	0	0					
	0	0	0	0	0					
	0	0	0	0	0					
CHEMICALS	0	0	0	0	0					
	0	0	0	0	0					
	0	0	0	0	0					
	0	0	0	0	0					
AUXILIARY MATERIALS	0	0	0	0	0					
	29.456	21.274	8.182	21.274	8.182					
	39	28	11	28	11					
UPSTREAM RAW MATERIALS TRANSPORTS	47.499	44.770	2.730	42.586	4.914					
	784.181	739.113	45.068	703.059	81.122					
	69.735	65.727	4.008	62.521	7.214					
	0	0	0	0	0					
	66.030	43.969	22.060	43.969	22.060					
	625	416	209	416	209					
	40	28	12	28	12					
	0	0	0	0	0					
	0	0	0	0	0					
	0	0	0	0	0					
	131	95	36	95	36					
	66	48	18	48	18					
	1.384	925	459	925	459					
DELIVERY TRANSPORTS	4.810.115	4.801.558	8.556	4.797.993	12.121					
	579.525	578.494	1.031	578.065	1.460					
	219.425	219.034	390	218.872	553					
WASTES	3.223.042	2.918.161	304.882	2.789.890	433.152					
	3.142	2.780	363	2.663	479					
	598	432	166	432	166					
	87	63	24	63	24					
	0	0	0	0	0					
	0	0	0	0	0					
TOTAL	24.855.083	23.241.595	1.613.488	22.495.315	2.359.768					

Confidential data

ENVIRONMENTAL PAYBACK INDICATORS	Udm	ALTERNATIVE 1	ALTERNATIVE 2
Carbon Footprint Pay Back	-	*15,4*	*10,5*

PERFORMANCE COMPARATOR | **IMPACTS CALCULATOR** | INVENTORY CALCULATOR | SIMULATION DATA LOGGER

Figure 137 Eco-DSD Impacts Calculator component part 2

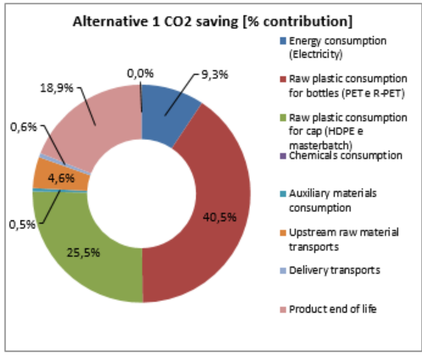
Eco-DSD tool release version: v4.1
Released by: Team Eco-Sostenibilità

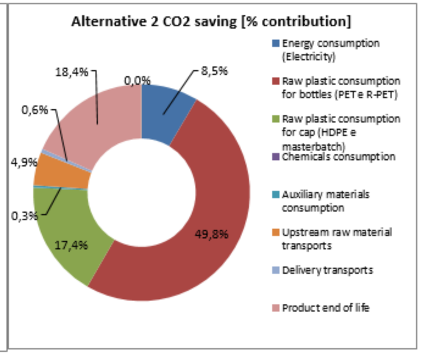
Project title	**Bottle + cap weight reduction - Mineral Still Water 0,5L Products**
Starting design	Bottle 0,5L (8,7 g) + Cap D28 (1,36 g)
EcoDesign alternative 1	Bottle 0,5L (8,2 g) + Cap D28 (0,90 g)
EcoDesign alternative 2	Bottle 0,5L (7,8 g) + Cap D28 (0,90 g)

FUNCTIONAL UNIT	bottles/year	427.000.000	Production budget

Selected environmetnal impact categories: Climate change
Summary of potential environmental saving:

Alternative 1	**1.613.488** **6,5%**	**kg CO2 eq/FU**
Alternative 2	**2.359.768** **9,5%**	**kg CO2 eq/FU**



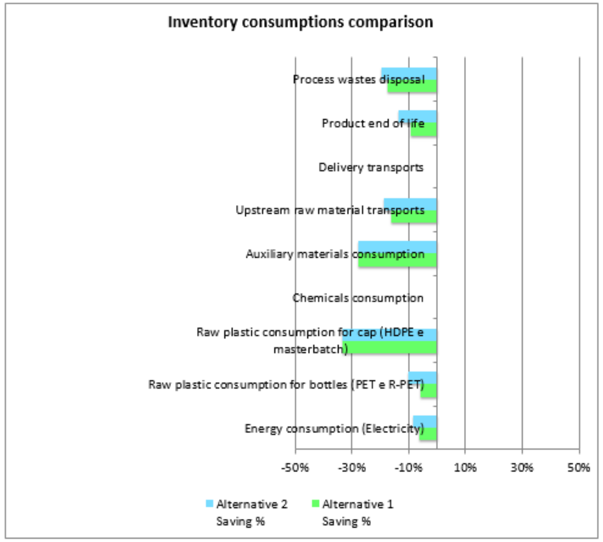


Environmental impact savings

Life cycle aspects	Alternative 1 CO2 eq saving [kg CO2 eq]	Alternative 1 CO2 eq saving [% contribution]	Alternative 2 CO2 eq saving [kg CO2 eq]	Alternative 2 CO2 eq saving [% contribution]
Energy consumption (Electricity)	150.860	9,35%	200.336	8,49%
Raw plastic consumption for bottles (PET e R-PET)	653.518	40,50%	1.176.333	49,85%
Raw plastic consumption for cap (HDPE e masterbatc	410.904	25,47%	410.904	17,41%
Chemicals consumption	0	0,00%	0	0,00%
Auxiliary materials consumption	8.193	0,51%	8.193	0,35%
Upstream raw material transports	74.600	4,62%	116.045	4,92%
Delivery transports	9.978	0,62%	14.135	0,60%
Product end of life	304.882	18,90%	433.152	18,36%
Process wastes disposal	553	0,03%	670	0,03%
TOTAL	1.613.488	100,00%	2.359.768	100,00%

Inventory consumption savings

Life cycle aspects	Udm	Starting design	Alternative 1	Alternative 1 Saving %	Alternative 2	Alternative 2 Saving %
Energy consumption (Electricity)	kWh/UF	4.599.723	4.312.802	-6,2%	4.218.703	-8,3%
Raw plastic consumption for bottles (PET e R-PET)	kg/UF	3.748.605	3.533.168	-5,7%	3.360.818	-10,3%
Raw plastic consumption for cap (HDPE e masterbatc	kg/UF	584.876	389.524	-33,4%	389.524	-33,4%
Chemicals consumption	kg/UF	0	0	0,0%	0	0,0%
Auxiliary materials consumption	kg/UF	23.665	17.091	-27,8%	17.091	-27,8%
Upstream raw material transports	n° trucks/UF	294	247	-16,1%	239	-18,7%
Delivery transports	n° trucks/UF	9.356	9.356	0,0%	9.356	0,0%
Product end of life	kg/UF	4.291.667	3.885.700	-9,5%	3.714.900	-13,4%
Process wastes disposal	kg/UF	65.845	54.401	-17,4%	52.838	-19,8%



Economic savings

Life cycle aspects	Alternative 1 economic saving (€)	Alternative 2 economic saving (€)
Energy consumption (Electricity)	Confidential data	
Raw plastic consumption for bottles (PET e R-PET)		
Raw plastic consumption for cap (HDPE e masterbatc		
Chemicals consumption		
Auxiliary materials consumption		
Upstream raw material transports		
Delivery transports		
Product end of life		
Process wastes disposal		
TOTAL		

PERFORMANCE COMPARATOR | IMPACTS CALCULATOR | INVENTORY CALCULATOR | SIMULATION DATA LOGGER

Figure 138 Eco-DSD Performance Comparator component – Lightning of 0,5L bottle and cap San Benedetto Still Mineral Water

Once the data are feed to the “Simulation data logger”, in this space, the data can be re-elaborated. In the “Inventory Calculator” component of Eco-DSD on the base of the data elaborated in “Simulation data logger”, all the inventory results are calculated for every flow and life cycle process included in the system boundaries. The inventory data are scaled with reference to the functional unit defined and therefore a variation of functional unit determines an automatic reescalation of the results. In the “Impacts calculator” component the environmental impacts are calculated automatically. Specific emission factors are acquired by ERD for all flows and life cycle processes considered. In function of the environmental impact category selected the relative emission factors are feed to Eco-DSD for the calculation of specific environmental impacts. The organization in order to improve the comprehensibility has chosen to show one impact category at a time and to switch with a command to other impact categories in function of needs. A version of Eco-DSD with three categories in the same time has been however elaborated. The same functional concept is applied for the calculation of economic costs, where the unitary economic costs are acquired by a database elaborated specifically.
The “Performance comparator” is the last component of Eco-DSD where the results are summarized. Three types of results are shown:

- Environmental impact savings: in this case the design alternative 1 permits to save 1.613.488 kg CO2 eq while the alternative 2.359.768. The diagram on the left permits to quickly see the aspects that contributes more to the saving. In this case, on the average, the 45% of the saving is associated to reduction of PET consumption for bottles production, 22% to the reduction of HDPE consumption for caps production, the 9% to the reduction of electricity consumption, the 18% to the reduction of end of life wastes, the 5% to the reduction of cap transport and transports of other raw materials, while the other processes do not have relevant contributions to the saving.
- Inventory consumption savings: in the case of the most important flows and life cycle processes the saving of resources are highlighted. In this case the design alternative 2 permits the saving of 381.020 kWh of electricity, of 387.787 kg of PET and RPET, 195.352 kg of HDPE and for example to save 55 trucks to transport caps.
- Economic saving: in this part the organization can assess the improvement in terms of economic performance. It is a very important aspect to support the integration in the decision making process of economic and environmental performance. As previously declared, for policy and confidentiality reasons of the organization the economic results have been not shown.

The results obtained can be interpreted also with a multiscale assessment perspective. In fact, the effects of the project, according with MLCA model introducing by OES2 method, can be assessed at organizational and product level. The total saving of the project equal to 2.359.768 kg CO2 eq in the case of the design alternative 2 with a functional unit of 427.000.000 of bottles of 0,5L is equal to a:

- -0,0055 kg CO2/bottle and therefore considering for example the environmental performance of 0,5L EcoGreen returned by MLCA model and stored in the ERD (table 46, COD1750) equal to 0,0896 kg CO2 eq/bottle, this saving generates a potential improvement of the product performance of -6,3%.
- Instead at level of the San Benedetto PET Italian Mineral Water Sub Division, that has a total emission equal to 184.230 t CO2 eq, this saving generates a potential improvement of the Sub Division performance of -1,3%.

Finally, the project has a carbon footprint payback value of 10,5, it significates that every 10,5 functional units produced with the new design specific the GHG emissions of the production of one functional unit is neutralized by the saving.

3.4.1.2. Organizational ecodesign

3.4.1.2.1. Goal and scope

The goal of the project is to assess the potential environmental saving in terms of GHG emissions due to the acquisition of a new site (Viggianello) located in the south of Italy. The Viggianello site is located in a strategic area to serve the Italian regions of Sicilia, Calabria, Basilicata, Puglia and Campania. The acquisition has been assessed in order to delocalize a part of the production of Scorzè site to improve the level of service in the south of Italy and reduce the environmental impacts related to products transport. In the following table have been shown the starting design parameters and the parameters related to the two design alternatives assessed.

	Description
Starting design	All water products, 1,5L and 2,0L considered, are produced in the site of Scorze
First ecodesign alternative	The production of 21.484.700 L of water products, 1,5L and 2,0L, is transferred from the site of Scorzè to the new site of Viggianello
Second design alternative	The production of 89.118.100 L of water products, 1,5L and 2,0L, is transferred from the site of Scorzè to the new site of Viggianello

Table 59 Starting design and new ecodesign alternatives assessed.

The assessment is intended to assist the organization to identify the potential environmental and economic savings related to the acquisition of a new productive site in Viggianello in order to delocalize a part of the production currently produced from Scorzè site and destined to the market of south Italy. The products involved are of formats 1,5L and 2L and at level of the last format also EcoGreen 2L is involved.

The Functional Unit (FU) was identified as the total volume delocalized from the Scorzè site to the Viggianello site. Two different functional units have been used for the two different ecodesign alternatives assessed: 21.484.700 litres/year for the first alternative and 89.118.100 litres/year for the second alternative.

The **system boundaries** include all pertinent processes to the ecodesign project that are indented as all the processes that undergoes a variation as effect of the ecodesign project. The life cycle processes are:

- Transport of all materials for products production: Primary packaging materials (PET, RPET, preforms, labels, caps) secondary packaging materials (shrink film, paper handle, adhesive for paper handle) tertiary packaging materials (pallet, stretch film, cardboard interlayer, pallet label). The distances have been characterized in function of the two production sites;
- Transport for all auxiliary materials such as chemicals and wastes;
- Transport for the delivery of products. Specific distances have been calculated using the EID_SB_Downstream_mapping in the case of Scorzè site while in the case of Viggianello site the distances have been assessed considering the same delivery provinces in the south Italy.

The environmental impacts of climate change have been assessed using the IPCC 2013 GWP 100a v 1.00 (IPCC, 2016). A cut off of 5% has been used.

The ecodesign assessment has been performed using the Eco-DSD.

Considering the relevance of this project, the results have been certified by third in 2015 (CSQA certification body accredited by ACCREDIA)

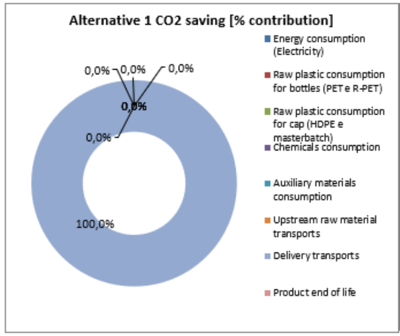
Eco-DSD tool release version: v4.1
Released by: Team Eco-Sostenibilità

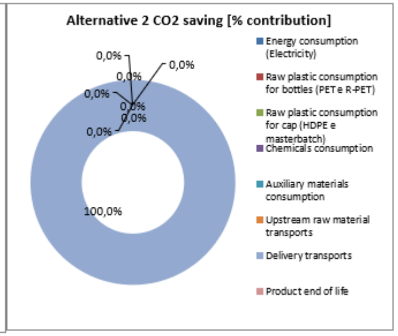
Project title	**Acquisition of the new site (Viggianello) in the south Italy**
Starting design	All water products, 1,5L and 2,0L considered, are produced in the site of Scorze
EcoDesign alternative 1	The production of 21.484.700 L of water products, 1,5L and 2,0L, is transferred from the site of Scorzè to the new site of Viggianello
EcoDesign alternative 2	The production of 89.118.100 L of water products, 1,5L and 2,0L, is transferred from the site of Scorzè to the new site of Viggianello

FUNCTIONAL UNIT	litres/year	21.484.700 and 89.118.100	Production budget

Selected environmetnal impact categories: Climate change
Summary of potential environmental saving:

Alternative 1	1.378.600 55,9%	kg CO2 eq/FU
Alternative 2	5.216.700 54,8%	kg CO2 eq/FU



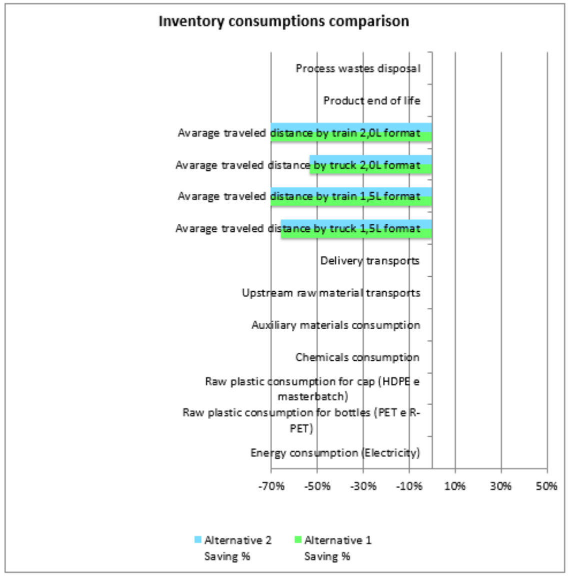


Environmental impact savings

Life cycle aspects	Alternative 1 CO2 eq saving [kg CO2 eq]	Alternative 1 CO2 eq saving [% contribution]	Alternative 2 CO2 eq saving [kg CO2 eq]	Alternative 2 CO2 eq saving [% contribution]
Energy consumption (Electricity)		0,00%		0,00%
Raw plastic consumption for bottles (PET e R-PET)		0,00%		0,00%
Raw plastic consumption for cap (HDPE e masterbatch)		0,00%		0,00%
Chemicals consumption		0,00%		0,00%
Auxiliary materials consumption		0,00%		0,00%
Upstream raw material transports	-116.600	0,00%	-449.600	0,00%
Delivery transports	1.495.200	100,00%	5.666.300	100,00%
Product end of life		0,00%		0,00%
Process wastes disposal		0,00%		0,00%
TOTAL	1.378.600	100,00%	5.216.700	100,00%

Inventory consumption savings

Life cycle aspects	Udm	Starting design	Alternative 1	Alternative 1 Saving %	Alternative 2	Alternative 2 Saving %
Energy consumption (Electricity)	kWh/UF			0,0%		0,0%
Raw plastic consumption for bottles (PET e R-PET)	kg/UF			0,0%		0,0%
Raw plastic consumption for cap (HDPE e masterbatc	kg/UF			0,0%		0,0%
Chemicals consumption	kg/UF			0,0%		0,0%
Auxiliary materials consumption	kg/UF			0,0%		0,0%
Upstream raw material transports	n° trucks/UF	20,4	20,4	0,0%	20,4	0,0%
Delivery transports	n° trucks/UF	1.478	1.478	0,0%	1.478	0,0%
Avarage traveled distance by truck 1,5L format	km/travel	709	241	-66,0%	241	-66,0%
Avarage traveled distance by train 1,5L format	km/travel	424	0	-100,0%	0	-100,0%
Avarage traveled distance by truck 2,0L format	km/travel	652	304	-53,4%	304	-53,4%
Avarage traveled distance by train 2,0L format	km/travel	125	0	-100,0%	0	-100,0%
Product end of life	kg/UF			0,0%		0,0%
Process wastes disposal	kg/UF			0,0%		0,0%



Economic savings

Life cycle aspects	Alternative 1 economic saving (€)	Alternative 2 economic saving (€)
Energy consumption (Electricity)	Confidential data	
Raw plastic consumption for bottles (PET e R-PET)		
Raw plastic consumption for cap (HDPE e masterbatc		
Chemicals consumption		
Auxiliary materials consumption		
Upstream raw material transports		
Delivery transports		
Product end of life		
Process wastes disposal		
TOTAL		

PERFORMANCE COMPARATOR | IMPACTS CALCULATOR | INVENTORY CALCULATOR | SIMULATION DATA LOGGER

Figure 139 Eco-DSD Performance Comparator component – Acquisition of the new site of Viggianello and delocalization of production

3.4.1.2.2. Inventory analysis, impact assessment and results interpretation

The results at inventory level show a consistent reduction of the distances travelled by products, on the average, at level of the format of 1,5L the distance travelled passes from 709 km by truck plus 424 km by train (Scorzè site) to 241 km by truck (Viggianello site). In the case of the format 2L, on the average, the distance travelled by products passes from 652 km by truck plus 125 km by train (Scorzè site) to 304 km by truck (Viggianello site). Therefore, in the first case a reduction of -66% of distances travelled by truck has been observed while in the second case has been observed a reduction of -53,4%. Obliviously in both cases the number of trucks is the same. Focusing on the second design alternative, the results show as the environmental impacts at level of raw material acquisition has growth of -449,6 t CO2 eq. It is due to the increasing of the transport distances travelled by packaging components, especially by PET. In fact, the PET must be transfer to the transformers that produce the preforms that are used from the Viggianello site. From the other side, the consistent reduction of the distances travelled by truck and the avoiding distances travelled by train for the products delivery, permit to the Viggianello site to generate a relevant reduction of GHG emissions. In fact, in this case the saving of GHG emissions is equal to 5.666,3 t CO2 eq. Globally the balance is positive and the saving in the case of the second eco design alternative is equal to 5.216,7 t CO2 eq (reduction of -54,8%).

The results obtained can be interpreted also with a multiscale assessment perspective. The total saving of the project equal to 5.216.700 kg CO2 eq in the case of the design alternative 2 with a functional unit of 89.118.100 of litres/year is equal to a:

- -0,058 kg CO2/litre and in this case this saving has generated an improvement of the performance of the product delivered about of -6,0% (EcoGreen 2L).
- Instead at level of the San Benedetto PET Italian Mineral Water Sub Division, that has a total emission equal to 184.230 t CO2 eq, this saving generates a potential improvement of the Sub Division performance of -2,8%.

Finally, the project has a carbon footprint payback value of 1,2, it significates that after every 1,2 functional units is delocalized the GHG emissions of the transport of one functional unit is neutralized by the saving.

3.4.1.3. Process ecodesign

3.4.1.3.1. Goal and scope

The goal of the project is the design of a new bottling line that will be introduced in the site of Viggianello that actually presents only one productive line. In the present study the new line has designed to produce San Benedetto Still Mineral Water in the format 2L. The line has been designed in order to have improvement characteristics respect to the line 1. In the following table have been shown the starting design parameters and the parameters related to the design alternative assessed.

	Bottling line specification
Starting design	Bottling line 1 (works with bottle 2L 26,7g and caps 1,4g)
First ecodesign alternative	Bottling line 1 (works with bottle 2L 26,7g and caps 0,9g)

Table 60 Starting design and new ecodesign alternatives assessed.

As shown in the previously table the new line has been designed to be able to works with lighting bottles and caps. Furthermore, the line 2 has been assembled with energy saving components and therefore should has better energy performance respect to line 1.

Therefore, the assessment is intended to assist the organization to identify the potential environmental and economic savings related to the installation of a new bottling line in the site of Viggianello in order to realized product 2L with improved characteristics. In this case, considering the curve shown in figure 133, the contribution of the bottling line is higher because it includes also the possibility to works with lightened bottles and caps. Therefore, the contribution of bottling lines increases to 25% while the contribution of bottle design and production and of the cap design decrease respectively to 51% and 4%. The products involved are of format 2L and also EcoGreen 2L is involved.

The **Functional Unit (FU)** was identified as the annual budgeted production equal to 72.261.456 bottles/year.

The **system boundaries** include all pertinent processes to the ecodesign project that are indented as all the processes that undergoes a variation as effect of the ecodesign project. The life cycle processes are:

- PET and RPET plastic consumption for bottle production including also the transport from the suppliers. In the case of Viggianello site, the PET and RPET has been transported to the transformer for the production of preforms. After, the preforms have been transported to the Viggianello site;
- HDPE plastic consumption for cap production including also the transport from the suppliers;
- Masterbatch consumption for cap production including also the transport from the suppliers;
- Process of preforms production realized by the transformers;
- Electricity consumption for bottle and cap production;
- Cardboard boxes consumption for cap transport;
- Pallet consumption for cap transport;
- Transport process of the caps from the production site located in Paese (TV) to the bottling site located in Viggianello (PZ);
- End of life wastes. The bottle weight reduction and the cap weight reduction permit to reduce the waste generated in end of life stage.

The environmental impacts of climate change have been assessed using the IPCC 2013 GWP 100a v 1.00 (IPCC, 2016). A cut off of 5% has been used.

The ecodesign assessment has been performed using the Eco-DSD.

3.4.1.3.2. Inventory analysis, impact assessment and results interpretation

The results at inventory results shown as the new line being designed for work with lightened bottles and caps permits respect to line 1 respectively to avoid the consumption of 142.926 kg of PET and RPET (reduction -7%), and 30.341 kg of HDPE (reduction of -31%). The new line shows better energy performance at level of the blow moulding machine for the bottles production and also at level of the bottling line. Globally an energy saving of 220.352 kWh has been obtained (reduction of -19%). In terms of environmental performance on climate change, the new line permits a total saving of 1.864 t CO_2eq about 90% of them are due to plastic consumption reduction for bottle production, 6% to energy saving and about 3% to reduction of plastic consumption for caps production. At product level, the new line permits to save 0,025 kg CO_2/bottle generating a potential improvement of the performance of the product about of -9,2% (EcoGreen 2L). Instead, at level of the San Benedetto PET Italian Mineral Water Sub Division, the project can generate a potential improvement of the Sub Division performance of -1,0%. The project shows a carbon footprint payback of 3,5.

Eco-DSD tool release version: v4.1
Released by: Team Eco-Sostenibilità

Project title	**Installation of a new bottling line in the Viggianello site**
Starting design	Bottling Line 1 produces water products 2,0 L (specifications: bottle weight 26,7 g + caps 1,30 g)
EcoDesign alternative 1	Bottling Line 2 produces water products 2,0 L (specifications: bottle weight 25,0 g + caps 0,90 g)

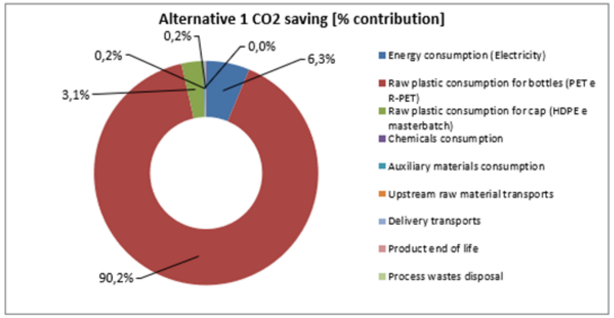
FUNCTIONAL UNIT	bottles/yeat	72.261.456	Production budget

Selected environmetnal impact categories: Climate change
Summary of potential environmental saving:

Alternative 1	**1.864.109**	kg CO2 eq/FU
	22,27%	saving CO2eq %

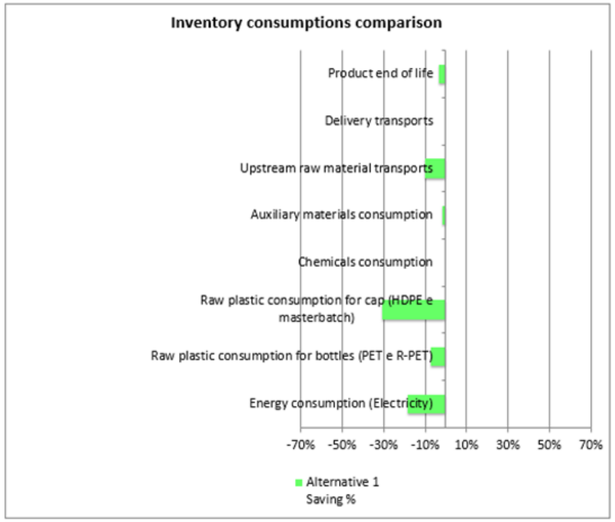
Environmental impact savings

Life cycle aspects	Alternative 1 CO2 eq saving [kg CO2 eq]	Alternative 1 CO2 eq saving [% contribution]
Energy consumption (Electricity)	128.080	6,28%
Raw plastic consumption for bottles (PET e R-PET)	1.838.937	90,17%
Raw plastic consumption for cap (HDPE e masterbatch)	63.818	3,13%
Chemicals consumption	0	0,00%
Auxiliary materials consumption	4.120	0,20%
Upstream raw material transports	-175.390	0,00%
Delivery transports	0	0,00%
Product end of life	4.461	0,22%
Process wastes disposal	84	0,00%
TOTALE	**1.864.109**	100,00%



Inventory consumption savings

Life cycle aspects	Udm	Starting design	Alternative 1	Alternative 1 Saving %
Energy consumption (Electricity)	kWh/UF	1.180.790	960.438	-19%
Raw plastic consumption for bottles (PET e R-PET)	kg/UF	2.020.132	1.877.206	-7%
Raw plastic consumption for cap (HDPE e masterbatch)	kg/UF	98.230	67.890	-31%
Chemicals consumption	kg/UF	0	0	0%
Auxiliary materials consumption	kg/UF	193.355	190.267	-2%
Upstream raw material transports	n° trucks/UF	368	331	-10%
Delivery transports	n° trucks/UF	240	240	0%
Product end of life	kg/UF	284.107	275.079	-3%



Economic savings

Life cycle aspects	Alternative 1 economic saving (€)
Energy consumption (Electricity)	Confidential
Raw plastic consumption for bottles (PET e R-PET)	
Raw plastic consumption for cap (HDPE e masterbatch)	
Chemicals consumption	
Auxiliary materials consumption	
Upstream raw material transports	
Delivery transports	
Product end of life	
Process wastes disposal	
TOTAL	

PERFORMANCE COMPARATOR | IMPACTS CALCULATOR | INVENTORY CALCULATOR | SIMULATION DATA LOGGER

Figure 140 Eco-DSD Performance Comparator component – Installation of a new bottling line in the Viggianello site (Line 2)

3.5. TEST 4: Application of OES2 method to criticalities on environmental management areas (4) - Part EcoEfficiency

This test has the objective to assess the capacity of OES2 method to face the gaps on life cycle management related to criticalities on ecoefficiency assessment

Life Cycle Management Critical Areas	Identified gaps
4. Ecoinnovation criticalities	13. Lack of indicators for ecoefficiency assessment

Table 61 Identified gaps on ecoinnovation – Part Ecoefficiency, faced by OES2 method in the test 4.

In order to face these gaps OES2 method applies:

- One EMT: ISO 140045 for ecoefficiency assessment;
- One STEM: IWEE (Indicator of Work Environmental Efficiency).

The OES2 method supports the implementation of ecoefficiency according to ISO14045 that in the present test has been applied to bottling processes. Therefore, in this case the ecoefficiency assessment has had only internal purposes. The system boundaries considered, includes all flows of resources consumed by the bottling line in order to produce 1000 litres of water or drink packed that are: electricity, thermal energy, chemicals, water, raw material scraps. Therefore, the functional value selected has been defined as the reference performance in terms of resource consumption generated by the bottling line to pack a volume of 1000 litres of water or drink. In order to simplify the comprehensibility, the assessment has been conducted at inventory level. This choice is according to ISO14045 that allows to conduct ecoefficiency assessment on the base of life cycle inventory results. The ecoefficiency indicator has been defined as the ratio between the functional value to the performance in terms of resource consumption generated by the bottling line to pack a volume of 1000 litres of water or drink. In this context, the IWEE introduced by OES2, according with methodology shown in the chapter 2, permits to combine the ecoefficiency assessments related to energy, chemicals, water and raw materials consumptions. Although the assessment has been conducted for all twenty bottling lines located in the Scorzè site, the results focus only on the eight bottling lines that produce mineral water products.

3.5.1. Process ecoefficiency assessment using IWEE

The ecoefficiency assessment has been conducted weekly. Regarding energy consumptions have been collected data for every bottling line on weekly electricity consumption and thermal energy consumption. Regarding chemicals, the specific chemicals and water consumptions have been characterized, in the case of every bottling line, for the most relevant hygienic treatments that are: alkaline CIP, acid CIP, COP, filling of circuit of the rinsing machine, filling of bowl of the rinsing machine. These consumptions could vary for every bottling line in function of technical characteristics of the bottling line. The weekly occurrence frequency has been registered for every hygienic treatment in order to assess the total chemical consumptions. Finally, related to raw material scraps, the average weekly percentage value has been assessed for every bottling line. In table 62 has been shown an example of the collected data, the example it is referred to the bottling line L53. Considering the volume of water bottled by every bottling line have been calculated the performance in terms of resource consumption to packed 1000 litres of water. As reference performance have been considered the values defined by the organizations as performance targets that for example for the bottling line L53 are: 2,59 kWh/1000 litres for electricity consumption performance, 0,29 Sm^3/1000 litres for thermal energy consumption, the correct frequency for each hygienic treatment considering production aspects (set in the washing matrices); a percentage equal to 0,74% for the raw materials scraps.

In the table 63 have been shown the results of the assessment of IWEE sub components. According to IWEE methodology, a single score for to evaluate the three areas have been obtained using an economic weighting rule (energy, hygienic treatments, scraps). On average, for bottling lines that produce water products, this rule considers respectively the following weights: 80% energy, 16% hygienic treatments and 4% raw materials scraps (mainly PET bottles). The weight coefficients have been assessed for every bottling line considering specific consumptions and cost. The IWEE results have been provided in terms of percentage score and in terms of ecoefficiency classes. In order to attribute the ecoefficiency class the following criteria has been used:

- IWEE value >92%: Class 1 (Best);
- 84% ≤ IWEE value ≤ 92%: Class 2;
- IWEE<84%: Class 3 (Worst).

The performance in terms of GHG emissions is also associated with the IWEE values (table 64).
The following tables shown with reference to the bottling line L53, that has been selected as example, the data collected and the elaboration to calculate IWEE according with the methodology developed. The data elaboration and the IWEE calculation has been automatized, in fact, for every bottling line has been developed an informatic support programmed in excel language. The results show as the IWEE gives a global assessment of the ecoefficiency on the base of resource consumptions and allows to see which sub components have influenced the performance through a multi-level perspective simplifying the identification of hotspots. The use of evaluation classes can be supportive in the communication of performance to top management. On the average, in the case of the bottling lines that realize water products, an increase of one percentage point of IWEE determines a reduction of respectively of: -1,5% of GHG emissions related to resources consumed by the bottling line, and -2,1% of economic costs. The IWEE has been extended to the other bottling lines that realized water products and in the figures 65 and 66 are shown the trends of IWEE compared with OEE. A total of 373 weekly results have been considered (424 weekly data deleting the 51 not productive weeks). In order to simplify the trend analysis for both trends have been added the moving averages (5 periods). In order to evaluate how much IWEE introduce new information on process efficiency, the two indicators have been compared considering statistically the following criteria:

- Differentiation criterion 1: the two indicators shown weekly variations in opposite directions;
- Differentiation criterion 2: The two indicators shown weekly variations in the same directions but with different magnitude (+/- 50%, calculated as the ratio between the weekly IWEE variation and the weekly OEE variation);
- In the other cases has been considered that the two indicators give the same information.

In the 36% of cases, the weekly results respond to the first differentiation criterion, while, on the average, in the 74% of cases them respond to the second differentiation criterion. Therefore, only in the 26% of the cases IWEE and OEE give information of processes efficiency that can be considered equivalent.

				CONSUMPTIONS								
				Energy			Hygienic treatments					Scraps
	Low/Medium/High Season	Bottling line	State of the line	Electricity direct consumption	Electricity indirect consumption	Thermal energy consumption	Frequency Alkaline CIP treatments	Frequency Acid CIP treatments	Frequency of filling of circuit of the rinsing machine treatments	Frequency of filling of bowl of the rinsing machine treatments	Frequency COP treatments	Raw material scraps %
Week	BS/MS/AS	-	Productive or not	kWh/week	kWh/week	Sm3/week	n°/week	n°/week	n°/week	n°/week	n°/week	%
week 1	Low season	L53	Not Productive	-	-	-	-	-	-	-	-	-
week 2	Low season	L53	Productive	10.272	24.362	2.770	1	1	3	1	7	0,64%
week 3	Low season	L53	Productive	10.921	24.928	2.834	1	0	0	1	4	0,54%
week 4	Low season	L53	Productive	11.688	29.355	2.023	2	0	5	1	10	0,52%
week 5	Low season	L53	Productive	14.260	33.662	2.320	2	0	3	1	8	0,52%
week 6	Low season	L53	Productive	13.294	32.917	1.064	1	1	4	1	9	0,53%
week 7	Low season	L53	Productive	17.259	40.569	1.311	2	0	1	1	6	0,98%
week 8	Low season	L53	Productive	17.371	46.581	1.577	2	0	1	1	6	1,01%
week 9	Low season	L53	Not productive	-	-	-	-	-	-	-	-	-
week 10	Low season	L53	Productive	7.648	13.251	295	1	1	4	1	9	0,92%
week 11	Low season	L53	Productive	12.548	27.772	618	2	0	4	1	9	0,48%
week 12	Low season	L53	Productive	7.318	13.057	517	1	1	4	1	9	1,57%
week 13	Low season	L53	Productive	8.445	16.919	670	2	0	4	1	9	0,70%
week 14	Low season	L53	Productive	7.755	17.954	711	1	0	3	1	6	0,31%
week 15	Medium season	L53	Productive	13.978	30.670	512	1	1	4	1	9	1,17%
week 16	Medium season	L53	Productive	11.721	26.787	447	2	0	4	1	9	0,92%
week 17	Medium season	L53	Productive	12.115	28.697	443	1	0	5	1	10	0,76%
week 18	Medium season	L53	Productive	9.532	21.744	336	2	0	4	1	9	0,49%
week 19	High season	L53	Productive	11.845	27.649	366	1	1	4	1	9	0,50%
week 20	High season	L53	Productive	12.062	27.427	363	2	0	4	1	9	0,48%
week 21	High season	L53	Productive	11.903	25.584	338	2	0	4	1	9	0,58%
week 22	High season	L53	Productive	11.854	25.669	339	1	0	5	1	10	0,56%
week 23	High season	L53	Productive	11.533	25.474	245	1	1	5	1	11	0,47%
week 24	High season	L53	Productive	17.976	40.235	386	2	0	1	1	6	0,57%
week 25	High season	L53	Productive	12.511	25.785	319	2	0	5	1	11	0,59%
week 26	High season	L53	Productive	11.785	25.697	318	1	0	5	1	10	0,45%
week 27	High season	L53	Productive	10.643	22.307	276	2	0	4	1	9	0,63%
week 28	High season	L53	Productive	13.008	26.398	277	1	1	4	1	9	0,74%
week 29	High season	L53	Productive	17.286	36.318	382	2	0	1	1	6	0,77%
week 30	High season	L53	Productive	17.333	37.562	376	1	0	1	1	7	0,85%
week 31	High season	L53	Productive	14.106	26.447	265	2	0	1	1	6	1,73%
week 32	Medium season	L53	Productive	11.163	22.997	229	1	1	4	1	9	1,18%
week 33	Medium season	L53	Productive	11.698	25.336	253	2	0	4	1	9	1,34%
week 34	Medium season	L53	Productive	9.511	21.990	215	2	0	3	1	7	0,59%

				CONSUMPTIONS									
				Energy			Hygienic treatments					Scraps
	Low/Medium/High Season	Bottling line	State of the line	Electricity direct consumption	Electricity indirect consumption	Thermal energy consumption	Frequency Alkaline CIP treatments	Frequency Acid CIP treatments	Frequency of filling of circuit of the rinsing machine treatments	Frequency of filling of bowl of the rinsing machine treatments	Frequency COP treatments	Raw material scraps %
Week	BS/MS/AS	-	Productive or not	kWh/week	kWh/week	Sm3/week	n°/week	n°/week	n°/week	n°/week	n°/week	%
week 35	Medium season	L53	Productive	11.035	25.291	247	1	0	5	1	10	0,87%
week 36	Medium season	L53	Productive	10.677	26.399	284	1	1	4	1	9	0,75%
week 37	Medium season	L53	Productive	11.934	30.934	333	2	0	4	1	9	0,57%
week 38	Medium season	L53	Productive	11.852	27.879	300	2	0	4	1	9	0,98%
week 39	Medium season	L53	Productive	11.464	23.123	176	1	0	5	1	10	1,13%
week 40	Medium season	L53	Productive	7.639	14.448	110	1	0	2	1	5	0,77%
week 41	Low season	L53	Productive	11.979	32.705	796	1	1	4	1	9	1,06%
week 42	Low season	L53	Productive	12.492	35.364	861	2	0	4	1	9	0,52%
week 43	Low season	L53	Productive	10.329	28.938	774	1	0	4	1	10	0,73%
week 44	Low season	L53	Not productive	-	-	-	-	-	-	-	-	-
week 45	Low season	L53	Productive	8.429	18.857	1.134	1	1	4	0	8	1,42%
week 46	Low season	L53	Productive	12.732	33.319	2.005	2	0	4	1	9	0,94%
week 47	Low season	L53	Productive	11.784	33.361	1.996	1	0	5	1	10	0,67%
week 48	Low season	L53	Productive	8.701	23.918	1.431	2	0	3	1	7	0,00%
week 49	Low season	L53	Productive	12.757	35.914	5.441	1	1	4	1	9	0,80%
week 50	Low season	L53	Productive	10.255	26.721	4.048	2	0	3	1	7	0,52%
week 51	Low season	L53	Productive	13.396	36.312	5.501	1	0	5	1	12	0,79%
week 52	Low season	L53	Productive	11.588	30.244	3.220	2	0	4	1	9	0,51%
week 53	Low season	L53	Productive	8.857	22.308	2.375	1	1	3	1	7	0,00%

Table 62 Example of data collected to assess IWEE for bottling lines. The data are referred to the bottling line L53.

				Assessment of IWEE components									
				Energy			Hygienic treatments					Scraps	
	Low/Medium/High Season	Bottling line	State of the line	Electricity direct consumption	Electricity indirect consumption	Thermal energy consumption	Frequency Alkaline CIP treatments	Frequency Acid CIP treatments	Frequency of filling of circuit of the rinsing machine treatments	Frequency of filling of bowl of the rinsing machine treatments	Frequency COP treatments	Scarto cotta %	Raw material scraps %
Week	**BS/MS/AS**	**-**	**Productive or not**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**
week 1	Low season	L53	Not Productive	-	-	-	-	-	-	-	-	N.A.	-
week 2	Low season	L53	Productive	87,1%	100,0%	65,7%	100,0%	100,0%	100,0%	100,0%	100,0%	N.A.	100,0%
week 3	Low season	L53	Productive	83,8%	100,0%	65,7%	100,0%	0,0%	0,0%	100,0%	100,0%	N.A.	100,0%
week 4	Low season	L53	Productive	84,5%	98,9%	99,2%	100,0%	100,0%	80,0%	100,0%	90,0%	N.A.	100,0%
week 5	Low season	L53	Productive	79,4%	98,9%	99,2%	100,0%	100,0%	100,0%	100,0%	100,0%	N.A.	100,0%
week 6	Low season	L53	Productive	91,1%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	N.A.	100,0%
week 7	Low season	L53	Productive	86,5%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	N.A.	70,6%
week 8	Low season	L53	Productive	92,1%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	N.A.	68,6%
week 9	Low season	L53	Not productive	-	-	-	-	-	-	-	-	N.A.	-
week 10	Low season	L53	Productive	72,3%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	N.A.	75,9%
week 11	Low season	L53	Productive	92,4%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	N.A.	100,0%
week 12	Low season	L53	Productive	68,4%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	N.A.	44,3%
week 13	Low season	L53	Productive	76,8%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	N.A.	98,7%
week 14	Low season	L53	Productive	88,7%	100,0%	100,0%	100,0%	0,0%	66,7%	100,0%	83,3%	N.A.	100,0%
week 15	Medium season	L53	Productive	88,7%	100,0%	71,1%	100,0%	100,0%	100,0%	100,0%	100,0%	N.A.	75,4%
week 16	Medium season	L53	Productive	92,4%	100,0%	71,1%	100,0%	100,0%	100,0%	100,0%	100,0%	N.A.	95,8%
week 17	Medium season	L53	Productive	93,3%	99,0%	74,9%	100,0%	0,0%	80,0%	100,0%	90,0%	N.A.	100,0%
week 18	Medium season	L53	Productive	89,8%	99,0%	74,9%	100,0%	100,0%	75,0%	100,0%	77,8%	N.A.	100,0%
week 19	High season	L53	Productive	97,6%	95,0%	83,0%	100,0%	100,0%	100,0%	100,0%	100,0%	N.A.	100,0%
week 20	High season	L53	Productive	95,0%	95,0%	83,0%	100,0%	100,0%	100,0%	100,0%	100,0%	N.A.	100,0%
week 21	High season	L53	Productive	93,4%	98,8%	86,5%	100,0%	100,0%	100,0%	100,0%	100,0%	N.A.	100,0%
week 22	High season	L53	Productive	94,1%	98,8%	86,5%	100,0%	0,0%	80,0%	100,0%	90,0%	N.A.	100,0%
week 23	High season	L53	Productive	96,4%	99,2%	100,0%	100,0%	100,0%	80,0%	100,0%	81,8%	N.A.	100,0%
week 24	High season	L53	Productive	97,7%	99,2%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	N.A.	100,0%
week 25	High season	L53	Productive	91,5%	100,0%	94,5%	100,0%	100,0%	100,0%	100,0%	100,0%	N.A.	100,0%
week 26	High season	L53	Productive	96,8%	100,0%	94,5%	100,0%	0,0%	80,0%	100,0%	90,0%	N.A.	100,0%
week 27	High season	L53	Productive	93,1%	100,0%	94,5%	100,0%	100,0%	100,0%	100,0%	100,0%	N.A.	100,0%
week 28	High season	L53	Productive	94,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	N.A.	92,8%
week 29	High season	L53	Productive	97,3%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	N.A.	88,9%
week 30	High season	L53	Productive	96,5%	100,0%	100,0%	100,0%	0,0%	100,0%	100,0%	100,0%	N.A.	81,0%
week 31	High season	L53	Productive	83,5%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	N.A.	39,6%
week 32	Medium season	L53	Productive	84,8%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	N.A.	75,3%
week 33	Medium season	L53	Productive	89,2%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	N.A.	66,0%

				Assessment of IWEE components									
				Energy			**Hygienic treatments**					**Scraps**	
	Low/Medium/High Season	**Bottling line**	**State of the line**	**Electricity direct consumption**	**Electricity indirect consumption**	**Thermal energy consumption**	**Frequency Alkaline CIP treatments**	**Frequency Acid CIP treatments**	**Frequency of filling of circuit of the rinsing machine treatments**	**Frequency of filling of bowl of the rinsing machine treatments**	**Frequency COP treatments**	**Scarto cotta %**	**Raw material scraps %**
Week	**BS/MS/AS**	**-**	**Productive or not**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**
week 34	Medium season	L53	Productive	90,1%	98,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	N.A.	100,0%
week 35	Medium season	L53	Productive	89,3%	98,0%	100,0%	100,0%	0,0%	80,0%	100,0%	90,0%	N.A.	100,0%
week 36	Medium season	L53	Productive	90,3%	91,8%	99,7%	100,0%	100,0%	100,0%	100,0%	100,0%	N.A.	100,0%
week 37	Medium season	L53	Productive	94,6%	91,8%	99,7%	100,0%	100,0%	100,0%	100,0%	100,0%	N.A.	100,0%
week 38	Medium season	L53	Productive	85,9%	91,8%	99,7%	100,0%	100,0%	100,0%	100,0%	100,0%	N.A.	90,4%
week 39	Medium season	L53	Productive	90,8%	100,0%	100,0%	100,0%	0,0%	80,0%	100,0%	90,0%	N.A.	78,6%
week 40	Medium season	L53	Productive	85,1%	100,0%	100,0%	100,0%	0,0%	100,0%	100,0%	100,0%	N.A.	100,0%
week 41	Low season	L53	Productive	91,4%	98,4%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	N.A.	65,6%
week 42	Low season	L53	Productive	94,8%	98,4%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	N.A.	100,0%
week 43	Low season	L53	Productive	81,5%	85,5%	100,0%	100,0%	0,0%	100,0%	100,0%	90,0%	N.A.	95,3%
week 44	Low season	L53	Not productive	-	-	-	-	-	-	-	-	N.A.	-
week 45	Low season	L53	Productive	71,0%	93,3%	100,0%	100,0%	100,0%	75,0%	0,0%	87,5%	N.A.	49,1%
week 46	Low season	L53	Productive	83,1%	93,3%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	N.A.	73,6%
week 47	Low season	L53	Productive	88,5%	91,8%	100,0%	100,0%	0,0%	80,0%	100,0%	90,0%	N.A.	100,0%
week 48	Low season	L53	Productive	85,9%	91,8%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	N.A.	100,0%
week 49	Low season	L53	Productive	84,7%	88,4%	40,4%	100,0%	100,0%	100,0%	100,0%	100,0%	N.A.	87,3%
week 50	Low season	L53	Productive	78,4%	88,4%	40,4%	100,0%	100,0%	100,0%	100,0%	100,0%	N.A.	100,0%
week 51	Low season	L53	Productive	81,5%	88,4%	40,4%	100,0%	0,0%	100,0%	100,0%	91,7%	N.A.	88,2%
week 52	Low season	L53	Productive	85,8%	96,6%	62,7%	100,0%	100,0%	100,0%	100,0%	100,0%	N.A.	100,0%
week 53	Low season	L53	Productive	82,8%	96,6%	62,7%	100,0%	100,0%	100,0%	100,0%	100,0%	N.A.	100,0%

Table 63 Example of assessment of IWEE subcomponents in case of a bottling process. The results are referred to the bottling line L53.

				IWEE final assessment											
				IWEE components % Score			IWEE components Performance Class			IWEE global % score	IWEE global Performance Class	IWEE components GHG emissions			IWEE global GHG emissions
	Low/Medium/High Season	Bottling line	State of the line	Energy	Hygienic treatments	Scraps	Energy	Hygienic treatments	Scraps			GHG emissions from energy consumption	GHG emissions from hygienic treatments	GHG emissions from raw material scraps	Total GHG emissions
Week	**BS/MS/AS**		**Productive or not**	**%**	**%**	**%**	**Class**	**Class**	**Class**	**%**	**Class**	**kg CO2eq/1000lt**	**kg CO2eq/1000lt**	**kg CO2eq/1000lt**	**kg CO2eq/1000lt**
week 1	Low season	L53	Not Productive	-	-	-	-	-	-	-	-	-	-	-	-
week 2	Low season	L53	Productive	87,1%	100,0%	100,0%	CL3	CL1	CL1	90,4%	CL2	1,57	0,119	0,058	1,743
week 3	Low season	L53	Productive	83,8%	54,2%	100,0%	CL3	CL3	CL1	78,3%	CL3	1,63	0,030	0,049	1,706
week 4	Low season	L53	Productive	84,5%	92,3%	100,0%	CL3	CL1	CL1	86,9%	CL2	1,61	0,071	0,047	1,733
week 5	Low season	L53	Productive	79,4%	100,0%	100,0%	CL3	CL1	CL1	84,8%	CL2	1,72	0,056	0,047	1,820
week 6	Low season	L53	Productive	91,1%	100,0%	100,0%	CL2	CL1	CL1	93,4%	CL1	1,50	0,091	0,048	1,636
week 7	Low season	L53	Productive	86,5%	100,0%	70,6%	CL3	CL1	CL3	88,6%	CL2	1,58	0,038	0,089	1,704
week 8	Low season	L53	Productive	92,1%	100,0%	68,6%	CL2	CL1	CL3	92,7%	CL1	1,48	0,035	0,092	1,608
week 9	Low season	L53	Not productive	-	-	-	-	-	-	-	-	-	-	-	-
week 10	Low season	L53	Productive	72,3%	100,0%	75,9%	CL3	CL1	CL3	78,4%	CL3	1,89	0,199	0,083	2,168
week 11	Low season	L53	Productive	92,4%	100,0%	100,0%	CL2	CL1	CL1	94,3%	CL1	1,48	0,058	0,043	1,577
week 12	Low season	L53	Productive	68,4%	100,0%	44,3%	CL3	CL1	CL3	74,0%	CL3	2,00	0,220	0,142	2,358
week 13	Low season	L53	Productive	76,8%	100,0%	98,7%	CL3	CL1	CL1	82,7%	CL3	1,78	0,103	0,064	1,944
week 14	Low season	L53	Productive	88,7%	74,5%	100,0%	CL3	CL3	CL1	86,2%	CL2	1,54	0,054	0,028	1,620
week 15	Medium season	L53	Productive	88,7%	100,0%	75,4%	CL3	CL1	CL3	90,5%	CL2	1,54	0,089	0,106	1,734
week 16	Medium season	L53	Productive	92,4%	100,0%	95,8%	CL2	CL1	CL1	94,1%	CL1	1,48	0,062	0,084	1,622
week 17	Medium season	L53	Productive	93,3%	79,6%	100,0%	CL2	CL3	CL1	90,7%	CL2	1,46	0,040	0,069	1,571
week 18	Medium season	L53	Productive	89,8%	89,3%	100,0%	CL3	CL2	CL1	90,2%	CL2	1,52	0,078	0,044	1,641
week 19	High season	L53	Productive	97,6%	100,0%	100,0%	CL1	CL1	CL1	98,2%	CL1	1,40	0,095	0,045	1,539
week 20	High season	L53	Productive	95,0%	100,0%	100,0%	CL2	CL1	CL1	96,3%	CL1	1,44	0,058	0,043	1,537
week 21	High season	L53	Productive	93,4%	100,0%	100,0%	CL2	CL1	CL1	95,1%	CL1	1,46	0,060	0,052	1,572
week 22	High season	L53	Productive	94,1%	79,6%	100,0%	CL2	CL3	CL1	91,3%	CL2	1,45	0,040	0,050	1,540
week 23	High season	L53	Productive	96,4%	91,4%	100,0%	CL1	CL1	CL1	95,5%	CL1	1,41	0,102	0,042	1,560
week 24	High season	L53	Productive	97,7%	100,0%	100,0%	CL1	CL1	CL1	98,3%	CL1	1,40	0,032	0,052	1,480
week 25	High season	L53	Productive	91,5%	100,0%	100,0%	CL2	CL1	CL1	93,7%	CL1	1,49	0,062	0,053	1,605
week 26	High season	L53	Productive	96,8%	79,6%	100,0%	CL1	CL3	CL1	93,3%	CL1	1,41	0,039	0,040	1,489
week 27	High season	L53	Productive	93,1%	100,0%	100,0%	CL2	CL1	CL1	94,9%	CL1	1,47	0,067	0,057	1,590
week 28	High season	L53	Productive	94,0%	100,0%	92,8%	CL2	CL1	CL1	95,2%	CL1	1,45	0,090	0,067	1,608
week 29	High season	L53	Productive	97,3%	100,0%	88,9%	CL1	CL1	CL2	97,5%	CL1	1,40	0,033	0,070	1,505
week 30	High season	L53	Productive	96,5%	87,3%	81,0%	CL1	CL2	CL2	93,8%	CL1	1,41	0,019	0,077	1,509
week 31	High season	L53	Productive	83,5%	100,0%	39,6%	CL3	CL1	CL3	85,0%	CL2	1,63	0,048	0,157	1,839

				IWEE final assessment											
				IWEE components % Score			IWEE components Performance Class			IWEE global % score	IWEE global Performance Class	IWEE components GHG emissions			IWEE global GHG emissions
	Low/Medium/High Season	Bottling line	State of the line	Energy	Hygienic treatments	Scraps	Energy	Hygienic treatments	Scraps			GHG emissions from energy consumption	GHG emissions from hygienic treatments	GHG emissions from raw material scraps	Total GHG emissions
Week	**BS/MS/AS**		**Productive or not**	**%**	**%**	**%**	**Class**	**Class**	**Class**	**%**	**Class**	**kg CO2eq/1000lt**	**kg CO2eq/1000lt**	**kg CO2eq/1000lt**	**kg CO2eq/1000lt**
week 32	Medium season	L53	Productive	84,8%	100,0%	75,3%	CL3	CL1	CL3	87,6%	CL2	1,61	0,116	0,106	1,831
week 33	Medium season	L53	Productive	89,2%	100,0%	66,0%	CL3	CL1	CL3	90,4%	CL2	1,53	0,064	0,121	1,715
week 34	Medium season	L53	Productive	90,1%	100,0%	100,0%	CL2	CL1	CL1	92,7%	CL1	1,51	0,073	0,053	1,641
week 35	Medium season	L53	Productive	89,3%	79,6%	100,0%	CL3	CL3	CL1	87,8%	CL2	1,53	0,046	0,079	1,652
week 36	Medium season	L53	Productive	90,3%	100,0%	100,0%	CL2	CL1	CL1	92,8%	CL1	1,51	0,114	0,067	1,693
week 37	Medium season	L53	Productive	94,6%	100,0%	100,0%	CL2	CL1	CL1	96,0%	CL1	1,44	0,059	0,052	1,553
week 38	Medium season	L53	Productive	85,9%	100,0%	90,4%	CL3	CL1	CL1	89,1%	CL2	1,59	0,066	0,089	1,743
week 39	Medium season	L53	Productive	90,8%	79,6%	78,6%	CL2	CL3	CL3	87,9%	CL2	1,50	0,043	0,102	1,648
week 40	Medium season	L53	Productive	85,1%	87,3%	100,0%	CL3	CL2	CL1	86,3%	CL2	1,60	0,052	0,069	1,724
week 41	Low season	L53	Productive	91,4%	100,0%	65,6%	CL2	CL1	CL3	92,1%	CL1	1,49	0,101	0,096	1,689
week 42	Low season	L53	Productive	94,8%	100,0%	100,0%	CL2	CL1	CL1	96,1%	CL1	1,44	0,056	0,047	1,542
week 43	Low season	L53	Productive	81,5%	86,2%	95,3%	CL3	CL2	CL1	83,1%	CL3	1,67	0,050	0,066	1,790
week 44	Low season	L53	Not productive	-	-	-	-	-	-	-	-	-	-	-	-
week 45	Low season	L53	Productive	71,0%	88,2%	49,1%	CL3	CL2	CL3	73,7%	CL3	1,92	0,182	0,132	2,235
week 46	Low season	L53	Productive	83,1%	100,0%	73,6%	CL3	CL1	CL3	86,2%	CL2	1,64	0,063	0,085	1,790
week 47	Low season	L53	Productive	88,5%	79,6%	100,0%	CL3	CL3	CL1	87,1%	CL2	1,54	0,043	0,060	1,646
week 48	Low season	L53	Productive	85,9%	100,0%	100,0%	CL3	CL1	CL1	89,5%	CL2	1,59	0,084	0,000	1,672
week 49	Low season	L53	Productive	84,7%	100,0%	87,3%	CL3	CL1	CL2	88,1%	CL2	1,61	0,102	0,072	1,785
week 50	Low season	L53	Productive	78,4%	100,0%	100,0%	CL3	CL1	CL1	84,0%	CL3	1,74	0,078	0,047	1,865
week 51	Low season	L53	Productive	81,5%	86,4%	88,2%	CL3	CL2	CL2	82,9%	CL3	1,67	0,042	0,071	1,786
week 52	Low season	L53	Productive	85,8%	100,0%	100,0%	CL3	CL1	CL1	89,5%	CL2	1,59	0,067	0,046	1,703
week 53	Low season	L53	Productive	82,8%	100,0%	100,0%	CL3	CL1	CL1	87,2%	CL2	1,65	0,145	0,000	1,793

Table 64 Example of assessment of IWEE components in case of a bottling process. The results are referred to the bottling line L53.

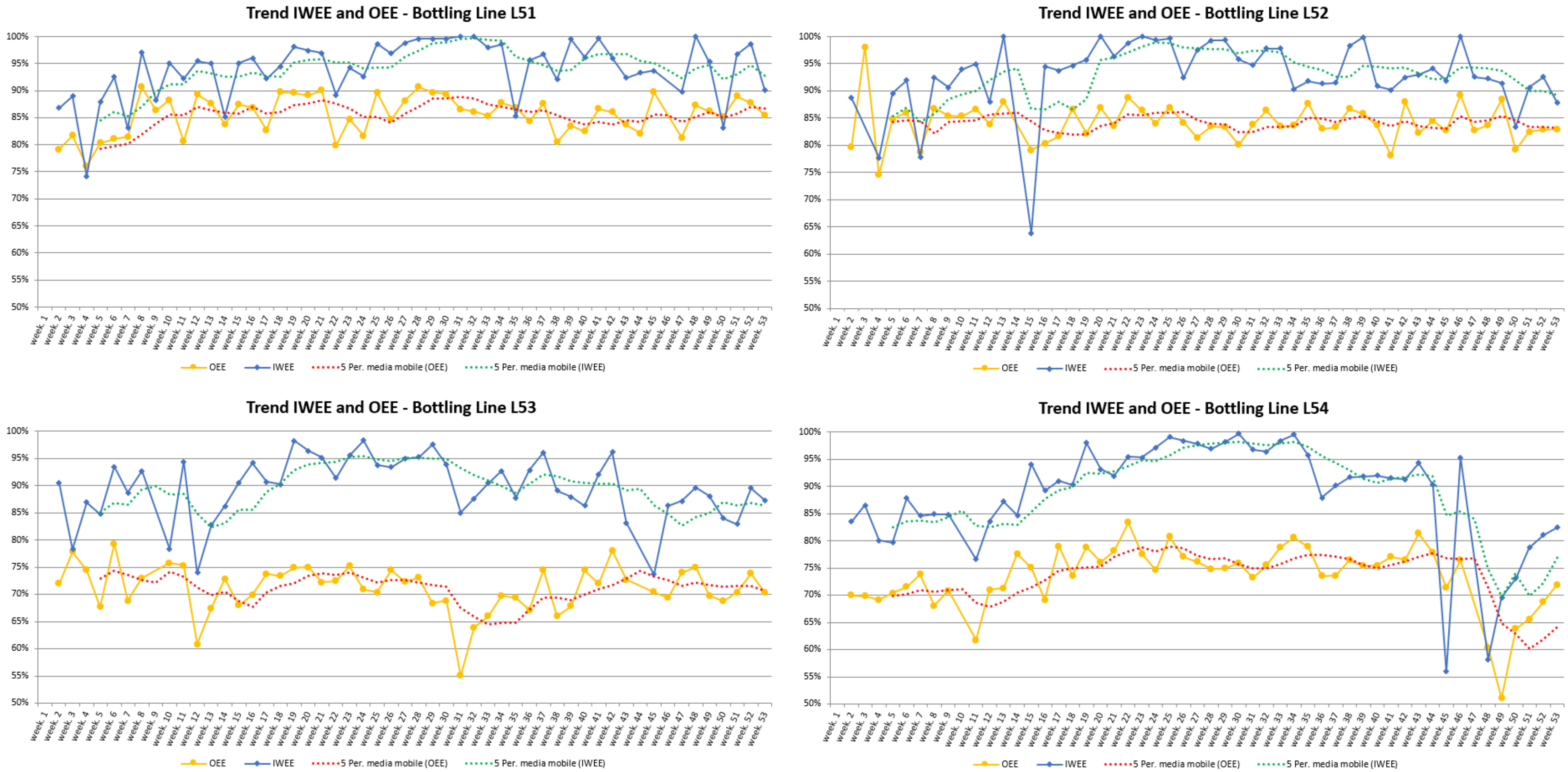


Table 65 Weekly trends of IWEE and OEE. The results are referred to the bottling lines: L51, L52, L53, L54.

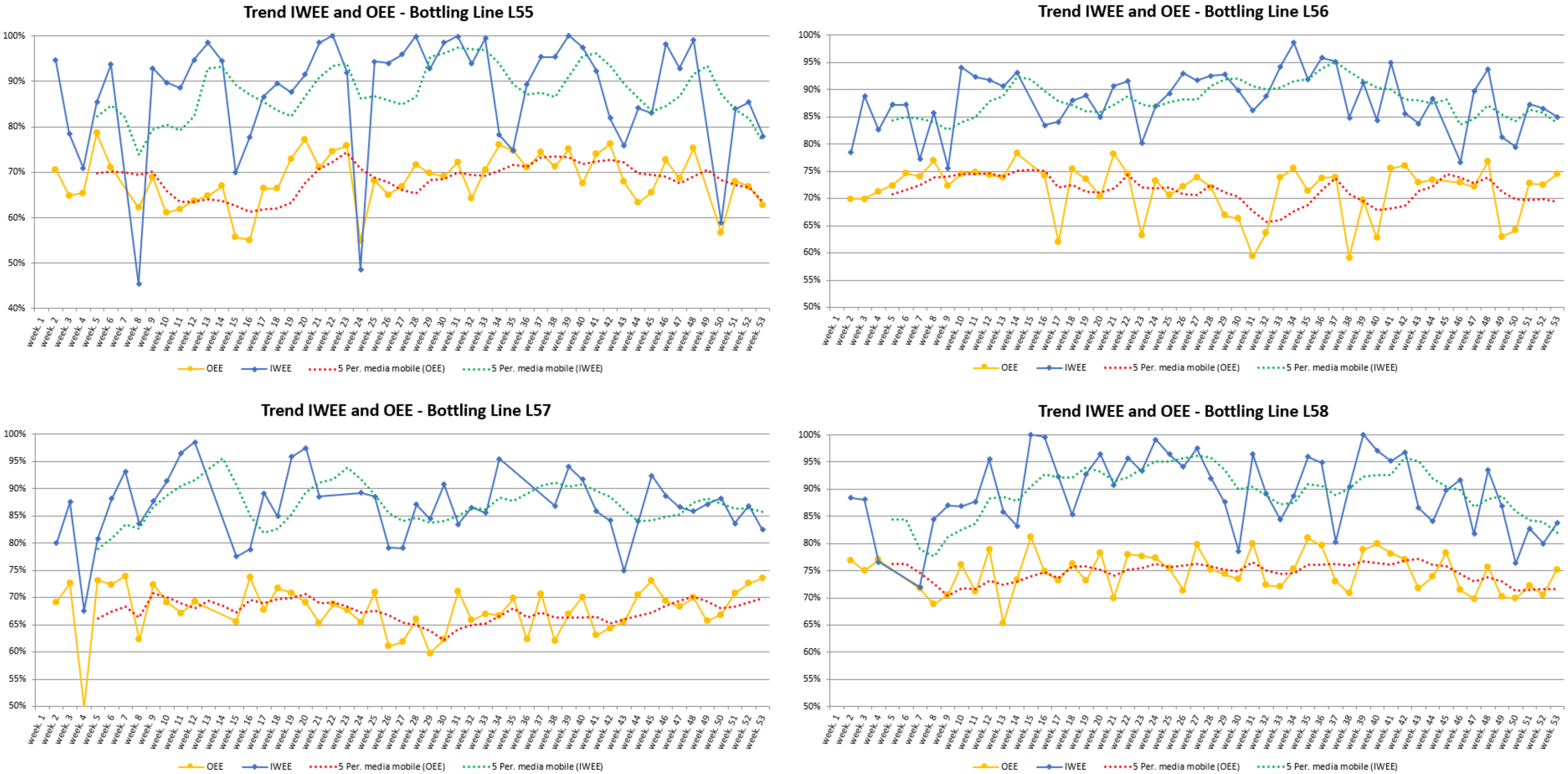


Table 66 Weekly trends of IWEE and OEE. The results are referred to the bottling lines: L55, L56, L57, L58.

The deepening on the trend comparison can be made focusing on some examples. Four examples have been selected from the trends chart of the bottling line L53, these examples can be considered general inasmuch they can be identified also in the other bottling lines.

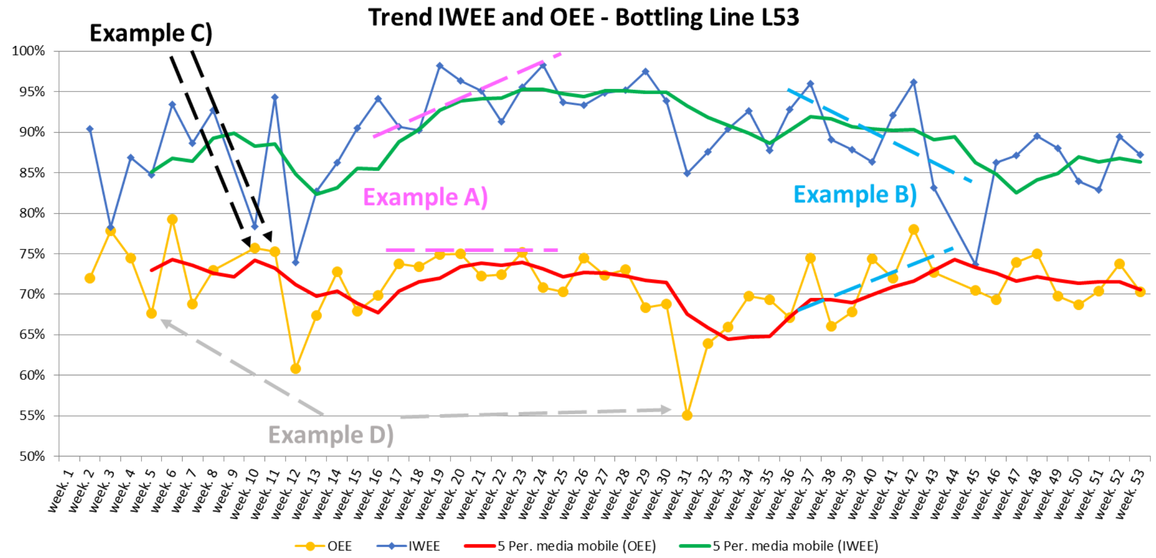


Table 67 Examples of differences on weekly trends of IWEE and OEE. The results are referred to the bottling line L53.

The examples A and B focus on multi weekly trends analysis. The example A (values from week 17 to week 24) shows a trend where the weekly values of IWEE increase (from about 90% to about 99%) while OEE weekly values are about constant (ranging from 73% to 75%). In this case for the same OEE values the IWEE indicator measures that the bottling line generates resource consumptions with a reduction of 9%. The example B (values from week 38 to week 45) shows a trend where the weekly values of IWEE decrease of about 12%, while OEE weekly values increase of about 6%. In this case the IWEE indicator has permitted to identify an increasing of about 12% of resource consumptions although OEE increase of about 6%.

The examples C and D focus instead on the analysis of point that have in the first case the same values of OEE but different values of IWEE and in the second case, the same value of IWEE but different values of OEE. In fact, in the case C, the weeks 10 and 11 have about the same OEE values (75,7% and 75,3%) while IWEE is significantly different (78,4% and 94,3%). Finally, in the case D, the weeks 5 and 31 have about the same IWEE values (85%) while OEE is significantly different (67,6% and 55,1%). The results show as the two indicators provide complementary information on process efficiency and therefore as the IWEE introduce a new perspective of assessment. The two indicators have three important differences:

1. **The informative content**: the IWEE introduces the measure of the efficiency of resource consumptions therefore respect to OEE permits to assess the environmental impacts and the economic costs related to different levels of ecoefficiency;
2. **Sensibility to improvement projects**: the IWEE focusing on resource consumptions is able to identify variations of resource consumptions due to improvement projects such as process technology innovation. In the example below on week 31 an energy saving project has been applied to the bottling line reducing the electric installed power of 6%. The average weekly value of IWEE raise from 89,5% to 91,1%. The OEE values remain the same because are independent by electric power installed.

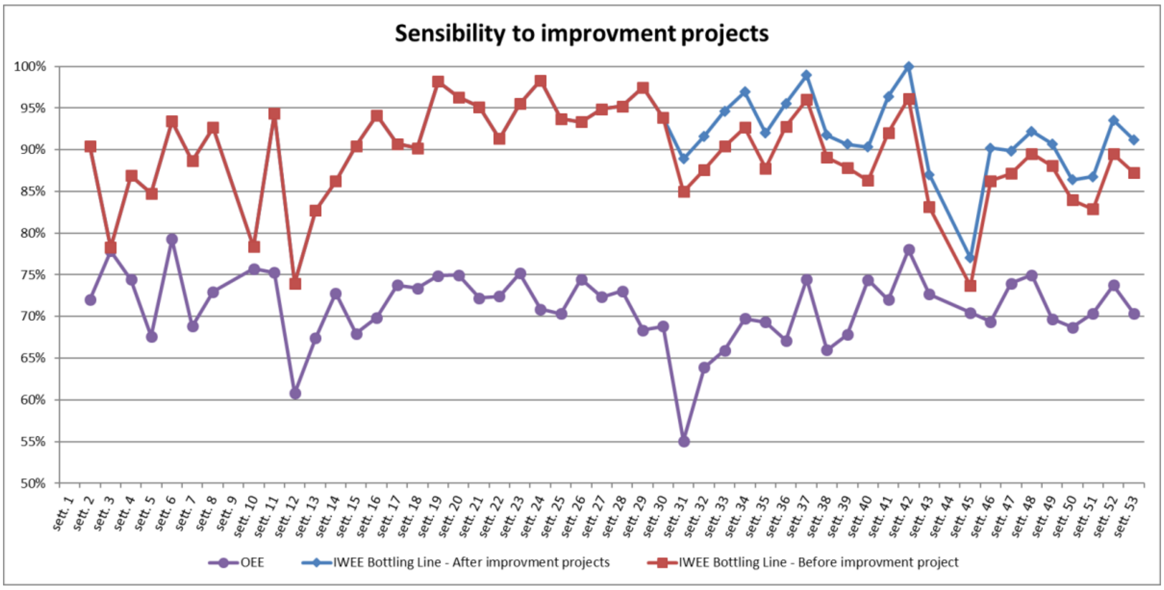


Table 68 Example of IWEE variation due to the effect of an energy efficiency project.

3. **Sensibility to productive configurations**: The IWEE have parameters of reference performance fixed while a part of reference performance parameters of OEE are mobile. The sense of this sentence can be explained whit the following example. The OEE is given by the following equation:

$$OEE = A \cdot UE \cdot QR \quad [3.3]$$

$$A = \frac{Uptime}{Uptime + Downtime} \quad [3.4]$$

$$UE = \frac{Product\ units\ realized}{Product\ units\ theoretically\ realizable} \quad [3.5]$$

$$QR = \frac{Conformed\ product\ units\ realized}{Product\ units\ realized} \quad [3.6]$$

Where
A= Availability;
UE= Uptime Efficiency;
QR= Quality Rate;
$Uptime$= time on which the bottling line works effectively to produce product units;
$Downtime$= sum of all time on which the bottling line doesn't works (e.g. failures arrests, setup arrests, planned arrest for other activities such as hygienic treatments).
The sum between uptime and downtime is the planned time of work (hours for single work shift multiply the number of scheduled shifts in the week).

Theoretically, observing the mathematical relationships that permit the calculation of OEE, it is evident that different days can have the same OEE values independently from how the work is planned. In, fact, the OEE components A and UE are dependent from how much efficiently the time to work has been used and not from how the work has been planned. In this way theoretically, a week where the production is planned with single shift can has the same OEE of a week planned with double shift. The IWEE instead is sensitive to changes of productive configurations that influence how the bottling line works and therefore how the bottling line consumes the resources. However, the relationships between the main variables that characterize the productive configurations and the IWEE values should be investigate in order to understand deeply the trend of IWEE. It is important to underline that these variables influence continuously the performance of the bottling line and therefore to assess their influences is a fundamental step to correctly evaluate and manage the IWEE trend. This aspect has been faced in the following paragraph.

3.5.1.1. Statistical correlations between IWEE and productive variables

According to the methodology developed in the chapter 2, the IWEE introduces a IPLE index (Index of Potential Loss of Ecoefficiency). This index, has been introduced in order to support the trend assessment, evaluating how productive configurations could influence the ecoefficiency level. In fact, as emerged in the last part of the previously paragraph, excluding spot events (measure errors, accidental events, etc.) two types of changes can influence the ecoefficiency: changes of technologies, that could change intrinsically the level of resource consumption, and changes of productive configurations, that could influence how the bottling line works.

Focusing on the second aspect, the first step is the statistical analysis of correlation between the IWEE and the variables that characterize a productive configuration of a bottling line. Through interviews and meetings with experts on bottling processes has been possible to identify a list of variables that could characterize the productive configuration. These variables are listed following: volume produced (litres/week), productive run average length (minutes/run), number of format changes (n° format changes/week), hourly bottling line speed (bottles/hour), work shift configuration (work shifts/day), production time (minutes/week) and not productive time (minutes/week).

Being request a statistical approach, the SEDM module of OES2 method has required the application of the decision making tool for statistical issues. The tool is the software Statgraphics XVII. The multiple variable analysis has been conducted to identify the Pearson correlation coefficients for the statistically significant pairs of variables. The following figure shows the correlation results.

Pearson Product-Moment Correlations

-1,0 … 1,0

	Production time	Not productive time	Volume produced	Production run avarage length	Number of format changes	Hourly bottling line speed	Work shift configuration	IWEE
Production time		-0,62	0,99	0,24	-0,20	0,14	0,81	0,74
Not productive time	-0,62		-0,66	0,32	0,38	-0,40	-0,61	-0,50
Volume produced	0,99	-0,66		0,19	-0,20	0,29	0,80	0,79
Production run avarage length	0,24	0,32	0,19		-0,24	-0,27	0,03	0,32
Number of format changes	-0,20	0,38	-0,20	-0,24		-0,05	-0,30	-0,15
Hourly bottling line speed	0,14	-0,40	0,29	-0,27	-0,05		0,15	0,48
Work shift configuration	0,81	-0,61	0,80	0,03	-0,30	0,15		0,47
IWEE	0,74	-0,50	0,79	0,32	-0,15	0,48	0,47	

Table 69 Pearson correlation results between IWEE and variables that characterize productive configurations

The P-value test has been used to test the statistical significance of the estimated correlations. P-values below 0,05 indicate statistically significant non-zero correlations at the 95,0% confidence level. The following pairs of variables have P-values below 0,05:

- IWEE – Production time. High correlation;

- IWEE – Not productive time. Medium correlation;
- IWEE – Volume produced. High correlation;
- IWEE – Production run average length. Medium correlation;
- IWEE – Hourly bottling line speed. Medium correlation;
- IWEE – Work shift configuration. Medium correlation.

These variables show a significant correlation to IWEE and therefore have been considered to assess their direct influence on IWEE during the IPLE elaboration. Other correlation analysis have allowed to identify variables that influence indirectly IWEE trend, influencing the variables that influence directly the IWEE trend.

Pearson Product-Moment Correlations

-1,0 … 1,0

	Time lost Not productive time	Times for scheduled maintenance	Times for format changes	Times for hygienic treatments	Times lost for failures and micr	Time lost for defects	Number of Product code	Number of format changes
Not productive time		0,04	0,36	0,28	0,92	0,43	0,36	0,32
Times for scheduled maintenance	0,04		0,17	0,19	0,00	0,09	0,16	0,13
Times for format changes	0,36	0,17		0,09	0,44	-0,08	0,71	0,72
Tmes for hygienic treatments	0,28	0,19	0,09		0,16	0,36	0,31	0,24
Times lost for failures and micr	0,92	0,00	0,44	0,16		0,04	0,42	0,40
Time lost for defects	0,43	0,09	-0,08	0,36	0,04		-0,04	-0,08
Number of Product code	0,36	0,16	0,71	0,31	0,42	-0,04		0,99
Number of format changes	0,32	0,13	0,72	0,24	0,40	-0,08	0,99	

Table 70 Pearson correlation results between not productive time and other variables that characterize productive configurations

In fact, the figures 70 and 71 show as the variables "Number of product code" and "Number of format changes" have high and medium correlations respectively with "Time for formant changes" and "Time lost for failures and micro stops" that influence significantly the not productive time. Medium inverse correlations can be found between "Number of product code" and "Number of format changes" and the variable "Production run average length". Therefore, the variables "Number of product code" and "Number of format changes" must be considered for its indirect effects on IWEE. Furthermore, these two variables are very important to assess the effects of aspects related to market demand (e.g. demand to increase the products differentiation) on the process efficiency.

Pearson Product-Moment Correlations

	Production run average length	Number of Product code	Number of format changes	Hourly bottling line speed
Production run average length		-0,51	-0,56	0,37
Number of Product code	-0,51		0,99	0,11
Number of format changes	-0,56	0,99		0,07
Hourly bottling line speed	0,37	0,11	0,07	

Table 71 Pearson correlation results between production run average length and other variables that characterize productive configurations

3.5.1.2. Calculation of the Index of Potential Loss of Ecoefficiency (IPLE)

According to the methodology developed in the chapter 2, the IPLE has been calculated. The IPLE calculation requires the application of the statistical discriminant analysis and therefore, also in this case the SEDM module provide by OES2 method has active the use of the software Statgraphics XVII.
For the discriminant analysis have been considered only the variables that influence directly the IWEE trend. For every variable has been calculated an index to normalize the variables. Therefore, the following five indexes have been calculated:

1. Index of productive time incidence (I_{PTI}). This index considers the ratio between not productive time and the productive time;
2. Index of productive run average length (I_{RAL});
3. Index of hourly bottling line speed (I_{BLS});
4. Index of work shift configuration (I_{WSC});
5. Index of volume produced (I_{VP}).

Therefore, all the six direct variables identify during the statistical correlation analysis have been considered in the indexes. The five indexes have been calculated for every bottling line for every week assessed. The discriminant analysis has been conducted considering as discriminant factor the IWEE state. The approach to identify the IWEE state has been already discussed in the chapter 2. A mathematical algorithm implemented in the software has been used in order to identify the discriminant function that is the mathematical linear combinations of the indexes that best discriminate the two IWEE states.

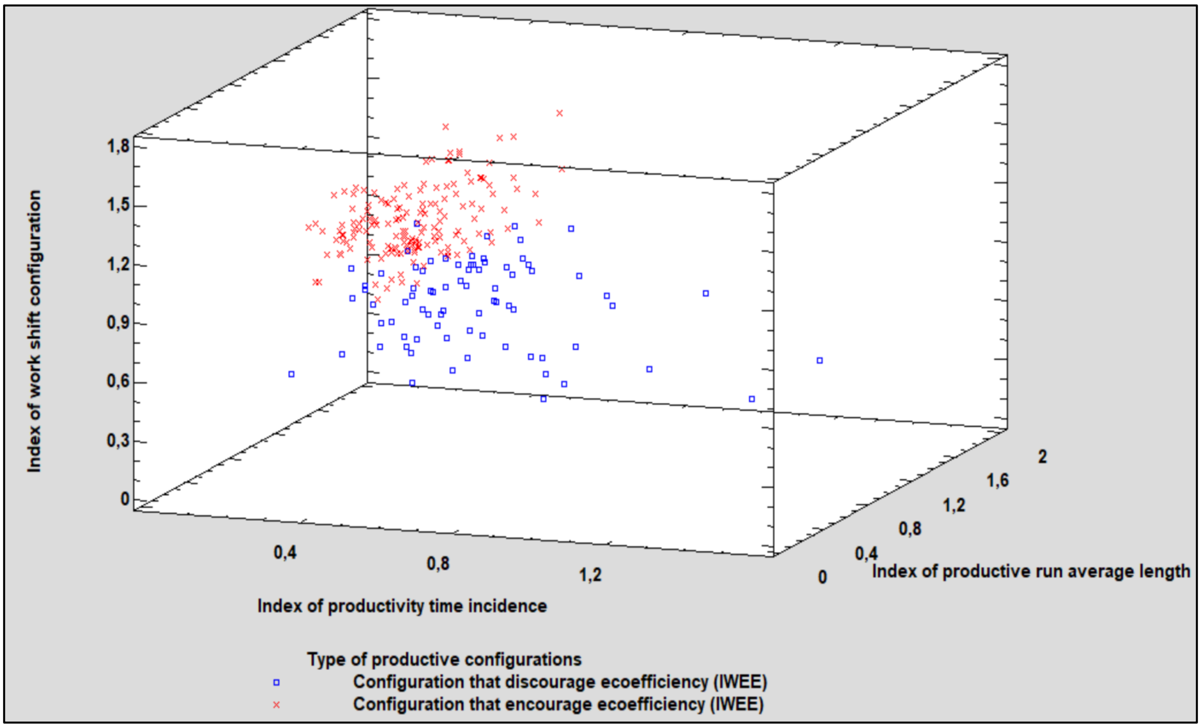


Table 72 3D scatterplot of results of statistical discriminant analysis. The chart considers three of five indexes.

The following discriminant function has been identified:

$$IWEE\ state = -0{,}421 \cdot I_{PTI} + 0{,}349 \cdot I_{RAL} + 0{,}283 \cdot I_{BLS} + 0{,}395 \cdot I_{WSC} + 0{,}559 \cdot I_{VP}$$

Therefore, the ecoeffciency is promoted by the reduction of I_{PTI} that corresponds to a reduction of the not productive time with the same productive time, or to an increase of production time with the same not productive time. It is promoted by the increase of the average length of productive run, by the increase of the bottling line speed, by the increase of the bottled volume and by the use of more intensive working shifts configuration that increase the hours of continuous production of the bottling line. Following the developed methodology, two thresholds have been identified in order to classify the results in the three different assessment classes.

- IPLE lower threshold: 1,250
- IPLE upper threshold: 1,489

Therefore, IPLE values higher than the upper threshold are classified in "Class 1", IPLE values lower the value of 1,250 have been classified in "Class 3". Therefore, the IPLE values that are included in the in interval between the two thresholds have been identified in "Class 2". It is important to underline, according with statistical theory on discriminant analysis, the values associate to the intermedia class (class 2 in this case) are considered uncertain. In this way the values in class 1 encourage ecoefficiency at the 95,0% confidence level, values in class 3 discourage ecoefficiency at the 95,0% confidence level, finally, values in class 2, being uncertain can have both behaviours but on average they are neutral. In fact, the following average values can be considered in the case of the bottling lines that realize water products:

- IPLE values in class 1 determines on average an increasing of IWEE of 7%;
- IPLE values in class 3 determines on average a reduction of IWEE of -13%;
- IPLE values in class 2 are about neutral (+0,1% of IWEE).

3.5.1.3. Use of IPLE to support IWEE trend analysis

The Index of Potential Loss of Ecoefficiency (IPLE) has been applied to the example previously made on the bottling line 53 to assess its capacity to support IWEE trend assessment. In the following two figures have been shown the fourth previously examples.

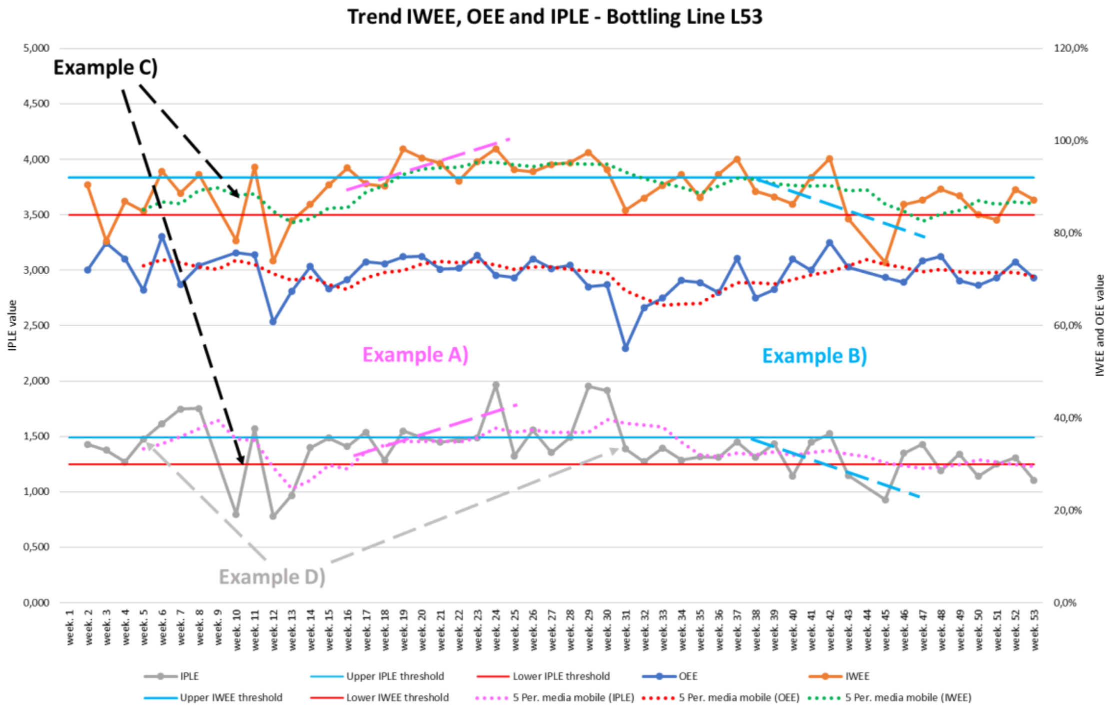


Table 73 Application of IPLE to support the IWEE assessment. The results refer to the bottling line L53.

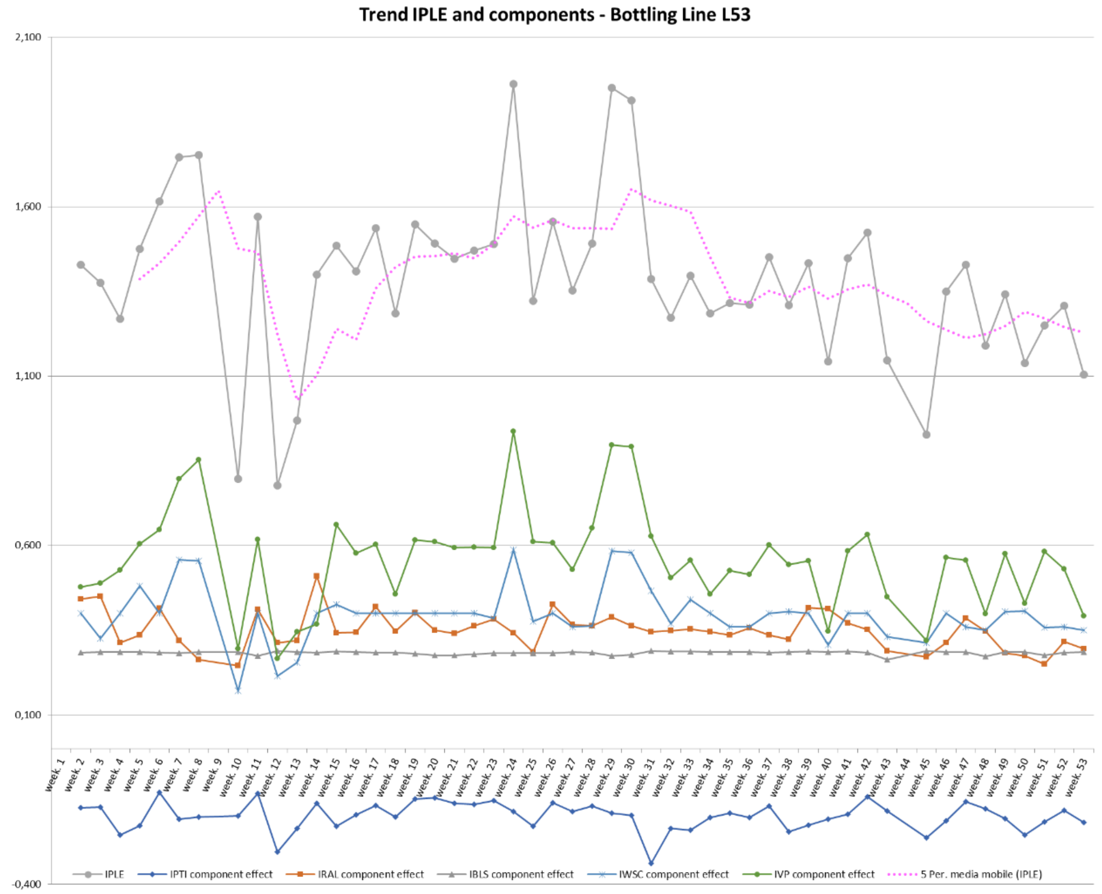


Table 74 Trend of IPLE and the weighted effects of its five components. The results refer to the bottling line L53

In the case of example A it is possible to notice as the increasing of IWEE is supported by an increasing of IPLE and therefore from an increasing of productive configurations that encourage the process ecoefficiency. The opposite reasoning can be done for the example B. In the case of the example C, the increasing of IWEE is associated to an increasing of IPLE that pass from the class 3 (week 10) to class 1 (week 11). The reason of this increasing can be found in the following figure, where it is possible to see how all IPLE components increase in the week 11. Finally, considering the example D, it is possible to see as the IPLE has about the same values in the weeks 5 and 31.

In the average, there is a correspondence of the 74% between the IPLE class and the IWEE class, therefore, in the case of the bottling lines that realized water products, the IPLE is able to explain the 74% of IWEE trend. If the cases where the IPLE is on the bottom of class 2 and IWEE in class 3 and the cases where IPLE is on the upper of the class 2 and IWEE in class 1 are considered acceptable, in the sense of not incorrect attribution, the correspondence increases to 97,5%. Therefore, only in the 2,5% of the case there is an incorrect attribution (IPLE in class 1 and IWEE in class 3 or the contrary). The incorrect attribution, is note in the discriminant analysis as the error of false attribution and exist for every model elaborate with this statistical technique.

3.5.1.4. Use of IPLE to support the elaboration of alternative scenarios

The IPLE can be used also to support the elaboration of alternative scenarios in order to simulate the effects of productive configurations. The following example has been elaborated for the bottling line L51 where a change of scheduled work shifts has been introduced in order to increase the index of work shift configuration to promote an increasing of ecoefficiency. The simulation has been conducted maintaining constant the total volume produced (equal to 117.684.916 litres/year), therefore only a partial temporal shift of volumes has been realized (according with figure 75). The double and the triple working shit have been favourite. In this case a total of 13 weeks (figure below) have been potentially improved in terms of IPLE class with a potential improvement of IWEE equal to +2,9% and therefore a potential economic saving related to resource consumptions equal to -6% and a potential saving of GHG emissions of -4,3%.

			BASE SCENARIO		ALTERNATIVE SCENARIO		ALTERNATIVE SCENARIO							BASE SCENARIO
		Season	Weekly work shifts	Wekly work days	Weekly work shifts	Wekly work days								
Week	Month	BS/MS/AS	shifts/week	days/week	shifts/week	days/week	IPTI	IRAL	IBLS	IWSC	IVP	IPLE score	IPLE class	IPLE class
sett. 2	january	Low season	12,75	6,0	12,8	6,0	0,313	0,892	1,007	0,912	0,881	1,317	CL2	CL2
sett. 3	january	Low season	15,00	6,0	15,0	6,0	0,294	1,464	1,005	1,073	1,050	1,682	CL1	CL1
sett. 4	february	Low season	15,00	6,0	15,0	6,0	0,637	0,662	0,989	1,073	0,817	1,123	CL3	CL3
sett. 5	february	Low season	14,75	6,0	14,8	6,0	0,331	1,018	0,999	1,055	0,998	1,473	CL2	CL2
sett. 6	february	Low season	14,00	6,0	14,0	6,0	0,279	1,106	1,003	1,001	0,990	1,501	CL1	CL1
sett. 7	february	Low season	10,00	5,0	10,0	5,0	0,300	0,863	0,979	0,858	0,679	1,171	CL3	CL3
sett. 8	february	Low season	15,00	6,0	15,0	6,0	0,211	0,963	1,003	1,073	1,120	1,581	CL1	CL1
sett. 9	february	Low season	10,00	5,0	15,0	5,0	0,220	0,753	1,001	1,288	1,110	1,583	CL1	CL3
sett. 10	march	Low season	15,00	6,0	15,0	6,0	0,205	1,144	0,996	1,073	1,117	1,643	CL1	CL1
sett. 11	march	Low season	15,00	6,0	15,0	6,0	0,307	0,829	1,005	1,073	1,040	1,449	CL2	CL2
sett. 12	march	Low season	12,00	6,0	15,0	6,0	0,174	0,861	1,005	1,073	1,157	1,582	CL1	CL2
sett. 13	march	Low season	13,00	6,0	15,0	6,0	0,218	0,899	1,003	1,073	1,113	1,551	CL1	CL2
sett. 14	march	Low season	8,00	4,0	15,0	6,0	0,254	1,611	1,003	1,073	1,081	1,767	CL1	CL2
sett. 15	april	Medium season	15,00	6,0	15,0	6,0	0,180	1,606	0,996	1,073	1,141	1,828	CL1	CL1
sett. 16	april	Medium season	18,00	7,0	15,0	6,0	0,209	1,075	1,003	1,073	1,122	1,622	CL1	CL1
sett. 17	april	Medium season	18,00	7,0	15,0	6,0	0,262	1,201	1,002	1,073	1,073	1,616	CL1	CL1
sett. 18	april	Medium season	15,00	6,0	15,0	6,0	0,219	0,829	0,997	1,073	1,106	1,521	CL1	CL1
sett. 19	may	High season	18,00	7,0	15,0	6,0	0,128	1,008	0,970	1,073	1,163	1,646	CL1	CL1
sett. 20	may	High season	18,00	7,0	15,0	6,0	0,129	0,948	0,953	1,073	1,141	1,608	CL1	CL1
sett. 21	may	High season	15,00	6,0	15,0	6,0	0,127	1,345	0,965	1,073	1,158	1,760	CL1	CL1
sett. 22	may	High season	13,00	6,0	15,0	6,0	0,241	1,513	0,953	1,073	1,038	1,701	CL1	CL1
sett. 23	june	High season	12,00	5,0	15,0	6,0	0,185	0,787	0,984	1,073	1,122	1,526	CL1	CL2
sett. 24	june	High season	19,00	7,0	15,0	6,0	0,298	1,137	0,998	1,073	1,039	1,558	CL1	CL1
sett. 25	june	High season	20,00	7,0	15,0	6,0	0,195	1,127	1,000	1,073	1,131	1,651	CL1	CL1
sett. 26	june	High season	18,00	7,0	15,0	6,0	0,255	0,966	1,001	1,073	1,079	1,540	CL1	CL1
sett. 27	june	High season	20,00	7,0	15,0	6,0	0,201	1,202	0,999	1,073	1,125	1,670	CL1	CL1
sett. 28	july	High season	20,00	7,0	15,0	6,0	0,169	1,235	1,001	1,073	1,158	1,714	CL1	CL1
sett. 29	july	High season	20,00	7,0	15,0	6,0	0,154	1,094	0,987	1,073	1,156	1,667	CL1	CL1
sett. 30	july	High season	20,00	7,0	15,0	6,0	0,159	1,162	0,981	1,073	1,144	1,679	CL1	CL1
sett. 31	july	High season	15,00	6,0	15,0	6,0	0,241	0,873	1,003	1,073	1,093	1,522	CL1	CL1
sett. 32	august	Medium season	15,00	6,0	15,0	6,0	0,214	0,960	1,003	1,073	1,117	1,577	CL1	CL1
sett. 33	august	Medium season	14,00	6,0	15,0	6,0	0,227	0,887	1,007	1,073	1,110	1,543	CL1	CL2
sett. 34	august	Medium season	8,00	4,0	12,0	5,0	0,183	0,854	1,004	1,030	0,918	1,425	CL2	CL3
sett. 35	august	Medium season	5,50	5,0	12,0	5,0	0,188	0,585	0,991	1,030	0,902	1,316	CL2	CL3
sett. 36	september	Medium season	10,00	5,0	12,0	5,0	0,224	0,825	1,005	1,030	0,888	1,381	CL2	CL3
sett. 37	september	Medium season	9,00	5,0	12,0	5,0	0,180	0,857	1,004	1,030	0,921	1,429	CL2	CL3
sett. 38	september	Medium season	11,25	5,0	12,0	5,0	0,274	0,893	0,968	1,030	0,822	1,336	CL2	CL2
sett. 39	september	Medium season	14,00	6,0	12,0	5,0	0,318	0,826	1,004	1,030	0,824	1,306	CL2	CL2
sett. 40	september	Medium season	15,00	6,0	15,0	6,0	0,253	0,864	1,004	1,073	1,083	1,508	CL1	CL1
sett. 41	october	Low season	15,00	6,0	15,0	6,0	0,217	0,889	1,003	1,073	1,113	1,549	CL1	CL1
sett. 42	october	Low season	10,00	5,0	12,0	5,0	0,203	0,934	1,006	1,030	0,905	1,438	CL2	CL2
sett. 43	october	Low season	12,00	7,0	12,0	5,0	0,227	0,706	1,004	1,030	0,885	1,336	CL2	CL3
sett. 44	october	Low season	10,00	5,0	12,0	5,0	0,273	0,882	1,004	1,030	0,853	1,361	CL2	CL3
sett. 45	november	Low season	10,00	5,0	12,0	5,0	0,170	0,863	1,003	1,030	0,927	1,439	CL2	CL2
sett. 47	november	Low season	12,13	6,0	12,9	6,0	0,327	0,769	0,988	0,921	0,856	1,252	CL2	CL3
sett. 48	november	Low season	12,00	5,0	12,0	5,0	0,192	1,131	0,997	1,030	0,905	1,509	CL1	CL1
sett. 49	dicember	Low season	10,00	5,0	10,0	5,0	0,203	0,840	1,004	0,858	0,752	1,251	CL2	CL2
sett. 50	dicember	Low season	9,00	4,0	9,0	4,0	0,286	0,785	0,872	0,966	0,550	1,089	CL3	CL3
sett. 51	dicember	Low season	15,00	6,0	15,0	6,0	0,233	1,117	1,004	1,073	1,100	1,615	CL1	CL1
sett. 52	dicember	Low season	13,00	5,0	13,0	5,0	0,214	1,353	0,998	1,116	0,964	1,644	CL1	CL1
sett. 53	dicember	Low season	6,00	3,0	6,0	3,0	0,227	0,989	1,005	0,858	0,443	1,121	CL3	CL3

Table 75 Effects on IPLE class due to changes in scheduled working shifts.

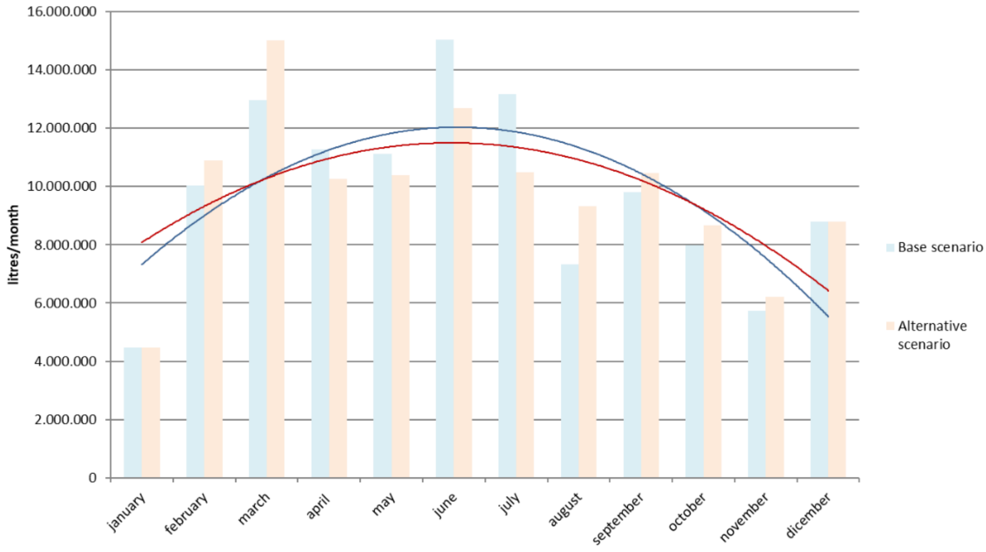


Table 76 Effects on monthly volumes produced due to changes in scheduled working shifts.

3.5.1.5. IWEE informatic implementation

According the methodology developed in the chapter 2, the IWEE has been informatized. A tool programmed in excel language has been developed and applied to every bottling line. The tool is based on four components (see following figures):

- IWEE - Data logger: where the data are automatically feed using programmed links with EID interfaces;
- IWEE – IPLE calculator: where the variables on productive configuration are automatically acquired and elaborated to calculate the indexes and the IPLE;
- IWEE – IWEE calculator: where the sub component and the global score of IWEE are calculated;
- IWEE – IWEE Dashboard: where the results are summarized in order to simplify the monitoring and the assessment of IWEE.

The data have been elaborated starting from data extracted by business informatic systems (BISs) of the organization. It is important to underline that specific modules to calculate some variables have been required. In fact, for example, the data on productive run average length did not exist and therefore it has been obtained elaborating an excel interface that re-elaborate a data report file that contains the hourly production for every day of the year diversifying the products in function of the specific rotation index that is an element that permits to group products of the same format.

				CONSUMPTIONS								
				ENERGY			HYGIENIC TRATMENTS					SCRAPS
			State of the line	Electricity direct consumption	Electricity indirect consumption	Thermal energy consumption	Frequency Alkaline CIP treatments	Frequency Acid CIP treatments	Frequency of filling of circuit of the rinsing machine treatments	Frequency of filling of bowl of the rinsing machine treatments	Frequency COP treatments	Raw material scraps %
Week	Low/Medium/High Season	Bottling line	Productive or not	kWh/week	kWh/week	Sm3/week	n°/week	n°/week	n°/week	n°/week	n°/week	%
week. 1	Low season	L53	Not productive	199	0	0	0	0	0	0	0	0,00%
week. 2	Low season	L53	Productive	10.272	24.362	2.770	1	1	3	1	7	0,64%
week. 3	Low season	L53	Productive	10.921	24.928	2.834	1	0	0	1	4	0,54%
week. 4	Low season	L53	Productive	11.688	29.355	2.023	2	0	5	1	10	0,52%
week. 5	Low season	L53	Productive	14.260	33.662	2.320	2	0	3	1	8	0,52%
week. 6	Low season	L53	Productive	13.294	32.917	1.064	1	1	4	1	9	0,53%
week. 7	Low season	L53	Productive	17.259	40.569	1.311	2	0	1	1	6	0,98%
week. 8	Low season	L53	Productive	17.371	46.581	1.577	2	0	1	1	6	1,01%
week. 9	Low season	L53	Not productive	611	0	0	0	0	1	0	1	0,00%
week. 10	Low season	L53	Productive	7.648	13.251	295	1	1	4	1	9	0,92%
week. 11	Low season	L53	Productive	12.548	27.772	618	2	0	4	1	9	0,48%
week. 12	Low season	L53	Productive	7.318	13.057	517	1	1	4	1	9	1,57%
week. 13	Low season	L53	Productive	8.445	16.919	670	2	0	4	1	9	0,70%
week. 14	Low season	L53	Productive	7.755	17.954	711	1	0	3	1	6	0,31%
week. 15	Medium season	L53	Productive	13.978	30.670	512	1	1	4	1	9	1,17%
week. 16	Medium season	L53	Productive	11.721	26.787	447	2	0	4	1	9	0,92%
week. 17	Medium season	L53	Productive	12.115	28.697	443	1	0	5	1	10	0,76%
week. 18	Medium season	L53	Productive	9.532	21.744	336	2	0	4	1	9	0,49%
week. 19	High season	L53	Productive	11.845	27.649	366	1	1	4	1	9	0,50%
week. 20	High season	L53	Productive	12.062	27.427	363	2	0	4	1	9	0,48%
week. 21	High season	L53	Productive	11.903	25.584	338	2	0	4	1	9	0,58%
week. 22	High season	L53	Productive	11.854	25.669	339	1	0	5	1	10	0,56%
week. 23	High season	L53	Productive	11.533	25.474	245	1	1	5	1	11	0,47%
week. 24	High season	L53	Productive	17.976	40.235	386	2	0	1	1	6	0,57%
week. 25	High season	L53	Productive	12.511	25.785	319	2	0	5	1	11	0,59%
week. 26	High season	L53	Productive	11.785	25.697	318	1	0	5	1	10	0,45%
week. 27	High season	L53	Productive	10.643	22.307	276	2	0	4	1	9	0,63%
week. 28	High season	L53	Productive	13.008	26.398	277	1	1	4	1	9	0,74%
week. 29	High season	L53	Productive	17.286	36.318	382	2	0	1	1	6	0,77%
week. 30	High season	L53	Productive	17.333	37.562	376	1	0	1	1	7	0,85%
week. 31	High season	L53	Productive	14.106	26.447	265	2	0	1	1	6	1,73%
week. 32	Medium season	L53	Productive	11.163	22.997	229	1	1	4	1	9	1,18%
week. 33	Medium season	L53	Productive	11.698	25.336	253	2	0	4	1	9	1,34%
week. 34	Medium season	L53	Productive	9.511	21.990	215	2	0	3	1	7	0,59%
week. 35	Medium season	L53	Productive	11.035	25.291	247	1	0	5	1	10	0,87%
week. 36	Medium season	L53	Productive	10.677	26.399	284	1	1	4	1	9	0,75%
week. 37	Medium season	L53	Productive	11.934	30.934	333	2	0	4	1	9	0,57%
week. 38	Medium season	L53	Productive	11.852	27.879	300	2	0	4	1	9	0,98%
week. 39	Medium season	L53	Productive	11.464	23.123	176	1	0	5	1	10	1,13%
week. 40	Medium season	L53	Productive	7.639	14.448	110	1	0	2	1	5	0,77%
week. 41	Low season	L53	Productive	11.979	32.705	796	1	1	4	1	9	1,06%
week. 42	Low season	L53	Productive	12.492	35.364	861	2	0	4	1	9	0,52%
week. 43	Low season	L53	Productive	10.329	28.938	774	1	0	4	1	10	0,73%
week. 44	Low season	L53	Not productive	455	0	0	2	0	4	1	9	0,00%
week. 45	Low season	L53	Productive	8.429	18.857	1.134	1	1	4	0	8	1,42%
week. 46	Low season	L53	Productive	12.732	33.319	2.005	2	0	4	1	9	0,94%
week. 47	Low season	L53	Productive	11.784	33.361	1.996	1	0	5	1	10	0,67%
week. 48	Low season	L53	Productive	8.701	23.918	1.431	2	0	3	1	7	0,00%
week. 49	Low season	L53	Productive	12.757	35.914	5.441	1	1	4	1	9	0,80%
week. 50	Low season	L53	Productive	10.255	26.721	4.048	2	0	3	1	7	0,52%
week. 51	Low season	L53	Productive	13.396	36.312	5.501	1	0	5	1	12	0,79%
week. 52	Low season	L53	Productive	11.588	30.244	3.220	2	0	4	1	9	0,51%
week. 53	Low season	L53	Productive	8.857	22.308	2.375	1	1	3	1	7	0,00%

	KEY PERFORMANCE INDICATORS								
	ENERGY			HYGIENIC TRATMENTS					SCRAPS
	KPI electricity direct	KPI electricity indirect	KPI thermal energy	KPI Frequency Alkaline CIP treatments	KPI Frequency Acid CIP treatments	KPI Frequency of filling of circuit of the rinsing machine treatments	KPI Frequency of filling of bowl of the rinsing machine treatments	KPI Frequency COP treatments	KPI Raw material scraps %
Week	kWh/1000 litres	kWh/1000 litres	Sm3/1000 litres	n°/week	n°/week	n°/week	n°/week	n°/week	%
week. 1	0,00	7,06	0,80	0	0	0	0	0	0,00%
week. 2	2,98	7,06	0,80	1	1	3	1	7	0,64%
week. 3	3,10	7,06	0,80	1	0	0	1	4	0,54%
week. 4	3,07	7,71	0,53	2	0	5	1	10	0,52%
week. 5	3,27	7,71	0,53	2	0	3	1	8	0,52%
week. 6	2,85	7,05	0,23	1	1	4	1	9	0,53%
week. 7	3,00	7,05	0,23	2	0	1	1	6	0,98%
week. 8	2,82	7,56	0,26	2	0	1	1	6	1,01%
week. 9	0,00	7,56	0,26	0	0	1	0	1	0,00%
week. 10	3,59	6,22	0,14	1	1	4	1	9	0,92%
week. 11	2,81	6,22	0,14	2	0	4	1	9	0,48%
week. 12	3,80	6,77	0,27	1	1	4	1	9	1,57%
week. 13	3,38	6,77	0,27	2	0	4	1	9	0,70%
week. 14	2,93	6,77	0,27	1	0	3	1	6	0,31%
week. 15	2,93	6,42	0,11	1	1	4	1	9	1,17%
week. 16	2,81	6,42	0,11	2	0	4	1	9	0,92%
week. 17	2,78	6,59	0,10	1	0	5	1	10	0,76%
week. 18	2,89	6,59	0,10	2	0	4	1	9	0,49%
week. 19	2,66	6,21	0,08	1	1	4	1	9	0,50%
week. 20	2,73	6,21	0,08	2	0	4	1	9	0,48%
week. 21	2,78	5,97	0,08	2	0	4	1	9	0,58%
week. 22	2,76	5,97	0,08	1	0	5	1	10	0,56%
week. 23	2,69	5,94	0,06	1	1	5	1	11	0,47%
week. 24	2,66	5,94	0,06	2	0	1	1	6	0,57%
week. 25	2,84	5,84	0,07	2	0	5	1	11	0,59%
week. 26	2,68	5,84	0,07	1	0	5	1	10	0,45%
week. 27	2,79	5,84	0,07	2	0	4	1	9	0,63%
week. 28	2,76	5,60	0,06	1	1	4	1	9	0,74%
week. 29	2,67	5,60	0,06	2	0	1	1	6	0,77%
week. 30	2,69	5,83	0,06	1	0	1	1	7	0,85%
week. 31	3,11	5,83	0,06	2	0	1	1	6	1,73%
week. 32	3,06	6,30	0,06	1	1	4	1	9	1,18%
week. 33	2,91	6,30	0,06	2	0	4	1	9	1,34%
week. 34	2,88	6,66	0,07	2	0	3	1	7	0,59%
week. 35	2,90	6,66	0,07	1	0	5	1	10	0,87%
week. 36	2,87	7,11	0,08	1	1	4	1	9	0,75%
week. 37	2,74	7,11	0,08	2	0	4	1	9	0,57%
week. 38	3,02	7,11	0,08	2	0	4	1	9	0,98%
week. 39	2,86	5,76	0,04	1	0	5	1	10	1,13%
week. 40	3,05	5,76	0,04	1	0	2	1	5	0,77%
week. 41	2,84	7,75	0,19	1	1	4	1	9	1,06%
week. 42	2,74	7,75	0,19	2	0	4	1	9	0,52%
week. 43	3,18	8,92	0,24	1	0	4	1	10	0,73%
week. 44	0,00	8,92	0,24	2	0	4	1	9	0,00%
week. 45	3,65	8,17	0,49	1	1	4	0	8	1,42%
week. 46	3,12	8,17	0,49	2	0	4	1	9	0,94%
week. 47	2,93	8,30	0,50	1	0	5	1	10	0,67%
week. 48	3,02	8,30	0,50	2	0	3	1	7	0,00%
week. 49	3,06	8,62	1,31	1	1	4	1	9	0,80%
week. 50	3,31	8,62	1,31	2	0	3	1	7	0,52%
week. 51	3,18	8,62	1,31	1	0	5	1	12	0,79%
week. 52	3,02	7,89	0,84	2	0	4	1	9	0,51%
week. 53	3,13	7,89	0,84	1	1	3	1	7	0,00%

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Table 77 IWEE – Data logger component

			State of the line	DATABASE OF VARIABLES ON PRODUCTIVE CONFIGURATIONS													
				Production time	Time for scheduled maintenance	Time for format changes	Time for hygienic treatments	Time lost for failures and micro arrests	Time lost for defects	Not productive time	Production run average length	Volum produced	Number of product codes	Number of format changes	Delayed to reach the cruise speed	Hourly bottling line speed	Work shift configuration
Week	Low/Medium/High Season	Bottling line	Productive or not	min/week	min/week	min/week	min/week	min/week	min/week	min/week	hours/run	litres/week	n° PC/week	n° FC/week	bottles/hour	bottles/hour	shifts/day
week. 1	Low season	L53	Not productive	-	-	-	-	-	-	-	-	-	-	-	-	-	-
week. 2	Low season	L53	Productive	2715	0	91	92	733	209	942	5,03	3.448.514	9	5	-2.204	38.105	2,0
week. 3	Low season	L53	Productive	2762	174	89	60	715	100	815	5,11	3.528.620	9	5	-4.808	38.327	1,6
week. 4	Low season	L53	Productive	2989	120	141	25	743	92	835	3,56	3.807.312	14	9	-7.997	38.213	2,0
week. 5	Low season	L53	Productive	3424	130	146	112	1345	123	1468	3,80	4.365.932	15	10	-1.780	38.253	2,4
week. 6	Low season	L53	Productive	3675	120	132	45	718	110	828	4,71	4.668.402	13	8	-7.732	38.109	2,0
week. 7	Low season	L53	Productive	4571	120	216	129	1632	162	1794	3,63	5.753.728	21	15	521	37.762	2,8
week. 8	Low season	L53	Productive	4828	120	195	113	1430	154	1584	2,98	6.164.766	27	21	3.195	38.306	2,8
week. 9	Low season	L53	Not productive	-	-	-	-	-	-	-	-	-	-	-	-	-	-
week. 10	Low season	L53	Productive	1671	136	84	10	354	82	436	2,79	2.131.552	10	4	-6.004	38.268	0,9
week. 11	Low season	L53	Productive	3649	0	122	135	785	109	894	4,68	4.467.330	13	8	-5.426	36.728	2,0
week. 12	Low season	L53	Productive	1496	120	614	10	334	6	340	3,56	1.927.786	7	2	-6.202	38.659	1,1
week. 13	Low season	L53	Productive	1960	120	100	0	593	277	870	3,63	2.498.062	9	4	-6.147	38.236	1,3
week. 14	Low season	L53	Productive	2083	0	79	15	392	308	700	5,79	2.650.920	6	3	-3.624	38.179	2,0
week. 15	Medium season	L53	Productive	3731	120	184	72	377	1252	1629	3,89	4.776.960	16	10	-113	38.410	2,1
week. 16	Medium season	L53	Productive	3276	120	179	15	274	936	1210	3,90	4.172.180	14	9	-2.847	38.207	2,0
week. 17	Medium season	L53	Productive	3431	120	116	37	349	733	1082	4,77	4.355.148	12	7	-3.808	38.081	2,0
week. 18	Medium season	L53	Productive	2596	120	91	15	302	549	851	3,93	3.299.940	11	7	131	38.135	2,0
week. 19	High season	L53	Productive	3551	130	160	0	350	659	1009	4,55	4.453.682	13	8	-5.362	37.626	2,0
week. 20	High season	L53	Productive	3573	120	142	49	433	572	1005	3,97	4.418.004	15	10	-5.909	37.095	2,0
week. 21	High season	L53	Productive	3472	130	167	10	551	530	1081	3,86	4.286.050	15	10	-3.579	37.034	2,0
week. 22	High season	L53	Productive	3455	120	156	7	552	557	1109	4,11	4.300.362	14	9	-4.565	37.340	2,0
week. 23	High season	L53	Productive	3388	120	126	15	448	486	934	4,34	4.285.532	13	8	-1.008	37.947	1,9
week. 24	High season	L53	Productive	5371	120	215	152	1069	804	1873	3,89	6.768.714	23	17	-1.190	37.807	2,9
week. 25	High season	L53	Productive	3496	120	167	50	890	492	1382	3,24	4.413.034	18	12	-4.554	37.869	1,9
week. 26	High season	L53	Productive	3479	120	117	40	588	456	1044	4,83	4.397.916	12	7	-5.917	37.924	2,0
week. 27	High season	L53	Productive	2997	205	123	27	563	405	968	4,16	3.817.766	12	7	-2.631	38.216	1,8
week. 28	High season	L53	Productive	3717	120	144	26	629	577	1206	4,13	4.712.302	15	9	-3.491	38.033	1,8
week. 29	High season	L53	Productive	5291	0	154	181	1255	765	2020	4,41	6.482.944	20	14	-2.580	36.758	2,9
week. 30	High season	L53	Productive	5197	120	112	139	1282	731	2013	4,12	6.445.626	21	15	-3.835	37.208	2,9
week. 31	High season	L53	Productive	3521	120	109	68	1834	708	2542	3,91	4.538.314	15	9	-2.108	38.668	2,3
week. 32	Medium season	L53	Productive	2845	0	120	20	950	497	1447	3,95	3.649.296	12	7	-9.110	38.481	1,9
week. 33	Medium season	L53	Productive	3132	120	116	14	902	622	1524	4,02	4.020.508	13	8	-1.187	38.511	2,2
week. 34	Medium season	L53	Productive	2592	120	114	0	613	395	1008	3,93	3.303.092	11	7	-3.932	38.230	2,0
week. 35	Medium season	L53	Productive	2971	0	162	0	701	458	1159	3,81	3.799.088	13	8	-3.875	38.362	1,8
week. 36	Medium season	L53	Productive	2911	0	148	0	844	414	1258	4,04	3.713.766	12	7	-7.050	38.273	1,8
week. 37	Medium season	L53	Productive	3421	120	98	85	572	497	1069	3,80	4.351.736	15	10	-4.055	38.162	2,0
week. 38	Medium season	L53	Productive	3070	120	64	70	984	531	1515	3,65	3.921.954	14	9	-2.478	38.325	2,0
week. 39	Medium season	L53	Productive	3125	120	61	80	879	535	1414	4,73	4.011.958	11	6	-3.439	38.515	2,0
week. 40	Medium season	L53	Productive	1967	52	65	45	524	282	806	4,68	2.506.778	7	3	-6.562	38.349	1,5
week. 41	Low season	L53	Productive	3290	120	102	105	654	524	1178	4,22	4.221.022	13	8	-3.259	38.490	2,0
week. 42	Low season	L53	Productive	3587	120	114	75	340	556	896	3,99	4.564.280	15	10	-4.408	38.174	2,0
week. 43	Low season	L53	Productive	2758	120	121	31	533	397	930	3,28	3.244.350	14	9	-5.792	35.290	1,7
week. 44	Low season	L53	Not productive	-	-	-	-	-	-	-	-	-	-	-	-	-	-
week. 45	Low season	L53	Productive	1847	2	318	0	434	399	833	3,08	2.307.552	10	6	-1.149	38.690	1,6
week. 46	Low season	L53	Productive	3191	120	108	90	792	491	1283	3,55	4.077.198	15	10	-3.205	38.332	2,0
week. 47	Low season	L53	Productive	3150	0	61	48	615	446	1061	4,38	4.017.808	12	7	-98	38.265	1,8
week. 48	Low season	L53	Productive	2364	120	48	101	399	328	727	3,94	2.880.632	10	6	-4.601	36.556	1,8
week. 49	Low season	L53	Productive	3264	120	102	77	757	540	1297	3,20	4.163.948	17	12	-3.540	38.272	2,0
week. 50	Low season	L53	Productive	2429	120	89	60	634	382	1016	3,11	3.098.124	13	9	-3.031	38.264	2,0
week. 51	Low season	L53	Productive	3409	120	113	75	554	649	1203	2,84	4.210.110	20	14	-2.918	37.050	1,8
week. 52	Low season	L53	Productive	3013	0	49	71	499	552	1051	3,59	3.831.772	14	9	-4.500	38.152	1,8
week. 53	Low season	L53	Productive	2215	120	52	160	389	415	804	3,36	2.826.380	11	7	-1.626	38.281	1,8

	INDEX OF POTENTIAL LOSS OF ECOEFFICIENCY						
	Index of productive time incidence	Index of productive run average lenght	Index of hourly bottling line speed	Index of work shift configuration	Index of valume produced	Index of Potential Loss of Ecoefficiency	
Week	-	-	-	-	-	Score	Class
week. 1	-	-	-	-	-	-	-
week. 2	0,414	1,268	1,003	1,012	0,853	1,429	CL2
week. 3	0,412	1,289	1,009	0,822	0,873	1,375	CL2
week. 4	0,606	0,897	1,006	1,012	0,942	1,269	CL2
week. 5	0,542	0,959	1,007	1,215	1,080	1,475	CL2
week. 6	0,306	1,188	1,003	1,012	1,155	1,615	CL1
week. 7	0,496	0,915	0,994	1,413	1,424	1,745	CL1
week. 8	0,479	0,751	1,008	1,402	1,525	1,753	CL1
week. 9	-	-	-	-	-	-	-
week. 10	0,472	0,702	1,007	0,432	0,527	0,797	CL3
week. 11	0,315	1,179	0,967	1,012	1,105	1,570	CL1
week. 12	0,725	0,898	1,017	0,544	0,477	0,778	CL3
week. 13	0,561	0,915	1,006	0,645	0,618	0,968	CL3
week. 14	0,383	1,459	1,005	1,012	0,656	1,399	CL2
week. 15	0,544	0,980	1,011	1,075	1,182	1,485	CL2
week. 16	0,465	0,983	1,005	1,012	1,032	1,409	CL2
week. 17	0,399	1,201	1,002	1,012	1,078	1,537	CL1
week. 18	0,479	0,992	1,004	1,012	0,817	1,285	CL2
week. 19	0,352	1,148	0,990	1,012	1,102	1,549	CL1
week. 20	0,343	1,001	0,976	1,012	1,093	1,492	CL1
week. 21	0,382	0,973	0,975	1,012	1,061	1,447	CL2
week. 22	0,389	1,037	0,983	1,012	1,064	1,471	CL2
week. 23	0,364	1,095	0,999	0,974	1,060	1,489	CL1
week. 24	0,441	0,981	0,995	1,487	1,675	1,962	CL1
week. 25	0,545	0,816	0,997	0,949	1,092	1,323	CL2
week. 26	0,380	1,218	0,998	1,012	1,088	1,556	CL1
week. 27	0,441	1,049	1,006	0,911	0,945	1,353	CL2
week. 28	0,404	1,041	1,001	0,917	1,166	1,491	CL1
week. 29	0,452	1,112	0,967	1,476	1,604	1,951	CL1
week. 30	0,466	1,040	0,979	1,466	1,595	1,914	CL1
week. 31	0,806	0,986	1,018	1,181	1,123	1,387	CL2
week. 32	0,561	0,996	1,013	0,936	0,903	1,273	CL2
week. 33	0,571	1,012	1,013	1,113	0,995	1,396	CL2
week. 34	0,481	0,990	1,006	1,012	0,817	1,284	CL2
week. 35	0,454	0,960	1,010	0,911	0,940	1,315	CL2
week. 36	0,484	1,019	1,007	0,911	0,919	1,311	CL2
week. 37	0,403	0,958	1,004	1,012	1,077	1,451	CL2
week. 38	0,583	0,921	1,009	1,025	0,970	1,309	CL2
week. 39	0,536	1,194	1,014	1,012	0,993	1,433	CL2
week. 40	0,495	1,181	1,009	0,775	0,620	1,142	CL3
week. 41	0,459	1,063	1,013	1,012	1,045	1,448	CL2
week. 42	0,338	1,005	1,005	1,012	1,129	1,524	CL1
week. 43	0,436	0,828	0,929	0,835	0,803	1,147	CL3
week. 44	-	-	-	-	-	-	-
week. 45	0,624	0,776	1,018	0,791	0,571	0,928	CL3
week. 46	0,504	0,894	1,009	1,012	1,009	1,349	CL2
week. 47	0,371	1,103	1,007	0,911	0,994	1,429	CL2
week. 48	0,421	0,993	0,962	0,886	0,713	1,190	CL3
week. 49	0,489	0,807	1,007	1,025	1,030	1,341	CL2
week. 50	0,606	0,785	1,007	1,028	0,767	1,139	CL3
week. 51	0,514	0,716	0,975	0,907	1,042	1,250	CL3
week. 52	0,434	0,904	1,004	0,911	0,948	1,307	CL2
week. 53	0,517	0,846	1,007	0,886	0,699	1,104	CL3

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Table 78 IWEE – IPLE calculator component

Week	Low/Medium/High Season	Bottling line	State of the line: Productive or not	ASSESSMENT OF IWEE COMPONENTS – ENERGY: IWEE electricity direct subcomponent (%)	ENERGY: IWEE electricity indirect subcomponent (%)	ENERGY: IWEE thermal energy subcomponent (%)	HYGIENIC TREATMENTS: IWEE Frequency Alkaline CIP treatments subcomponent (%)	HYGIENIC TREATMENTS: IWEE Frequency Acid CIP treatments subcomponent (%)	HYGIENIC TREATMENTS: IWEE Frequency of filling of circuit of the rinsing machine treatments subcomponent (%)	HYGIENIC TREATMENTS: IWEE Frequency of filling of bowl of the rinsing machine treatments subcomponent (%)	HYGIENIC TREATMENTS: IWEE Frequency COP treatments subcomponent (%)	SCRAPS: IWEE Raw material scraps % subcomponent (%)
week. 1	Low season	L53	Not productive	#N/D	#N/D	#N/D	#N/D	#N/D	#N/D	#N/D	#N/D	#N/D
week. 2	Low season	L53	Productive	87,1%	100,0%	65,7%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
week. 3	Low season	L53	Productive	83,8%	100,0%	65,7%	100,0%	0,0%	0,0%	100,0%	100,0%	100,0%
week. 4	Low season	L53	Productive	84,5%	98,9%	99,2%	100,0%	100,0%	80,0%	100,0%	90,0%	100,0%
week. 5	Low season	L53	Productive	79,4%	98,9%	99,2%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
week. 6	Low season	L53	Productive	91,1%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
week. 7	Low season	L53	Productive	86,5%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	70,6%
week. 8	Low season	L53	Productive	92,1%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	68,6%
week. 9	Low season	L53	Not productive	#N/D	#N/D	#N/D	#N/D	#N/D	#N/D	#N/D	#N/D	#N/D
week. 10	Low season	L53	Productive	72,3%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	75,9%
week. 11	Low season	L53	Productive	92,4%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
week. 12	Low season	L53	Productive	68,4%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	44,3%
week. 13	Low season	L53	Productive	76,8%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	98,7%
week. 14	Low season	L53	Productive	88,7%	100,0%	100,0%	100,0%	0,0%	66,7%	100,0%	83,3%	100,0%
week. 15	Medium season	L53	Productive	88,7%	100,0%	71,1%	100,0%	100,0%	100,0%	100,0%	100,0%	75,4%
week. 16	Medium season	L53	Productive	92,4%	100,0%	71,1%	100,0%	100,0%	100,0%	100,0%	100,0%	95,8%
week. 17	Medium season	L53	Productive	93,3%	99,0%	74,9%	100,0%	0,0%	80,0%	100,0%	90,0%	100,0%
week. 18	Medium season	L53	Productive	89,8%	99,0%	74,9%	100,0%	100,0%	75,0%	100,0%	77,8%	100,0%
week. 19	High season	L53	Productive	97,6%	95,0%	83,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
week. 20	High season	L53	Productive	95,0%	95,0%	83,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
week. 21	High season	L53	Productive	93,4%	98,8%	86,5%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
week. 22	High season	L53	Productive	94,1%	98,8%	86,5%	100,0%	0,0%	80,0%	100,0%	90,0%	100,0%
week. 23	High season	L53	Productive	96,4%	99,2%	100,0%	100,0%	100,0%	80,0%	100,0%	81,8%	100,0%
week. 24	High season	L53	Productive	97,7%	99,2%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
week. 25	High season	L53	Productive	91,5%	100,0%	94,5%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
week. 26	High season	L53	Productive	96,8%	100,0%	94,5%	100,0%	0,0%	80,0%	100,0%	90,0%	100,0%
week. 27	High season	L53	Productive	93,1%	100,0%	94,5%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
week. 28	High season	L53	Productive	94,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	92,8%
week. 29	High season	L53	Productive	97,3%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	88,9%
week. 30	High season	L53	Productive	96,5%	100,0%	100,0%	100,0%	0,0%	100,0%	100,0%	100,0%	81,0%
week. 31	High season	L53	Productive	83,5%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	39,6%
week. 32	Medium season	L53	Productive	84,8%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	75,3%
week. 33	Medium season	L53	Productive	89,2%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	66,0%
week. 34	Medium season	L53	Productive	90,1%	98,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
week. 35	Medium season	L53	Productive	89,3%	98,0%	100,0%	100,0%	0,0%	80,0%	100,0%	90,0%	100,0%
week. 36	Medium season	L53	Productive	90,3%	91,8%	99,7%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
week. 37	Medium season	L53	Productive	94,6%	91,8%	99,7%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
week. 38	Medium season	L53	Productive	85,9%	91,8%	99,7%	100,0%	100,0%	100,0%	100,0%	100,0%	90,4%
week. 39	Medium season	L53	Productive	90,8%	100,0%	100,0%	100,0%	0,0%	80,0%	100,0%	90,0%	78,6%
week. 40	Medium season	L53	Productive	85,1%	100,0%	100,0%	100,0%	0,0%	100,0%	100,0%	100,0%	100,0%
week. 41	Low season	L53	Productive	91,4%	98,4%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	65,6%
week. 42	Low season	L53	Productive	94,8%	98,4%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
week. 43	Low season	L53	Productive	81,5%	85,5%	100,0%	100,0%	0,0%	100,0%	100,0%	90,0%	95,3%
week. 44	Low season	L53	Not productive	#N/D	#N/D	#N/D	#N/D	#N/D	#N/D	#N/D	#N/D	#N/D
week. 45	Low season	L53	Productive	71,0%	93,3%	100,0%	100,0%	100,0%	75,0%	0,0%	87,5%	49,1%
week. 46	Low season	L53	Productive	83,1%	93,3%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	73,6%
week. 47	Low season	L53	Productive	88,5%	91,8%	100,0%	100,0%	0,0%	80,0%	100,0%	90,0%	100,0%
week. 48	Low season	L53	Productive	85,9%	91,8%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
week. 49	Low season	L53	Productive	84,7%	88,4%	40,4%	100,0%	100,0%	100,0%	100,0%	100,0%	87,3%
week. 50	Low season	L53	Productive	78,4%	88,4%	40,4%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
week. 51	Low season	L53	Productive	81,5%	88,4%	40,4%	100,0%	0,0%	100,0%	100,0%	91,7%	88,2%
week. 52	Low season	L53	Productive	85,8%	96,6%	62,7%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
week. 53	Low season	L53	Productive	82,8%	96,6%	62,7%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%

Week	IWEE FINAL RESULTS: IWEE ENERGY SCORE (%)	IWEE HYGIENIC TREATMENTS SCORE (%)	IWEE SCRAPS SCORE (%)	IWEE ENERGY CLASS (-)	IWEE HYGIENIC TREATMENTS CLASS (-)	IWEE SCRAPS CLASS (-)	IWEE SCORE (%)	IWEE CLASS (-)
week. 1	#N/D	#N/D	#N/D	FERMA	FERMA	FERMA	#N/D	FERMA
week. 2	87,1%	100,0%	100,0%	CL3	CL1	CL1	90,4%	CL2
week. 3	83,8%	54,2%	100,0%	CL3	CL3	CL1	78,3%	CL3
week. 4	84,5%	92,3%	100,0%	CL3	CL1	CL1	86,9%	CL2
week. 5	79,4%	100,0%	100,0%	CL3	CL1	CL1	84,8%	CL2
week. 6	91,1%	100,0%	100,0%	CL2	CL1	CL1	93,4%	CL1
week. 7	86,5%	100,0%	70,6%	CL3	CL1	CL3	88,6%	CL2
week. 8	92,1%	100,0%	68,6%	CL2	CL1	CL3	92,7%	CL1
week. 9	#N/D	#N/D	#N/D	FERMA	FERMA	FERMA	#N/D	FERMA
week. 10	72,3%	100,0%	75,9%	CL3	CL1	CL3	78,4%	CL3
week. 11	92,4%	100,0%	100,0%	CL2	CL1	CL1	94,3%	CL1
week. 12	68,4%	100,0%	44,3%	CL3	CL1	CL3	74,0%	CL3
week. 13	76,8%	100,0%	98,7%	CL3	CL1	CL1	82,7%	CL3
week. 14	88,7%	74,5%	100,0%	CL3	CL3	CL1	86,2%	CL2
week. 15	88,7%	100,0%	75,4%	CL3	CL1	CL3	90,5%	CL2
week. 16	92,4%	100,0%	95,8%	CL2	CL1	CL1	94,1%	CL1
week. 17	93,3%	79,6%	100,0%	CL2	CL3	CL1	90,7%	CL2
week. 18	89,8%	89,3%	100,0%	CL3	CL2	CL1	90,2%	CL2
week. 19	97,6%	100,0%	100,0%	CL1	CL1	CL1	98,2%	CL1
week. 20	95,0%	100,0%	100,0%	CL2	CL1	CL1	96,3%	CL1
week. 21	93,4%	100,0%	100,0%	CL2	CL1	CL1	95,1%	CL1
week. 22	94,1%	79,6%	100,0%	CL2	CL3	CL1	91,3%	CL2
week. 23	96,4%	91,4%	100,0%	CL1	CL1	CL1	95,5%	CL1
week. 24	97,7%	100,0%	100,0%	CL1	CL1	CL1	98,3%	CL1
week. 25	91,5%	100,0%	100,0%	CL2	CL1	CL1	93,7%	CL1
week. 26	96,8%	79,6%	100,0%	CL1	CL3	CL1	93,3%	CL1
week. 27	93,1%	100,0%	100,0%	CL2	CL1	CL1	94,9%	CL1
week. 28	94,0%	100,0%	92,8%	CL2	CL1	CL1	95,2%	CL1
week. 29	97,3%	100,0%	88,9%	CL1	CL1	CL2	97,5%	CL1
week. 30	96,5%	87,3%	81,0%	CL1	CL2	CL2	93,8%	CL1
week. 31	83,5%	100,0%	39,6%	CL3	CL1	CL3	85,0%	CL2
week. 32	84,8%	100,0%	75,3%	CL3	CL1	CL3	87,6%	CL2
week. 33	89,2%	100,0%	66,0%	CL3	CL1	CL3	90,4%	CL2
week. 34	90,1%	100,0%	100,0%	CL2	CL1	CL1	92,7%	CL1
week. 35	89,3%	79,6%	100,0%	CL3	CL3	CL1	87,8%	CL2
week. 36	90,3%	100,0%	100,0%	CL2	CL1	CL1	92,8%	CL1
week. 37	94,6%	100,0%	100,0%	CL2	CL1	CL1	96,0%	CL1
week. 38	85,9%	100,0%	90,4%	CL3	CL1	CL1	89,1%	CL2
week. 39	90,8%	79,6%	78,6%	CL2	CL3	CL3	87,9%	CL2
week. 40	85,1%	87,3%	100,0%	CL3	CL2	CL1	86,3%	CL2
week. 41	91,4%	100,0%	65,6%	CL2	CL1	CL3	92,1%	CL1
week. 42	94,8%	100,0%	100,0%	CL2	CL1	CL1	96,1%	CL1
week. 43	81,5%	86,2%	95,3%	CL3	CL2	CL1	83,1%	CL3
week. 44	#N/D	#N/D	#N/D	FERMA	FERMA	FERMA	#N/D	FERMA
week. 45	71,0%	88,2%	49,1%	CL3	CL2	CL3	73,7%	CL3
week. 46	83,1%	100,0%	73,6%	CL3	CL1	CL3	86,2%	CL2
week. 47	88,5%	79,6%	100,0%	CL3	CL3	CL1	87,1%	CL2
week. 48	85,9%	100,0%	100,0%	CL3	CL1	CL1	89,5%	CL2
week. 49	84,7%	100,0%	87,3%	CL3	CL1	CL2	88,1%	CL2
week. 50	78,4%	100,0%	100,0%	CL3	CL1	CL1	84,0%	CL3
week. 51	81,5%	86,4%	88,2%	CL3	CL2	CL2	82,9%	CL3
week. 52	85,8%	100,0%	100,0%	CL3	CL1	CL1	89,5%	CL2
week. 53	82,8%	100,0%	100,0%	CL3	CL1	CL1	87,2%	CL2

DASHBOARD | IWEE CALCULATOR | IPLE CALCULATOR | DATA LOGGER | ...

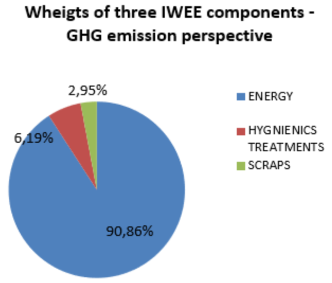
Table 79 IWEE – IWEE calculator

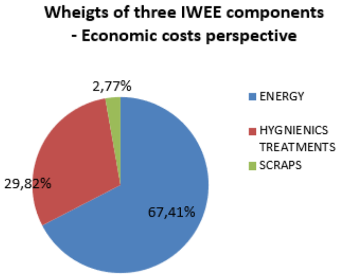
DASHBOARD		WEEK	sett. 19
BOTTLING LINE	53		CL1

IWEE SCORE	98%

	ECOEFFICIENCY CLASS	GHG emissions (kgCO2eq/1000 litres)	Delta % from standard	Economic costs (€/1000 litres)	Delta % from standard
ENERGY	CL1	1,398	2,5%	CONFIDENTIAL	
HYGNIENICS TREATMENTS	CL1	0,095	22,5%		
SCRAPS	CL1	0,045	-32,3%		
TOTAL	CL1	1,539	2,0%		

TOTAL	
kgCO2eq/week	6.855
€/week	CONFIDENTIAL





Variables that influence directly IWEE	Weekly value	Reference value	% variation from reference value	Ecoefficiency class
Work shift configuration	2,00	2,13	-6,3%	CL2
Production run average length	420	238	76,5%	CL1
Hourly bottling line speed	37.626	38000	-1,0%	CL2
Index of productive time incidence	0,352	0,43	-17,4%	CL1
Volume produced	4.453.682	4.445.293	0,2%	CL1
IPLE score	1,549	1,489	-3,8%	CL1

Variables that influece indirectly the IWEE	Weekly value	Reference value	% variation from reference value	Ecoefficiency class
Number of format changes	8	12,00	-33,3%	CL1
Number of product codes	13	22,00	-40,9%	CL1
Delayed to reach the cruise speed	-5.362	-4.000	34,0%	CL1

IWEE DASHBOARD | IWEE CALCULATOR | IPLE CALCULATOR | DATA LOGGER | ...

Table 80 IWEE – IWEE Dashboard

3.6. TEST 5: Application of OES2 method to criticalities on environmental management areas (5) - Part Decision Making

This test has the objective to assess the capacity of OES2 method to face the gaps on life cycle management related to criticalities on strategic decision making.

Life Cycle Management Critical Areas	Identified gaps
5. Strategic decision making criticalities	15. Lack of use of Decision making Tools (MCDA, optimization, statistical techniques, etc.)

Table 81 Identified gaps on strategic decision making, faced by OES2 method in the test 5.

In order to face these gaps OES2 method applies:

- One STEM: SEDM module (Strategic Environmental Decision Making module).

According to OES2 method, the SEDM module has the role to support and increase the use of tools specific to solve decision making processes. In OES2 two main types of decision making tools have been selected, one tool for optimization and solve multiobjectives decisional problems and a tool to support the solution of problems that required statistical approaches. While in the previously paragraph has been shown the activation of SEDM module to support the solution of the statistical problem related to discriminatory analysis for the development of IPLE index, in the present paragraph has been shown the activation of SEDM module to solve a problem related to multiobjectives optimization. It is important to underline, that the decisional issues face by organization change and evolve over the time and therefore the creation new models could be required. However, in the case of cyclical decisional making problems, such as raw material supplier mix selection, once the problem has been solved for the first time, when it re-examined in the future, an updating of the model could be often sufficient to obtain updated solutions.

3.6.1. Application of SEDM module to PET supplier mix selection decision making process considering environmental performance

The environmental impacts generated by the consumption of PET is one of the most relevant aspect that influence the life cycle performance of the organization especially at level of the San Benedetto PET Italian Mineral Water Sub Division. In fact, according to the results obtained by OLCA and LCA application (first paragraph of this chapter), PET consumption has a contribution of respectively about 33% on climate change performance of about 38% on water scarcity performance. According to PEFCR framework, these two impact categories are two of the most relevant. In this context, OES2 has been applied in order to face the decision making issue related to the PET suppliers mix selection.

3.6.1.1. Objectives setup

In order to solve the issue related to the PET suppliers mix selection the following objectives have been set:

- Minimization of environmental impacts on climate change;
- Minimization of environmental impacts on water scarcity;
- Assurance the respect of cost goal related to PET purchases set by the organization. For policy and confidentiality reasons of the organization the economic results have been not shown as in the rest of the PhD thesis. This aspect does not invalidate the objective of the application that focus on show as OES2 method is supportive to face identified scientific gaps related to life cycle environmental management. In fact, the PhD thesis has a methodological perspective, being the objective the creation of a new method.

Therefore, the objective is to develop a set of improvement scenarios (optimal solution) that respecting the cost goal related to PET purchases, improving the environmental performance on climate change and water scarcity impact categories. The Pareto front has been researched on order to identify not dominated scenarios. The new scenarios identified have been compared with the last supplier mix configuration used by the organization in order to assess potential improvements of environmental performance.

3.6.1.2. Multiobjectives optimization model developed

According to OES2 method and the SEDM module formulation shown in the previously chapter, the tool used in this PhD thesis to solve multiobjective issues is the software ModeFrontier. The results of this application have been shown and discussed during the exam of the course on stochastic methods attended during the PhD. The optimization model has been developed within the work space of ModeFrontier and the following figure shows the structure of the model.

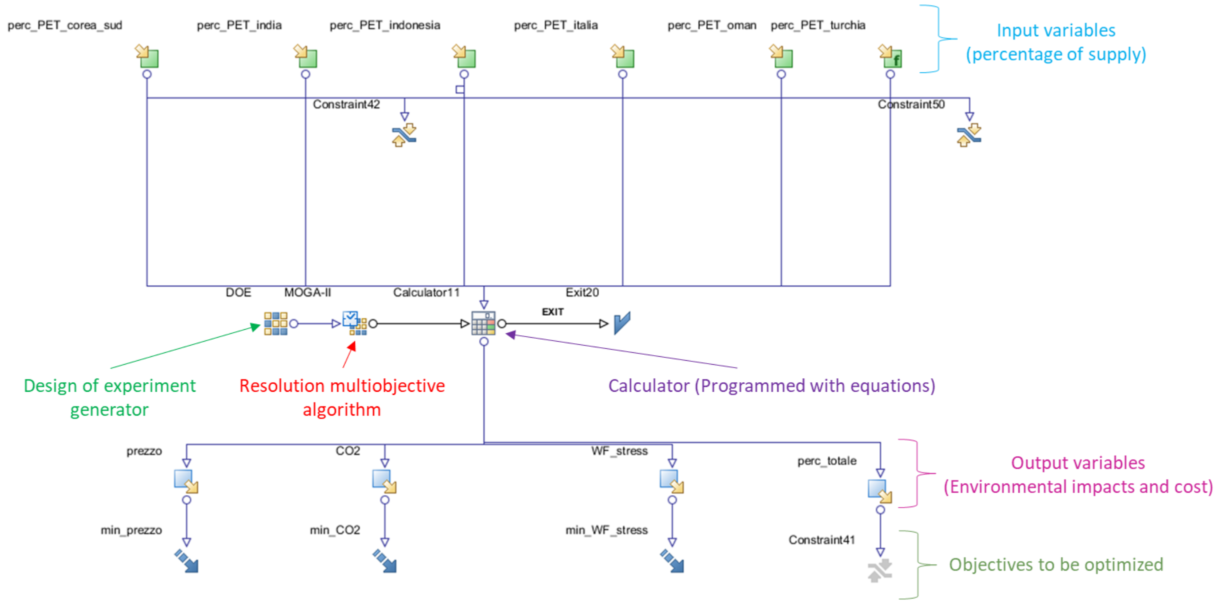


Figure 141 Model developed with ModeFrontier software. Application to decision making process related to PET suppliers mix selection.

3.6.1.2.1. <u>Input variables</u>

The input variables, are the variables that the model modifies in order to generates the different scenarios, in this case, therefore these variables are the percentages of supply relative to each PET supplier. Five different suppliers have been considered located in six different countries as shown in the following table.

PET Suppliers	Production site location	Impacts on climate change [t CO2 eq/t PET]	Impacts of water scarcity [m3/t PET]	Price
A	Indonesia	3,52	46,3	Confidential
	Turkey	3,13	51,0	
B	South Korea	3,47	50,2	
C	India	3,30	51,3	
D	Oman	3,34	48,1	
E	Italy	3,19	50,5	

Table 82 List of PET suppliers considered and relative environmental performance

For confidential reasons besides to PET prices have been do not declared also the name of the PET suppliers. The environmental performance of PET in the case of each supplier has been obtained from ERD interface that stored the results returned by MLCA model. In fact, the MLCA model, considering all life cycle processes that occurred in the case of San Benedetto PET Italian Mineral Water Sub Division has permitted to assess environmental impacts also of the different PET suppliers. These impacts have been calculated by MLCA model, elaborated in the SimaPro software work space, using Ecoinvent Database v3.1 opportunely adapted considering the differences at level of the different countries where are located the PET suppliers (e.g. different medium voltage electricity mix) that are relevant in to determine the environmental performance of each PET supplier. The environmental impacts consider the PET production with bottle grade and the impacts related to PET transport. The transports have been characterized specifically for each PET supplier considering the distances travelled by truck, ship and train to arrive to the Scorzè production site starting from the different sites of suppliers. Finally, the field of solutions research have been confined set constraints at level of the percentages that can be supplied by every supplier on the base of considerations of experts (delivery time, plastic quality (issues with workability, etc.), availability): percentage from supplier A (Indonesia) (lower limit: 0%; upper limit: 70%); percentage from supplier A (Turkey) (lower limit: 0%; upper limit: 45%); percentage from supplier B (South Korea) (lower limit: 20%; upper limit: 70%); percentage from supplier C (India) (lower limit: 10%; upper limit:70%); percentage from supplier (D) Oman (lower limit: 0%; upper limit: 50%); percentage from supplier E (Italy) (lower limit: 0%; upper limit: 30%).

3.6.1.2.2. Model equations and solver setup

In order to calculate the optimized solutions, algebraic linear equations have been programmed directly in the calculator component of ModeFrontier. The equations have been written use javascript language and permits the calculation of the total environmental impacts of climate change (CF_{Mix}), on water scarcity (WS_{Mix}) and the final price (P_{Mix}). The equations have been shown following, while the calculator has been shown in the figure 142.

$$CFmix_j = \sum_i^n \left(x_{i,j} \cdot CF_i\right) \quad [3.7]$$

$$WSmix_j = \sum_i^n \left(x_{i,j} \cdot WS_i\right) \quad [3.8]$$

$$Pmix_j = \sum_i^n \left(x_{i,j} \cdot P_i\right) \quad [3.9]$$

$$\sum_i^n \left(x_{i,j}\right) = 1 \quad [3.10]$$

Where:

$CFmix_j$= Final value of the impact on climate change category in the case of the solution generated at the j-esime iteration;

$WSmix_j$= Final value of the impact on water scarcity category in the case of the solution generated at the j-esime iteration;

$Pmix_j$= Final value of the price in the case of the solution generated at the j-esime iteration;

$x_{i,j}$= fraction of supply associate to the i-esime supplier in the case of the solution generated at the j-esime iteration.

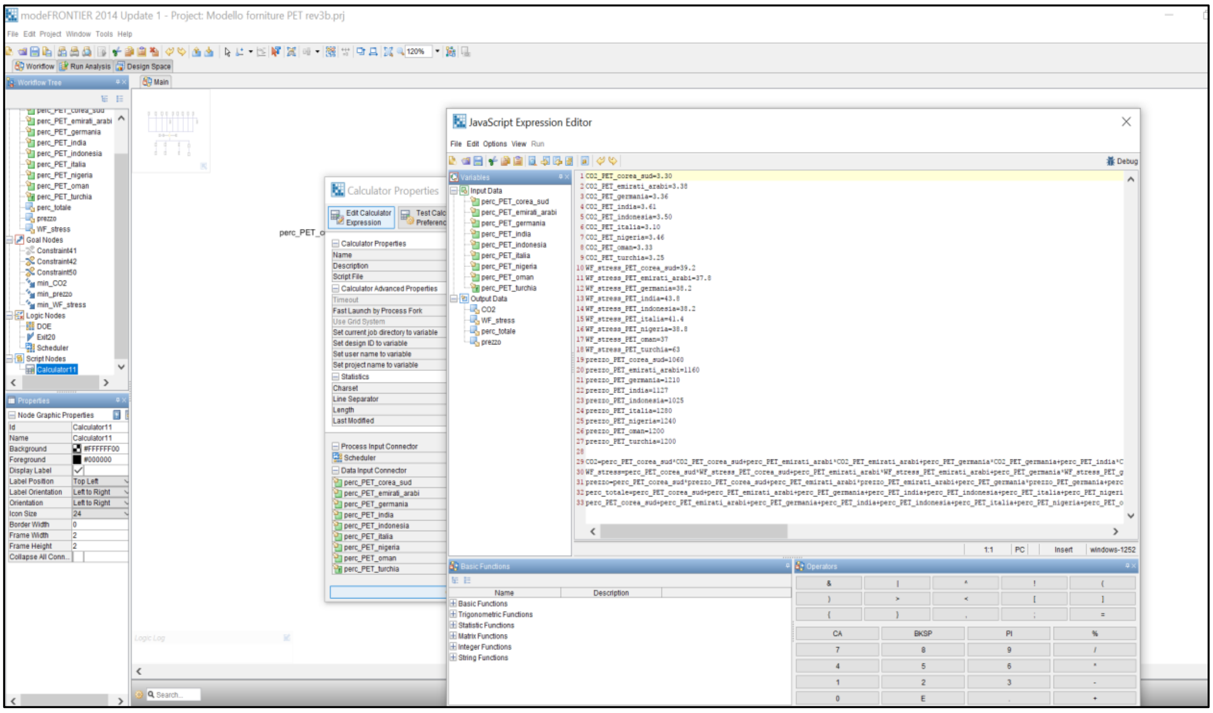


Figure 142 Equations written in javascript language into the calculator of ModeFrontier.

In order to complete the optimization model have been defined the Design of Experiment (DOE) and the resolution algorithm. The DOE Tool is used to perform the preliminary exploration of the design space and provides a set of initial points for design optimization. The DOE algorithm has been set with a random sequence. It fills randomly, with a uniform distribution, the design space. A number of 40 initial designs have been used with a random generator seed equal to 2.

In order to solve the multiobjective problem a genetic algorithm, has been used. In the specific, the Multi-Objective Genetic Algorithm (MOGA-II) algorithm has been used. It is an efficient multi-objective genetic algorithm that uses a smart multi-search elitism. This new elitism operator is able to preserve some excellent solutions without bringing premature convergence to local-optimal frontiers. The efficiency of this algorithm has been orderly proved on six well known test functions for multi-objective optimization, the results can be found in this pdf file. A total number of 60 generation has been set in the functionality parameter of MOGA. The algorithm attempts a total number of evaluations that is equal to the number of points in the Design of Experiment(DOE) table (the initial population) multiplied by the number of generations.

Finally, has been assessed the performance of the last suppliers mix configuration used by the organization that provide: 62% South Korea, 21% India, 14% Indonesia and 3% Oman. The environmental performance associated to this configuration are equal to: 3,44 t CO_2 eq/t PET and 49,9 m^3/t PET.

3.6.1.3. Optimized scenarios

The model developed have been returned 3.600 solutions of which the 69% feasible. In the following figure have been plotted all feasible solutions.

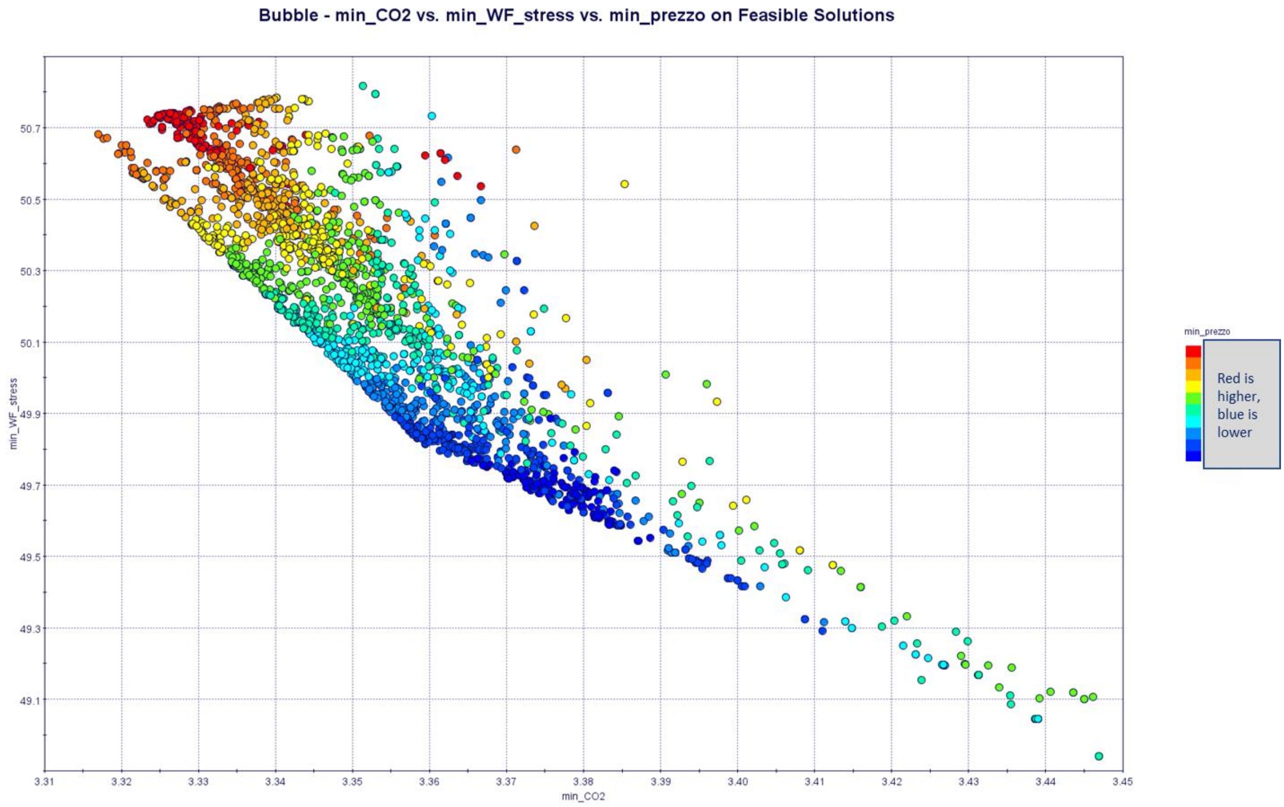


Figure 143 Set of feasible solutions returned by optimization model.

Subsequently the pareto front has been identified in order to identify the not dominated solutions that represents the optimal solutions. According to Pareto principle, all these solutions are equivalent, being not dominated. The choice of the most appropriate solution between the optimal solutions is a managerial question.

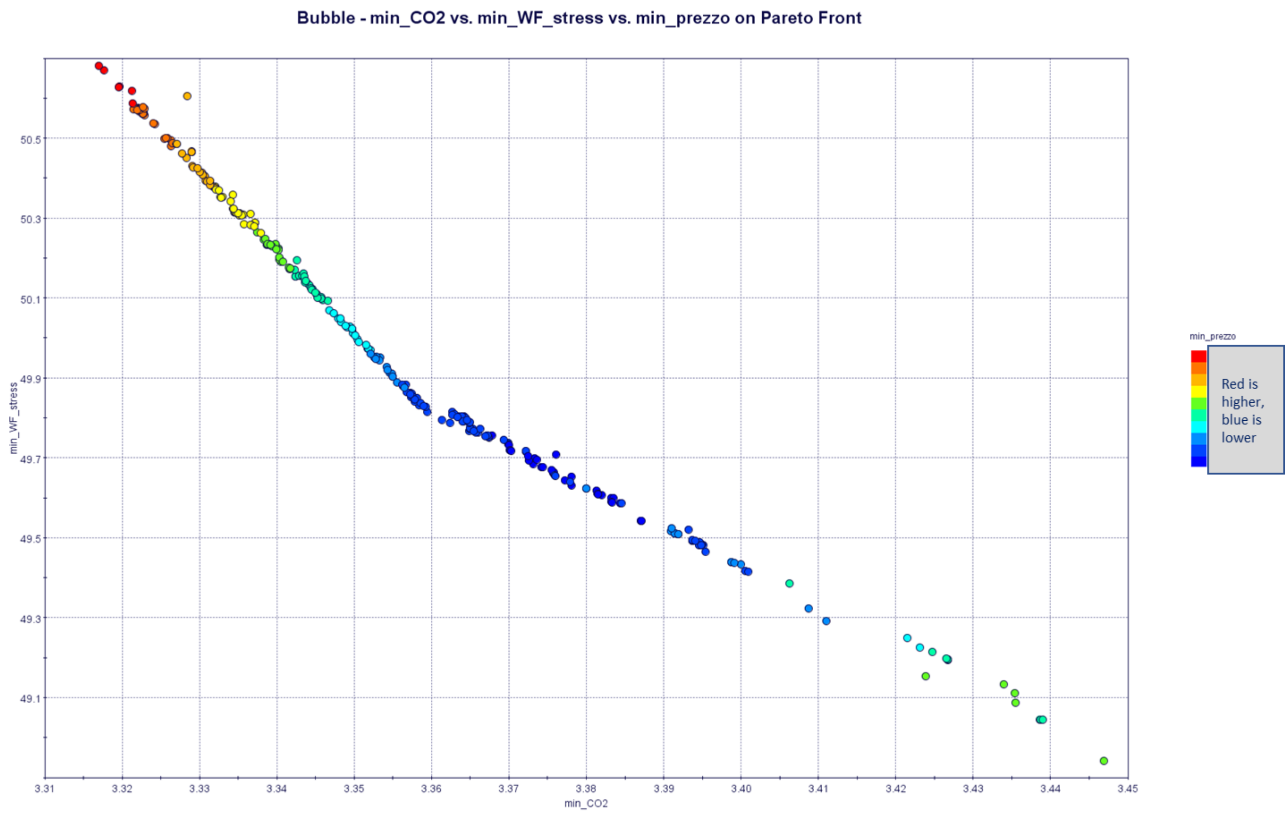


Figure 144 Pareto Front (set of solutions not dominated) returned by optimization model.

In this case, the selection criterion has been based on strategical consideration according to environmental strategy that prioritize the reduction of GHG emissions. In this way the optimal design solution has been selected between the optimal solutions of the Pareto Front that minimizes the impact on climate change category and at the same time assurance the respect of cost goal related to PET purchases set by the organization (see following figure). The optimal solution identified shown the following PET suppliers mix: 40% Supplier B (South Korea); 29% Supplier A (Turkey); 21% Supplier C (India); 10% Supplier E (Italy). The most relevant changes are the shift from the site production located in Indonesia to the site production located in Turkey in the case on supplier A with an increase of the supply from 14% to 29%. The supplier C located in India maintain the same quote, while the quote supplies by supplier B (South Korea) decreases with the introduction of a small quote from supplier E located in Italy (10%). This optimal solution permits to maintain the same level of cost of the last configuration of PET suppliers mix used by the organization but decreasing the carbon footprint performance to 3,30 t CO2 eq/t PET (-3,8%) while the water scarcity impact increase to 50,6 m3 eq/t PET (+2,0%).

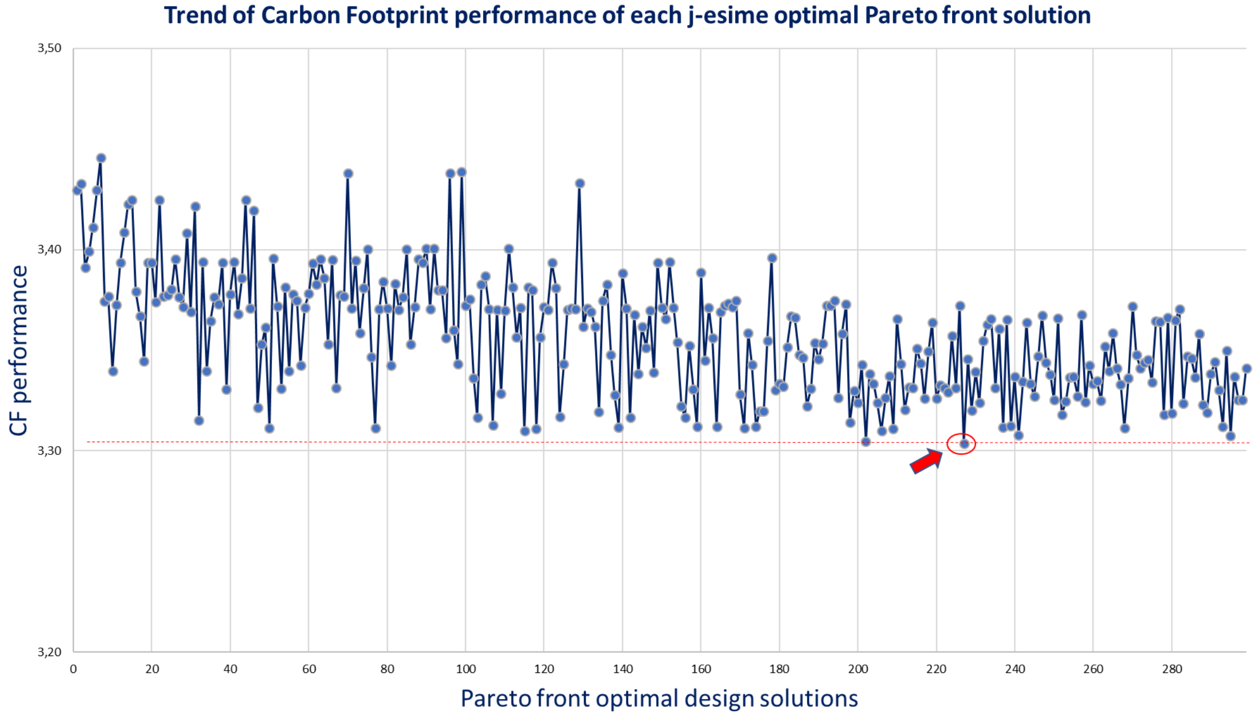


Figure 145 Selection of the solution between optimal solutions of Pareto Front prioritizing Carbon Footprint Performance

The results obtained can be interpreted also with a multiscale assessment perspective. In fact, the effects of this potential choice, according with MLCA model introducing by OES2 method, can be assessed at organizational and product level.

- At level of the San Benedetto PET Italian Mineral Water Sub Division, that has a total emission equal to 184.230 t CO2 eq, where 55.757 t CO2 eq of them are related to PET granulate, the introduction of optimal solution should generate a potential improvement of the Sub Division performance of -1,2%.
- At level of the San Benedetto EcoGreen product line, that has a total emission equal to 17.241 t CO2 eq, where 3.542 t CO2 eq of them are related to PET granulate, the introduction of optimal solution should generate a potential improvement of the EcoGreen product line performance of -0,9%.

3.7. TEST 6: Application of OES2 method to criticalities on environmental management areas (6)

This test has the objective to assess the capacity of OES2 method to face the gaps on life cycle management related to criticalities on strategic and managerial aspects.

Life Cycle Management Critical Areas	**Identified gaps**
6. Strategy & Management criticalities	16. Unbalanced environmental management strategies
	17. Divergence between intended and realized environmental management strategy

Table 83 Identified gaps on strategy & management, faced by OES2 method in the test 6.

In order to face these gaps OES2 method applies:

- One EMTs: ISO 140001 (part pertinent with life cycle performance management)
- One STEM: the ESSM (Environmental Sustainability Strategy Model).

In fact, as descripted at the start of this chapter, the organization has implement the requirement of ISO 140001 relevant for the management of life cycle performance. A brief description of this aspects has been following reported. After that an application of ESSM has been performed for the case of San Benedetto EcoGreen product family.

3.7.1. EMS – Results obtained at management level

In the present paragraph have been shown the results obtained at management level following the requirements of ISO14001 pertinent for the management of life cycle performance.

3.7.1.1. Planning action

The organization in order to manage life cycle performance have set objectives. The objectives have been distinguished for the organizational scale and for the product scale.

- Objectives at organizational scale: to track the environmental performance of San Benedetto Italian Mineral Water Division. According to this objective, San Benedetto has been applied OES2 to all productive sites and products. The first performance evaluation has been obtained in 2017 (206 kg CO_2 eq/1000 litres) and in 2018 the first performance variation will be assessed. In the future will be evaluated of define a target for the performance. The performance is internally communicated;
- Objectives at product scale: to track the environmental performance of the product line EcoGreen and support the improvement of performance according the presentation target defined (cross the -20% of reduction of GHG emissions respect the performance of 2013 by 2020). The target has been defined according to the Europe goal of the Climate Package 20 20 20 content in the Directive 2009/29/CE. The performance is periodically communicated to consumers.

The objectives have been defined consistently with the environmental policy, are measured, monitored and communicated. In order to increase the level of robustness of the assessment on objectives reachability has been introduced with OES2 method the ESSM that permits to test this aspect. An example of application of ESSM to product line EcoGreen has been shown in the second part of this paragraph.

3.7.1.2. Roles and Responsibilities

Responsibilities on the performance tracking have been defined internally. In fact, the organization has constituted a team for San Benedetto Eco Sustainability (see figure 146) made up of 5 members with specific functions:

- One member (1) works mainly on environmental impact assessment (MLCA model), data management (EID and ERD management), performance evaluation (Eco-EKA) and support to communication activities;
- The second member (2) works mainly of ecoefficiency (IWEE) and decision making processes (SEDM);
- The third member (3) works mainly on ecodesign (Eco-DSD) and strategical processes (ESSM);
- The fourth member (4) is a manager that interacts with top management in order to sustain the commitment, takes accountability for the effectiveness of the OES2 method; ensures that environmental objectives are established and are compatible with the strategic direction and the context of the organization, ensures that the resources needed are available and ensures that the environmental management system achieves its intended outcomes.
- The fifth member (5) is the director of the EcoSustainability team, it is a member of the top management and influences directly the process of establishing environmental performance goals and ensures the commitment of the organization. It is a member of the property of Acqua Minerale San Benedetto S.p.A. Group.

Figure 146 EcoSustainability team
(Dr Caniato (1); Dr. Manzato (4), Dr. Carraro (3), Dr Versace (5), PhD student Loss, Dr. Broglio (2))

3.7.1.3. Training

The organization has activated specific training paths to train the three new human resources of the Eco Sustainability team. The training activities have been focused on all management aspects related to OES2 method. The PhD student had directly take care of training activities. The actual level acquired by team members permit to San Benedetto to manage independently the OES2 method.

3.7.1.4. Communication

The organization has identified the communication activities on environmental performance differentiating two paths:

- Internal communication: the organization communicate the results to employees using visual management solution (Billboard on EcoGreen performance results executive summary on environmental performance (see figure 147). Furthermore, periodically meetings with top management are organized to communicate the environmental performance;
- External communication: the organization, according to define objective, communicates the environmental performance of product line EcoGreen. The timing, the communication activities and the text contents (e.g. claims) have been defined.

Figure 147 Communication report. Life Cycle performance on climate change of the San Benedetto Mineral Water Division and Product Line EcoGreen 2016.

3.7.1.5. Information and data management

The organization manages all information and data relevant for the assessment of life cycle environmental performance. The development of EID and ERD interfaces permits to decrease the time for data manage and to increase the affability.

When creating and updating documented information, the organization ensures an appropriate identification and description (e.g. a title, date, author, or reference number, format (e.g. language, software version) and media (e.g. paper, electronic)).

The information is protected and ensure in a centralized hard drive with a backup every hour. Only authorized people can have access to the data for confidentiality reasons. It permits to avoid improper use and the loss of integrity.

3.7.1.6. Life Cycle perspective and EcoDesign

The requirements of ISO14001 on ecodesign role and the life cycle perspective are fully respected through the implementation of OES2 method. Specific procedures have been defined in order to manage the main activities required by OES2 method:

- ecodesign procedure;
- MLCA model updating procedure;
- EID and ERD updating procedure for life cycle data management;
- Procedure to plan audit of third party for life cycle environmental performance certification.

The organization has also implements an action plan where the eco design projects have been scheduled and has defined timing and outputs regarding environmental performance assessment (updating OLCA and LCA data and results) and communication activities.

3.7.1.7. Audit

Audit activities have been performed. The internal audits on OES2 method have been conducted by PhD student. Not compliance results and improvement advices (e.g. on MLCA model, dataset selection, etc.) have been registered and subjectively solved by the organization implementing corrective action.
Also, external audit by performed by third has been conducted in order to certify the results on environmental performance according to requirements of ISO14040-44.

3.7.1.8. Management review and continual improvement

The environmental performance is periodically reviewed by top management to ensure the effectiveness, adequacy and suitability of the management of life cycle performance. Furthermore, the organization improves continually the suitability, adequacy and effectiveness of OES2 method to enhance environmental performance.

3.7.2. Application of ESSM to EcoGreen product line

In the present paragraph has been shown an application of Environmetnal Sustainability Strategy Model (ESSM) to San Benedetto EcoGreen product line. The ESSM supports the definition of environmental strategies at organizational and product level for the improvement of life cycle performance. In the case of San Benedetto, actually the organization, according with defined objectives has set a performance objective for the San Benedetto EcoGreen product line. The ESSM has been applied in order to test the reachability of environmental performance set as objective.

3.7.2.1. San Bendetto EcoGreen Product Line

The EcoGreen product family is a family of products with best environmental performance. In fact, this family of products has been developed through eco design processes such as lightening of bottle and of cap, and the use of recycle plastic (RPET) for the bottle production. Furthermore, this product line has the characteristic of is fully carbon neutral (emissions offset by carbon credits purchase).

Figure 148 The EcoGreen Product Line 2016.

3.7.2.2. Balancing the Environmental Sustainability Strategy (EES) – Product Level

According with the model descripted in the chapter 2 two components of the environmental strategy must be defined:

- EcoEfficiency EES component: the organization for the EcoGreen Product Line has been set, starting from environmental performance of 2013 (180,3 kg CO2 eq/1000 litre), a performance objective (cross the -20% of reduction of GHG emissions respect the performance of 2013 by 2020);
- EcoBranding EES component: in order to balancing the strategy, communication activities must be activated. In this case the communication strategy will be make thought a claim on the labels applied to the bottles.

3.7.2.3. Test of the environmental strategy components – Product level

The organization since 2013 has implemented different ecodesign projects to improve the environmental performance achieving the actual performance of 148,8 kg CO2 eq/1000 litre (-17,5%) thanks to the following projects:

Project type	Project	Improvements
EcoDesign - Product level 2014	Increase %RPET (1L; 1,5L; 2L)	The %REPT has been increased (1L, from 30% to 50%; 1,5L from 10% to 30%; 2L from 10% to 30%)
EcoDesign - Product level 2015	Introduction %RPET (0,5L)	A 10% of RPET has been introduced in bottle 0,5L
EcoDesign - Product level 2015	Lightening bottles 0,5L; 1L; 1,5L	The bottles weights have been reduced (0,5L from 9,5g to 8,7g; 1L, from 18g to 14,5g; 1,5L, from 22,8g to 18,8g)
EcoDesign - Product level 2015	Lightening caps 1L; 1,5L	The caps weights have been reduced (1L, from 1,4g to 0,9g; 1,5L from 1,4g to 0,9g)
EcoDesign - Product level 2016	Lightening bottles 2L	The bottle weight has been reduced (2L, from 28g to 25g)
EcoDesign - Product level 2016	Lightening caps 2L	The cap weight has been reduced (2L, from 1,4g to 0,9g)

Table 84 Ecodesign projects developed for improve products of EcoGreen line from 2013 to 2016.

The improvement of environmental performance has been assessed at Ecodesign stage with Eco-DSD tool and the effects has been monitored with Eco-EKA tool. Besides to 2020 different projects of ecodesign and ecoefficiency have been planned as listed in the following table:

Project type	Project	Improvements	Savings kgCO2eq/1000litres
EcoDesign - Product level	Lightening bottle and cap 0,5L	Lightening bottle 0,5L from 8,7g to 7,8 g + Lightening cap from 1,4g to 0,9g	0,84
EcoDesign - Product level	EcoGreen 2L (25g) Scorzè	Total conversion of EcoGreen 2,0L produced by Scorzè site from version 2012 to version 2016	0,25
EcoDesign - Organizational level	Increase Viggianello volumes 1L	Increase production volumes of 1,0L in new Viggianello site (in the south of Italy)	1,10
EcoDesign - Organizational level	Increase Viggianello volumes 2L	Increase production volumes of 2,0L in new Viggianello site (in the south of Italy)	0,09
EcoEfficiency	Increase electricity by trigeneration (Scorzè)	Increase of contribution of trigeneration to electricity mix of Scorzè site	3,84
EcoEfficiency	Energy saving (ISO50001 targets-Scorzè)	Energy saving projects according to ISO50001 targets	1,24
EcoEfficiency	Management of RPET supply chain	Management of RPET supply chain	0,40

Table 85 Ecodesign and ecoefficiency projects planned from 2017 to 2020.

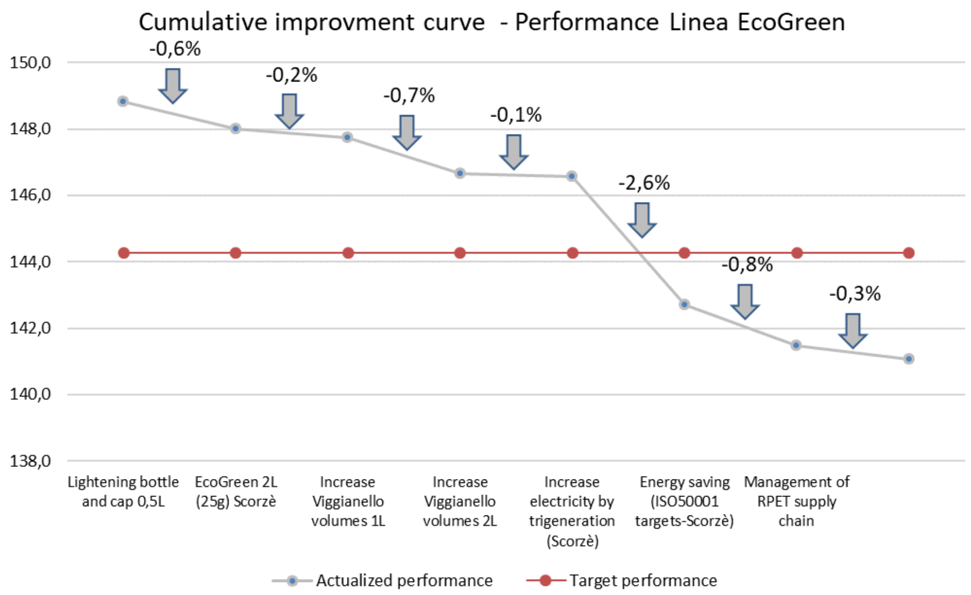


Figure 149 Cumulative effects of improvement projects – EcoGreen Product Line

According to ESSM all ecodesign and ecoefficiency projects have been take into account. The assessment of the saving has been conduct using ecodesign tool (Eco-DSD) while ecoefficiency improvement deriving form ISO50001 and MLCA SimaPro Model (variation of emission factors of electricity and RPET). The figure 149 shows the cumulative effect of improvement projects planned respect to the target performance. The results show consistency of the objective with the planned improvement activities.

In order to support the annual communication activities on the performance, specific activities must be planned: the internal audit for to verify the correctness on the assessment and external audit for certification by third. In this case. The activities are corrected planned and therefore consistently with the communication objective.

Finally, the consistency between results from ecoefficiency EES component and results from Ecobranding EES strategy is realized and therefore the strategy for the environmental performance of EcoGreen product Line is approved. Every year, the performance will be assessed with Eco-EKA in order to assess the improvement. In this case, the environmental performance achieved year by year have been communicated with specific product cards (see figure 150) and specific claims on product labels (see figure 151) according to ISO14021 on self-declared environmental claims (Type II environmental labelling). The communication processes shown the use of the last component of OES2 method introduced specifically to manage communication processes on life cycle environmental performance.

Figure 150 Specific cards for life cycle performance presentation.

Figure 151 Specific claim for life cycle performance communication to consumer. The claim is applied to the EcoGreen products labels.

CHAPTER FOUR: DISCUSSION

Highlights:

- **Discussion on methodological results**
- **Comparison of OES2 method with already published methods**
- **Discussion on industrial results**

4.1. Introduction to the discussion

In this chapter have been discussed research results. The discussion is structured in three sections:

1. Discussion on OES2 method structure & conceptualization; in order to discuss aspects related to the structure of the new method. It is advised to see table 86 during reading of this discussion section;
2. Discussion on OES2 method capabilities in the six life cycle management critical areas; in order to discuss the improvements introduced and compare OES2 method with the already existing methods for multiple EMTs use, in order to clarify the effective innovations introduced. The results are, in the case of all six critical areas, discussed before from a methodological point of view and after respect to the results obtained from the industrial tests conducted in San Benedetto S.p.A. It is advised to see tables 86 and 87 during reading of this discussion section;
3. SWOT analysis of OES2 method; in order to discuss potential benefits and threats deriving from the application of OES2 method.

This structure has been chosen in order to discuss, according the research objectives, the general methodological results obtained with OES2 method and the results obtained from the industrial applicative tests.

4.2. Discussion on OES2 method structure & conceptualization

To improve life cycle management performance of industrial organization a new method to combine Environmental Management Tools (EMTs) has been developed and presented in this research. The Organizational Environmental Sustainability System (OES2) (Loss et al., 2016) method proposes a solution to the issue related to EMTs selection due to the large availability of EMTs that is limiting the industrial implementation of them (Rossi et al., 2016). The EMTs selection has been conducted in order to face the criticalities on life cycle management identified with a scientific literature review (table 86) and following the most up to date developments on environmental management (e.g. new ISO standards). The method has been based on ISO EMTs in order to favour the industrial implementation and the comprehensibility by organizations. In fact, being the ISO EMTs developed with a consensus-based approach (considering all relevant stakeholders), with a high level of expertise (are developed by groups of experts from all over the world) and with a specific focus on industrial issues (standards have been developed to respond to needs of the market), the OES2 method benefits of these characteristics. Furthermore, the industrial application of the OES2 method may be favoured especially in the case of the organization have already implemented some of EMTs required by the method (e.g. ISO 14001). In this context, OES2 responds to the need to establish a framework for a complementary approach to promote a broader use of the ISO 14000 series.

The method has been developed on the Life Cycle Management (LCM) concept that in the last years has become the reference concept for the management of environmental performance (Gaudreault et al., 2009). It establishes a positive relationship between EMTs product oriented and EMTs organizational oriented confirming the hypothesis advanced by Ayres et al (2002). This perspective is supported by the tendency that has been possible to notice starting from 2015, according to which the LCA methodology, originally a product oriented EMT, has extended its scope to organizations with the new ISO/TS 14072 (OLCA) and from the other side, the new revision of ISO 14001 has increased the role of product ecodesign to improve the performance of organization. This positive interaction is due mainly the capacity of the two types of EMTs of support the improvement of the life cycle environmental management performance with a multiscale perspective where the organizational scale and the product/process scale interacting, permitting reciprocal improvements.

The OES2 method has based on a close loop cycle developed using the combination method. New interfaces have been introduced in order to give a framework off all the positive interaction between the selected EMTs. Some of these interfaces, such as the interface between the plan stage of EMS and the goal & scope definition of OLCA (or LCA) are important in order to improve the framework of interface already published in the literature regarding method for multiple EMTs use. In the case of this specific example, the EMS plans the OLCA (or LCA) study, defining the objective and therefore directly defining methodological requirements of goal & scope definition stage such as: system boundaries, functional unit, environmental impact assessment method, study purposes, etc. The combination method for multiple EMTs use has been chose inasmuch is most flexible and comprehensive. The flexibility deriving from the fact that the combination method permits of to concentrate on individual solutions. In fact, it permits, to the organization, to decides of primarily apply one EMT and, as a second step of to introduce, the other EMTs following a problem oriented perspective. While the comprehensiveness deriving from the fact that the combination method permits to include in the same method for multiple EMTs use a larger number of EMTs respect to integration method.

The combination of EMTs has required the methodological development of new tools, the STEMs (Supportive Tools to Environmental Management) (table 86). Two reasons for STEMs introduction have been identified. The first one is related to the fact that not all criticalities emerged on life cycle environmental management can be solved through the introduction of an EMT because not specific EMTs have been developed. The second one is related to the fact that during the EMTs implementation emerge limits and criticalities. Therefore, the STEMs have been defined as tools developed in order to improve the applicability and the use of EMTs. The introduction of STEMs is a methodological innovation in the field of methods for multiple EMTs use and responds to the need for practical tools that enable and support organizations to implement EMTs (Geibler et al., 2016). The OES2 method supports the management of all areas of life cycle management and implements seven EMTs and eight STEMs (see table 86). The OES2 method developed, despite the PhD thesis focus on the improvement of life cycle environmental performance of the organization and then the work had not focused on aspects not related to life cycle performance (e.g. legal compliance), has anyway considered indirectly these aspects during the EMTs selection stage in order to permits to the organizations that will adopt the method to have a complete approach of environmental management.

Life Cycle Management Critical Areas	Environmental Management Barriers (EMBs)	EMT selected	STEM developed
1. Environmental impacts assessment	Lack of Environmental Impact Assessment – Product Level	(1) LCA (ISO14040-44)	(1) MLCA model
	Lack of Environmental Impact Assessment – Organizational Level	(2) OLCA (ISO/TS 14072)	
	Correlation between product and organizational scale not considered	-	
	Lack of comprehensive impact assessment (Multi-indicators)	(1) LCA & (2) OLCA (ISO 14040-44 & ISO/TS 14072)	
	Issues on hotspots identification and on burdens shifting		
	Lack of Life Cycle Management approach		
	Impact assessment based on inventory indicators		
	Technical difficulties in large impact assessment data management	-	(2) ERD
2. Inventory resources consumptions assessment	Technical difficulties in large inventory data management	-	(3) EID
3. Performance evaluation & performance tracking	Lack of OPIs for environmental performance evaluation related to life cycle management	(3) Environmental Performance Evaluation (ISO 14031)	(4) Eco-EKA
	Difficulties in OPIs trends analysis		
4. Ecoinnovation	Lack of indicators for ecoefficiency assessment	(5) Ecoefficiency (ISO 14045)	(6) IWEE
	Difficulties in implementation of practical ecodesign processes and new eco-friendly alternative solutions comparison	(4) Ecodesign (ISO/TR 14062)	(5) Eco-DSD
5. Strategic decision making	Difficulties in the assessment of environmental performance of investments		
	Lack of use of Decision making Tools (MCDA, optimization, statistical techniques, etc.)	-	(7) SEDM module
6. Strategy & Management	Unbalanced environmental management strategies	(6) EMS (ISO 14001) & (7) Communication tools (ISO14021-24-25)	(8) ESSM
	Divergence between intended and realized environmental management strategy		

Table 86 List of gaps faced, EMTs included and STEMs introduced by OES2 method

Life Cycle Management Critical Areas	Environmental Management Barriers (EMBs)	1) LCA + EMS	2) LCA + EMS + EcoDesign	3) LCA + EMS + EcoDesign + Communication & Labels	4) EMS + EPE	5) EMS + EcoDesign	OES2 method
1. Environmental impacts assessment	Lack of Environmental Impact Assessment – Product Level	√	√	√			√
	Lack of Environmental Impact Assessment – Organizational Level						√
	Correlation between product and organizational scale not considered						√
	Lack of comprehensive impact assessment (Multi-indicators)	√	√	√			√
	Issues on hotspots identification and on burdens shifting	Partially	Partially	Partially		Partially	√
	Lack of Life Cycle Management approach	Partially	Partially	Partially			√
	Impact assessment based on inventory indicators	√	√	√			√
	Technical difficulties in large impact assessment data management						√
2. Inventory resources consumptions assessment	Technical difficulties in large inventory data management						√
3. Performance evaluation & performance tracking	Lack of OPIs for environmental performance evaluation related to life cycle management				Partially		√
	Difficulties in OPIs trends analysis				Partially		√
4. Ecoinnovation	Difficulties in implementation of practical ecodesign processes and new eco-friendly alternative solutions comparison						√
	Lack of indicators for ecoefficiency assessment						√
5. Strategic decision making	Lack of use of Decision making Tools (MCDA, optimization, statistical techniques, etc.)						√
	Difficulties in the assessment of environmental performance of investments		Partially	Partially		Partially	√
6. Strategy & Management	Unbalanced environmental management strategies			Partially			√
	Divergence between intended and realized environmental management strategy			Partially			√

Table 87 Comparison of the OES2 method and the types of already existing methods for multiple EMTs use

NB: In green the aspects that have been strongly improved by OES2 method and in blue the aspects already covered by already existing methods for multiple EMTs use

4.3. Discussion on OES2 method capabilities in the six life cycle management critical areas

4.3.1. Results discussion – Environmental impacts assessment (1) and inventory resources consumptions assessment (2)

Focusing on methodological results on life cycle environmental impact assessment and on the inventory resources consumptions assessment, the OSE2 method provides the combined implementation of Life Cycle Assessment (LCA) methodology at product and organizational scale (OLCA) in order to assess the environmental impacts of whole organization and of its products along the entire life cycle (table 86). While the LCA is considered a mature tool for environmental impact assessment at product level, the OLCA is considered to be one of the most important emerging application of life cycle approach (Hellweg et al., 2014). OES2 is the first method for multiple EMTs use that includes the OLCA (see table 87). The need to implement OLCA is strengthen by the new version of the ISO14001:2015 that has increase the importance at organizational level of the life cycle approach. Implementing OLCA within EMS provides several benefits to the organization; OLCA can increase the knowledge on internal processes and improve the understanding operations along the value chain (UNEP/SETAC, 2015). However, maintaining respected the standard requirements on LCA and OLCA the model of Multiscale LCA (MLCA) has been adopted introducing a new aspect in literature: one model able to assess the environmental impacts and the resources inventory consumptions concurrently for all the assessment scales such as process, product, product family, site, division, whole organization (table 87). The model permits to establish a correlation between the different assessment scales, allowing to assess the effects of changes occurred at product scale on the organizational scale or vice versa. The MLCA model solves this scientific gap, identified on environmental impact assessment and provides a methodological framework to measure the relationship between organizational and product scales responding to the need emerged from UNEP_SETAC initiative on OLCA (UNEP/SETAC, 2015). In fact, previously the existence of this relationship has been only declared but not measured. Furthermore, the MLCA model supports the organization to assess how a product ecodesign initiative could improve the organizational environmental performance responding to the new revision of ISO 14001:2015 that has strengthened the role of product ecodesign to improve organizational performance (Lewandowska et al., 2014). The MLCA model has been developed from the mathematical perspective and has been programmed in SimaPro programming language for the operative application. The methodological concepts remain valid, but the operative application could be significantly different with other professional LCA software (e.g. Gabi). In this context, the OES2 method (exploiting the MLCA model and LCA & OLCA methodologies), has permitted to quantify the environmental impacts and to identify the environmental significant aspects with a focus on the organization and its supply chain; supporting the quantification of targets along with the definition of specific objectives such as in the design of a green supply chain and identification of green suppliers. To support the actions prioritization to reduce environmental impacts of products, and operations of the organization, avoiding the issue of burden shifting. A concept of organizational burden shifting has been identified introducing a new aspect in literature (Loss et al., 2016). The method has been supportive also for the identification of environmental hotspots at different level such as between inputs or outputs, processes, business divisions, brands, regions or facilities. Doing so the organization identifies which areas are at risk and where opportunities exist for resource efficiency and emissions mitigation, regardless of whether they occur within the organization's boundary, upstream or downstream in the value chain. Finally, the application of MLCA model permits to study the product portfolio of the organization, identifying the products that contribute most to the environmental impacts of the organization and permitting also the comparison of the environmental performance of all products that compose the product portfolio in order to identify hotspots and improve portfolio management (Zvezdov et al., 2016). The MLCA model has been developed with an innovative multiparametric programming in the SimaPro software simplifying management of the model sections and modules, and simplifying the inventory data transfer. In this contest OES2 method is the first method for multiple EMTs use that introduce a fully correlation between the life cycle environmental performance of the organization and the life cycle environmental performance of the products realized (see table 87). The concept to conducting LCA for large number of products or for all products of an organization has been ever since considered a hard to do effort mainly because the data collection process has ever conduct manually. Furthermore, the only experiences on application of LCA to large product portfolio has been conducted using streamlined Life Cycle Analysis that is a simplified application of LCA methodology. This approach was determined by the not realistic possibility to collect and manually enter all data into LCA software. The OES2 method overcome these limits, introducing the Environmental Inventory Database (EID) that automatize the data collection process exploiting a systematic computer-aided extraction of environmental information already available in company-internal business informatic systems. The EID has based on seven different interfaces that permit to collect, manage and re-elaborate life cycle inventory data separately for the following areas: supply chain, production, products bills, energy consumptions, auxiliary materials consumptions, wastes and other emissions, delivery transports. These interfaces permit to collect data specifically for each product. This separation of data is also useful to make available re-elaborate data for other purposes of the organization. The interfaces for data extraction from business information systems of the organizations has been based on loading routines that have been centralized in EID, whereas the extraction queries that have been implanted directly into the existing data business information systems, that are the data sources. The excel programming code has been used to develop the EID and ERD. This choice has permitted to minimize the costs of develop, ensuring two important aspects: a high flexibility to custom EID during application test in function of specific business information systems of the organization, and a high compressibility by users of the organization. However, database excel based could be exposed to instability and crash problems in the presence of huge body of data, therefore, an upgrade of the system, translating the excel programmed software in a different informatic language maintaining the same structure of EID could be considered. The EID responds to the development directions identify by the scientific community that has identified the development of automated data transfer as the only promising way to manage huge body of life cycle inventory data through the development of new specifically designed tools. In order to permits the interaction between MLCA model and EID interfaces a set of programmed links have been introduced. This aspect is very useful inasmuch permits to automatize the feed operation of SimaPro MLCA model. Furthermore, the automatization of data feed operation to MLCA model permits to simplify the performance tracking, that not being a standalone assessment operation inasmuch it implies a cyclic data collection process and therefore the improvement introduced by EID increase over the time. Finally, also the process of results management has been automatized by OES2 method introducing the Environmental Results Database (ERD). In fact, besides the huge body of life cycle inventory data in input to the MLCA model, the model generates a huge body of results on life cycle environmental impacts and on inventory resources consumption analysis, that requires an automatized management approach. Therefore, the OES2 method respected to the most known methods for multiple EMTs use introduces operative solutions to improve the management of huge body of life cycle inventory data and of results on life cycle environmental impacts (see table 87).

Interesting results emerged from industrial implementation of OES2 method (test 1). The life cycle environmental impacts of whole San Benedetto Italian Mineral Water Division have been calculated. This application has been cited as the first application known to the world of OLCA (UNEP, 2017). It refers to all mineral water bottled products realized from all Italian manufacturing sites through the bottling of water extracted by San Benedetto springs located in: Scorzè (Province of Venice (VE)), Popoli (Province of Pescara (PE)), Viggianello (Province of Potenza (PZ)), Donato (Province of Biella (BI)), Atella (Province of Potenza (PZ)) (Manzardo et al., 2015). A total of 272 different products have been assessed concurrently with the MLCA model. The OES2 method applying OLCA methodology and the MLCA model has permits to assess the absolute values of environmental impacts of the whole division. All standardized impact category recognized at international level (12 impact categories) have been assessed. Focusing on climate change, water scarcity and fossil depletion impact categories, according to PEF, the impacts resulting for the year 2016 are respectively equal to: 2,91E+05 t CO2 eq/year, 4,27E+06 m3 eq/year and 1,07E+05 t oil eq/year. These results have permitted to San Benedetto to achieve the first goal at organizational level related to the assessment of life cycle environmental impacts of the Mineral Water San Benedetto Italian Division. The MLCA model has permitted to assess the environmental impacts also for the other scales: the two sub divisions (PET products and GLASS products), all single production sites, all single products and all life cycle processes. These results have been used to assess multiple contributions analysis identifying important information on which are the most relevant aspects to manage life cycle environmental impacts. At sub division level has been identified that the PET sub division is the most relevant to manage (contribution of 90%). The sites of Scorzè, Popoli and Viggianello shown the most relevant contributions to environmental impacts. Interesting results emerged from the identification of the contributions of different life cycle stages. In the case of climate change and fossil depletion impact categories the most relevant contributions derive from raw material extraction and transformation stage (on average 52%), from products delivery stage (on average 25%) and from production stage (on average 15%). However, in the case of water scarcity the contributions change and become respectively: 45%, 8% and 43%. This aspect has been very important for the organization that have from many years a business strategy for climate change impacts reduction, and it has allowed to knowledge new potential hotspots on which intervene to reduce impacts on water scarcity. The analysis has also permitted to the organization to identified also the life cycle processes on which act to manage and reduce environmental impacts related to different life cycle stages: consumption of PET granulate, use of RPET, plastic caps, shrink film that generates the greater contribution between the secondary packaging, consumption of electricity and transport to deliver products especially by truck. These results have been important to give to the organization specific tasks to perform ecodesign and ecoefficiency activities in order to improve its environmental life cycle performance. The application of OES2 method has improved the capability of the organization of identify and evaluate environmental aspects and their potential impacts, inasmuch the most significant environmental aspects play a crucial role in the formulation of effective environmental policy, in terms of the definition of objectives and targets, therein providing the basis for the entire EMS (Põder 2006). In this context the introduction of OLCA permits to overcome limits related to EMS that does not provides a method for the assessment of environmental aspects but only some general guidelines. In fact, with the introduction of OLCA and the MLCA model, a complete method for assessment of environmental aspects has been introduced. The OES2 method exploiting MLCA model, has permit to achieve the ambitious task (Zvezdov et al., 2016; Mainrenken et al., 2012) to cover the life cycle assessment of all 272 products, permitting to study in detail the product portfolio of the organization. Hotspots have been identified in the sets of products with format 0,25L; 0,33L; 0,40L; 0,75L and 1,5L. The full analysis of the product portfolio has permitted comparative analysis of the impacts generated from products in order to assess differences between different bottling processes such as standard bottling process respect to aseptic bottling process. In this case the second one generates for example an increasing of about 55% of GHG emissions mainly due to process reasons that imply higher energy consumptions and require a bottle with a higher mass. Comparative analysis has been also used to assess the differences between standard products and the ecogreen products. The second one resulting on average the 10% less impactful of the standard products considering all formats. The comparative analysis of the environmental impacts of similar product codes produced in different sites has been supportive to identify hotspots. The study of environmental impacts at product level has permitted to San Benedetto to identify all environmental impacts of all product codes related to ecogreen product line achieving the second strategic assessment goal of the organization. The MCLA model has been useful also to perform the life cycle inventory analysis with the previously strategy of multiple contribution analysis in order to identify hotspots in terms of resources consumptions. In fact, it has permitted to San Benedetto to assess the level of resources consumption of different sites and of different products. The full study of the product portfolio has been very supportive to the organization in order to assess and manage all aspects that have contribute to the environmental impacts assessed. In the case of San Benedetto this concept is aligned with the market demand of product differentiation that imply an expansion and pulverization of the product portfolio. This phenomenon is increased in the last years and it is market determined. Furthermore, this industrial case study, has delineated the existence of a strong relationship between the product development projects (such as bottle lightening projects) and specific product codes therefore the detailed study of product portfolio is required. This relationship is due to technical and commercial reasons. Other differences exist also between product codes of the same format that generate high variation of environmental impact related to design specification, production process technologies and different delivery destinations. In fact, the results show for example in the case of the format 0,5L exist a very wide range of variability (89,6 – 291,1 g CO_2 eq/bottle). On average the ratio between the maximum value of the range and the minimum value of the range considering the case of all formats is equal to 2. For all these reasons San Benedetto has promotes the detailed approach of study of the product portfolio at product code level. In fact, San Benedetto is already finishing to extend the MLCA model to water products of other brand and to all soft drinks products with San Benedetto brand and of third brand. The extension to these products has based on eco efficiency reasons but for strategic reasons has had a lesser priority of implementation respect to the San Benedetto Italian Mineral Water Division that has constituted the main assessment goal of the organization with the goal to assess all ecogreen products. In this contest the EID interfaces have been applied to San Benedetto and have allowed to collect all life cycle environmental inventory data. The organization has observed respect to its previously experience in LCA data management occurred the years before the implementation of OES2 method that the time to collect and elaborated the data has been decreased of 80%. The links between EID interfaces and SimaPro MLCA model have permitted to minimize the time for data entry. In fact, not considering the time that is requested to create the links the first assessment year, the time requested year by year is low and related only to the implementation of the changes of model that requires new links or the deletion of old links (e.g. introduction of new product codes, the deletion of some product codes). The introduction of EID is an important aspect for San Benedetto because all the data on the organization environmental performance are managed in a unique centralized database that has permitted to solve issues related data search and multiple sources of data. In this context, the EID provides data to other business function also for purposes different from environmental management. Furthermore, the EID implementation has permitted novel elaborations of raw data. A good example can be made for the product delivery stage where the introduction of EID permits to calculate the specific kilometric distances that each product travelled in truck, train and ship. These types of data have been useful to start new considerations on delocalization of production through the transfer of the production from a site to other sites. In fact, these data have supported the strategical decision of to acquire a new site in the south of Italy (Viaggianello site). Furthermore, the data collected by EID are used to sustain ecodesign and ecoefficiency activities. This industrial test shown as the use of EID to automatize data collection processes and data feed processes to SimaPro MLCA model permits to solve gap related to large data management and to make possible the study of large product portfolio. Currently, the organization is able to study 272 products in less of 2 months including time for LCA reporting and for the third part certification. The introduction of ERD in the same way has simplified the results management and has permitted to the organization to historicize the results in order to support the performance tracking at organizational scale and at product scale. In this context the organization has decide to assess the possibility to invest on EID including also an upgrade in association with a software house in order to translate from the excel language to another informatic language (e.g. Database MS SQL) in order to improve stability and security of database.

4.3.2. Results discussion – Performance evaluation & performance tracking (3)

Focusing on methodological results on environmental performance evaluation & performance tracking, OES2 applying the EPE methodology according to ISO 14031 permits to assess the life cycle environmental performance for all the assessment scales and especially for the organizational scale and the product scale (table 86). Often the organizations focus the attention of the trend of absolute environmental impacts (e.g. GHG emissions) without measuring the real improvements that can be assessed only introducing the concept of environmental performance that focus the attention on the trend of environmental performance indicators. They constitute indexed environmental impacts as a ratio (or other quantitative relationship) between the environmental impacts generated and the output of performance (e.g. reference product quantity). The OES2 method, using EPE, ensures the correct framework of assessment of life cycle environmental performance and support, according to ISO 14031 the introduction of environmental performance targets promoting the continuous improvement of life cycle environmental performance. In fact, the measure of a performance without fix a performance target does not support the improvement. The OSE2 method respect to other already exiting method for multiple EMTs use, expand the scope of EPE to the life cycle performance do not focusing only on "gate to gate" performance but considering the life cycle performance of whole life cycle including all processes with a cradle to grave approach according to the new revision of ISO 14001:2015. The OSE2 method can support also "cradle to cradle" assessments according with the new concept of circular economy that has increased the relevance to expand the scope of environmental management to the entire life cycle of products and organization. Furthermore, the OES2 method, respect to the other methods, expands the scope of EPE from the traditional organizational scale to the product scale according with the multiscale approach at the base of the OES2 method. This aspect is very important because permits to approach the performance evaluation to the assessment scales more frequently interested by investments and therefore, thanks also to the MLCA model that guarantee the effects correlation, permits to better understand the improvements in terms of organizational environmental performance due to investments on developing project at product and process scale. It permits to give to organizations more levers to manage its environmental performance. The OES2 method explores also the operative implementation of EPE regarding the life cycle environmental performance introducing the Eco Environmental Key Performance Analyzer (Eco – EKA). It is an operative tool that permits to automatize the calculation of environmental performance distinguishing between: IOPIs (Inventory Operative Performance Indicators) and the EOPIs (Environmental Operative Performance Indicators). The first one type of performance indicators permits to assess the performance in terms of resources consumptions, instead the second one, permits to assess the performance in terms of environmental impacts. The first type supports the assessment of the second type of performance indicators according with LCA methodology. It acquires and filter automatically the data from ERD permitting to reduce the time for performance evaluation. Eco – EKA provides a smart visualization of the results simplifying the performance evaluation both at organizational and product level. In fact, the results, in function of the organizational needs, are shown in two visualization dashboards, one for the organizational scale and one for the product scale. At the organizational scale, the performance of the main product categories that characterized the product portfolio resulting supportive to understand the whole performance. The Eco- EKA introduces the concept of Supportive Operative Performance Indicators (SOPIs) that supports the performance evaluation considering the trend of variables that indirectly influence the performance for example relating to internal product portfolio changes not due to new products (e.g. change of average product format) and to changes of impact factors of relevant life cycle processes (e.g. emission factor of most used raw materials). The assessment of the SOPIs is very important to correct interpreter the environmental performance trend inasmuch these variables could have opposite effects respect to the commitment of the organization to improve performance. An example can be the reduction of average product format in the water bottling sector, that depends from market demand, that intrinsically increase the PET plastic consumption and therefore the environmental impacts. In this case, the monitoring of SOPIs supports also the strategic decision making process, providing orientations to take decisions in order to focus investments and product eco design projects. The OES2 method introducing the Eco-EKA, respect to the other methods for multiple EMTs use, provides also an operational response to the need of tools to operatively monitor environmental performance and improving the communication of the evaluation to top management. (table 87). The Eco-EKA has been developed in excel programming code.

Interesting results emerged from industrial implementation of OES2 method (test 2). The application of OES2 method has allowed to understand to San Benedetto the importance to assess environmental aspects using the concept of performance according to ISO14031 without focus on absolute values of environmental impacts. According to the two assessment goals defined by San Benedetto the environmental performance of the San Benedetto Italian Mineral Water Division and of the EcoGreen product line have been analysed. The application of OES2 method has permitted to identify the performance of the San Benedetto Italian Mineral Water Division that for example on climate change category is equal to 206 kg CO_2 eq/1000 litres while the performance of the two Sub Divisions are of 194 kg CO_2 eq/1000 litres in the case of PET Sub Division and equal to 446 kg CO_2 eq/1000 litres in the case of GLASS Sub Division. These values have been obtained on year 2016 and constitute the first values for the performance tracking of the San Benedetto Division. Focusing on the PET Sub Division, interesting results emerged comparing the results obtained for the different production site where the best performance is related to the Viggianello site (156 kg CO_2 eq/1000 litres) while the worst performance is related to the Atella site (305 kg CO_2 eq/1000 litres). The use of the concept of environmental performance has permitted to San Benedetto of identify this hotspot. In this case the high impact of the Atella site it is related mainly to a product portfolio with high PET consumption (average PET consumption of 31 kg/1000 litres and an average format of 1 litre). Comparing this performance with the results of Scorzè that has an average PET consumption of 18,6 kg/1000 litres with a smaller average format (0,85 litre) it is possible to conclude that the product portfolio of Atella site shown a hotspot on PET consumption. The introduction of Eco-EKA has simplified the performance tracking. Focusing on the PET Subdivision of the Scorze site it has been identified a reduction trend starting from 2013 to 2016, with a reduction of -8,8%. The organization has an environmental objective for this production site of reduce by 2020 of 14% the GHG emissions. The analysis of the products portfolio performance at level of product format has supported the interpretation of variation trend from 2015 and 2016 that is very small (-0,8%). Although the organization has invested in ecodesign projects to improve the performance of the main formats (0,5L; 1L; 1,5L and 2L), a variation in market demand has produced a shift towards smallest formats as indicated by the table of SOPIs. Furthermore, to this aspect one adds another aspect related to the reduction of RPET consumption that is shown in the inventory part of Eco-EKA. This example shown as OES2 method, introducing Eco-EKA simplifies the evaluation of environmental life cycle performance at organizational level. The trend of IOPIs support the analysis and permits to assess the effects of the San Benedetto strategy in terms of reduction of resource consumptions at level of: PET, RPET, plastic cap, electricity, etc. The IOPIs at level of product format permit to have an exhaustive picture of the improvements that have generated the improvement al organizational level. For example, regarding the total plastic consumption for plastic bottle production (PET + RPET) a reduction of -3% at organizational level has been identified although the weight of bottles of the main formats have been significantly reduced: -6% 0,5L; -15% 1L; -1% 1,5L; -10% 2L. However, the reduction of the average format -6,7% has partially eroded the improvements introduced. This case shown as the introduction of SOPIs is supportive to the environmental performance evaluation. Focusing on the performance evaluation of ecogreen product line, the results shown from Eco-EKA permits to observe the effects of eco design projects occurred over the time and that has permitted to reduce from 2013 to 2016 of -17,5%

the GHG emissions. In the case of Ecogreen a hotspot has been identified relating to the RPET. In fact, in function of the supplier country the environmental impacts of RPET can vary significantly and therefore it is important to be careful during the supplier selection.

4.3.3. Results discussion – Ecoinnovation – EcoDesign part (4)

Focusing on methodological results on ecodesign, OES2 applying the methodology according to ISO/TR 14062 permits to introduce the concept of ecodesign in the organization (table 86). The ecodesign is the most important tool to develop and find innovative solutions to improve environmental performance and promote the innovation improving already existing products or developed new products. The OES2 method gives a key role to ecodesign, promoting a fully incorporation of environmental aspects in process of development for every scale (process, product and organizational) and in strategic decision making to assess investments jointly environmental aspects with technical and economic aspects. This approach has permitted to develop and adopt the new concept of organizational ecodesign introducing a new aspect in literature (Loss et al., 2016). Following this concept, the organization introduces a systemic innovation that produces changes at infrastructural level, where, the organization's layout (in the case of multisite organization) can be modified in order to improve environmental performance through the transferring of production processes from a site to other sites or through the acquisition of new sites located in strategical points that permit the improvement of environmental performance. This concept has been positively adopted to assess the potential improvements of environmental performance due to the introduction of a new site. The OES2 method exploits ecodesign to assess preventively the potential environmental performance of all relevant project of product and process development according the multiscale approach on which is based the OES2 method. The ecodesign implementation is formalized and controlled and the performance of improvement projects are measured and monitored using environmental performance indicators, following a continuous improvement approach according to the new revision of ISO 14001:2015. Considering these aspects, the OES2 method increases the ecodesign maturity level of the organization (Pigosso et al., 2013). The OES2 method provides an important support to the operative implementation of ecodesign. In fact, although the ecodesign is rather diffuse in the already exiting methods for multiple EMTs use, an important gap has emerged relating to the operative implementation regarding the need of tools to perform the comparison of performance of different ecodesign alternatives that can be use easily by designers. In order to respond to this gap, the OSE2 method has introduced the Eco Design Simulation Dashboard (Eco-DSD) that provides a work space to simulate different ecodesign alternatives (table 87). The Eco-DSD automatizes the inventory and environmental impacts calculation requiring to designer the only introduction of data on different alternatives design. It provides multiperspectives results on ecodesign project: savings in terms of environmental impacts, saving in terms inventory resource consumptions and saving in economic terms. The integration between environmental and economic performance permits to reinforce the decision-making processes. The results are characterized for the main life cycle processes. Furthermore, the ecodesign project results are visualized in a smart dashboard that permits to simplify the communication of results to top management and simplify the comparison between the different design alternatives. The Eco-DSD has been developed in excel programming code and permits an easy maintenance. Is has been developed and tested to be implemented to all assessment scales: process, product and organizational.

Interesting results emerged from industrial implementation of OES2 (test 3). The ecodesign has been applied to all the assessment scales: processes, product and organizational. According with the concept of multiscale correlation on which is based OES2 method, all eco design project generates effect on all assessment scales. Starting from the organizational scale, where has been introduced the new concept of organizational ecodesign, the application of San Benedetto provides interesting results. In fact, in this case the new acquisition of a site in the south Italy has permitted to modify the design of the San Benedetto PET Italian Mineral Water Sub Division reducing its impacts of -2,8%. The effects of this project are reflected also in the improvement of the performance of delocalized products that reduce the GHG emissions of -6%. Not all the activities of delocalization of production could generates positive effects at organizational level, in this context the new concept of burdens shifting at organizational level has been introduced. This applicative case shown as the concept of ecodesign is effectively extendable to organization and as the multiscale correlation is useful to identify additional effects on other assessment scales (e.g. product) of eco design projects performed at a specific assessment scale (e.g. organizational). This last aspect has been supported also from other application of ecodesign at product and process scale. In the first case, a project lightening of bottle body and plastic cap wheights, for still water product with format 0,5 litres has generated an improvement of -6,3% of the product performance corresponds an improvement of about -1,3% of the San Benedetto PET Italian Mineral Water Sub Division at organizational level. In the second case, a new bottling line has been introduced (process ecodesign) permitting a reduction of -9,2% of realized products and a reduction at organizational level of -1% of the San Benedetto PET Italian Mineral Water Sub Division. Another important aspect has emerged, it is related to the fact that the ecodesign application has permitted to San Benedetto to identify new potential savings that before did not known such as the saving of electricity for bottle production due to bottle lightening projects.

It is important to underline that the hotspots emerged from the application of OLCA and LCA are elements in input to the process of ecodesign. The applicative ecodesign cases presented shown this relationship adopted by San Benedetto. In fact, in the first case, San Benedetto acts on the product delivery stage, reducing the transport by truck introducing a new site. In the second case San Benedetto acts on raw material extraction stage, reducing the PET consumption through the lightening of one of the most important containers (format 0,5L). In the third case San Benedetto acts on the production stage, introducing a new line that reduce the energy consumption to pack the products. In this context, the hotspots identified along the life cycle have been used from San Benedetto to prioritize the investments in development projects of ecodesing. The OES2 method improves the operative implementation of ecodesign. The industrial application of Eco-DSD has shown as this tool supports designers during ecodesign activities. In fact, it provides a simulation work space where rapidly simulate ecodesign alternatives. The designers have found comfortable the structure of Eco-DSD. Finally, the organization has found useful that the dashboard provides results on environmental savings, inventory savings and economic saving supporting the integration mainly between environmental impacts and economic costs. San Benedetto has decided to implement the use of Eco-DSD for all relevant ecodesign projects, enclosing the results to the documentation necessary for budget allocation for project implementation.

4.3.4. Results discussion – Ecoinnovation – EcoEfficiency part (4)

Focusing on methodological results on ecoefficiency, OES2 applying the methodology according to ISO 14045 permits to introduce the concept of ecoefficiency in the organization (table 86). The ecoefficiency with the ecodesign is the second power of ecoinnovation in OES2 method. Although it is applicable to products in order to communicate to stakeholders the ecoefficiency performance of the product, while allowing this type of use if the company identifies the need, the OES2 method focus the attention of the use the ecoefficiency on the assessment of the environmental performance of productive processes of the organization in order to promote the reduction of environmental impacts and economic costs. This focus is very important from the organization perspective in order to improve its industrial competitivity. The inclusion of ecoefficiency is an innovation of OES2 method respecting to the other already exiting methods for multiple EMTs use. (table 87). The OES2 method does not stopped to require the application of ISO14045 but gives also a new operative solution to assess the ecefficiency of the organizational productive processes. This solution is the Indicator of Work Environmental Efficiency. IWEE permits a multiperspectives assessment of the process ecoefficiency including all relevant resource consumptions, such as: energy (all vectors), auxiliary materials (e.g. chemicals and water) and raw materials scraps. In the assessment is also considers the relevant outputs (e.g. wastewater). The economic weighting of the different aspects permits to calculate a single score and to prioritize the improvement solutions that prioritize the reduction of economic costs reducing also the environmental impacts. The assessment of IWEE components permits to identify hotspots. Furthermore, the single score of IWEE has been translated in terms of ecoefficiency classes in order to improve the communicability of the results. The IWEE represents a complementary perspective of process efficiency that gives “qualitative information on process efficiency” different from the “quantitative information on process efficiency” returned by classic process efficiency indicators used by organization such as OEE. The application of statistic discriminant analysis has been permitted to identify a discriminant function that has been used to calculate the Index of Potential Loss of Ecoefficiency (IPLE). This index is able to discriminate productive configurations that encourage ecoefficiency by configurations that discourage ecoefficiency. Productive configurations are set of different productive variables (e.g. production rate, working shifts, working time, etc.), that influence statistically the ecoefficiency of the process and that can be identified through statistical correlation analysis. IPLE is very useful to explain as productive variables influence the IWEE trend and therefore supports the IWEE trend analysis. The inclusion of IPLE to support the analysis of IWEE has responded to the need of considering environmental or energy related objectives in scheduling a flexible manufacturing system in order to improve the decision making process of planning and manufacturing activities (Favi et al., 2017). In order to automatize and simplify the IWEE and relative IPLE assessment the tool has been programmed in excel programming code. The results of the assessment are returned in a smart dashboard that provides the global IWEE result and the results for its components in terms of scores and classes. The dashboard provides the environmental impacts and the economic cost generated with the specific level of ecoefficiency, permitting to rapidly assess the cost of ecoefficiency failure. Finally, the assessment of the state of productive variables that influence the process ecoefficiency is provided in the dashboard in order to give operative suggestions to identify hotspots and to evaluate changing of production conditions in order to optimize the production planning. The setup of the range to evaluate the state of the different productive variables requires the involvement of the experts on the specific productive process under assessment. The implementation of IWEE by OES2 method represents a novelty that permits to assess ecoefficiency correlating environmental performance (e.g. GHG emissions) with economic performance (e.g. energy costs, costs of utilities, etc.) and typical production variables (production rate, working shifts, working time, etc.).

Interesting results emerged from industrial implementation of OES2 (test 4). The application of OES2 method has allowed to understand to San Benedetto the importance to assess the ecoefficiency level of its production processes according to ISO14045 in order to achieve reduction of environmental impacts and economic costs. According to this perspective, the IWEE has been applied to the bottling processes. The results shown as the IWEE is able to give new information to the organization on the process efficiency. This information is related to the level of resource consumption of the bottling line. The IWEE has been developed on inventory indicator in order to make more understandable the process performance. Respect to the OEE efficiency indicator used by San Benedetto and many other organization over the world, the IWEE provides additional information permitting to improve the capability of the organization to manage the process. Interesting results are emerged during the assessment of week that have the same value of OEE but very different resource consumptions. In these cases, it is clear that the IWEE permits to manage new aspects of process efficiency introducing new possibility of reduction of environmental impacts and economic costs. The IWEE has considered the following aspects in the application to San Benedetto: electricity consumption, hygienic treatments considering chemicals, water in input and water sent to wastewater treatment plant, raw materials scraps. In the case of water bottling lines an average value of IWEE equal to 90% has been assessed, identifying improvement opportunities on the bottling lines 55, 56, 57 and 58. The introduction of IPLE support the IWEE trend analysis. The variables that characterize production configurations can influence a lot the process ecoefficiency level. The results shown as in many cases significant variations of these variables generate significant variations of the process ecoefficiency. In this way the use of a statistical index, that permits to assess which productive configurations encourage the ecofficiency and which discourage the ecoefficiency, permits to give important additional information to better understand the trend. Six main variables have been identified in the case of the bottling line: productive and not productive times, average production run length, volume produced, working shift configuration and the hourly bottling line speed. Beside the variables that influence directly the ecoefficiency the organization must take into account also variables that influence indirectly the eco efficiency. In the case of the bottling line these variables are: the number of product codes realized and the number of format changes. On the average the results shown that, in the case of the bottling lines that produce water product, the productive configurations in class 1 generates consumptions lower that -21% respect to the productive configurations in class 3 and lower that -7% respect to the productive configurations in class 2. Another important aspect relating to IWEE has been the use of a weighting criterion based on economic cost considerations, that has permits to San Benedetto of prioritize the improvement routes that generate the highest cost reduction, considering that for the mathematical formulation of IWEE, the reduction of environmental impacts is intrinsically considered. The weighting criterion changes only the priorities of intervention. The IPLE besides to permit to explain the IWEE trend could be supportive in the elaboration of alternative scenarios where the productive configurations are changed in order to promote an improvement of process ecoefficiency. The test conducted changing the working shift configurations on the bottling line L51 has shown potential savings of -6% in economic terms and of -4,3% in GHG emissions terms. Finally, the informatic structure of IWEE has simplified to the organization the IWEE and IPLE calculation. Furthermore, the use of a dashboard has simplified the results visualization permitting to San Benedetto of operatively use the emerged information to improve the management of bottling processes. The organization has decided to full implement IWEE as a new indicator for process efficiency assessment and is evaluating of to extend indicator to bottle production processes. Furthermore, San Benedetto is evaluating the insertion of criteria based on the results of IWEE and IPLE into the new software for the production planning. This software, work with a heuristic logic, permits to generate optimal scenarios of production scheduling. The insertion of criteria of IWEE and IPLE can improve the process of scenarios identification, finding scenarios that beside respect all other constraints can also promote the reduction of resource consumptions and therefore of the production costs.

4.3.5. Results discussion – Strategic Decision Making (5)

Focusing on methodological results on strategic decision making the OES2 method introduces a novelty in the field of method for multiple EMTs use introducing the Strategic Environmental Decision Making module (SEDM module) that is a procedural tool that supports and favours the application of tool designed specifically for decision making (table 86). In fact, although the combination between decision making tools (e.g. mathematical optimization) and LCA methodology has been deeply investigate by the scientific community (De Luca et al., 2017), a gap exist at level of the already existing methods for multiple EMTs use that do not include these types of tools. The OES2 method responds to this gap (table 87). Although many tools for decision making have been developed by scientific community, the OES2 method focuses the attention on two tools: a tool to face industrial problems that require statistical techniques and a tool to face industrial problems that require mathematical optimization techniques. The choice to develop the SEDM module as a procedural tool is due to the impossibility to predetermine the specific decision making processes that the organization will face, therefore the choice has been of to insert a tool that stresses to the organization the need and the importance to use decision making tools to increase the robustness of the strategic decisions. In OES2 method, the use of these decision making tools is related with the implementation and the use of software available on the market. The software selection it is a choice that can be different organization by organization, in the specific case of this PhD thesis for statistical approaches has been used Statgraphic

XVII and for mathematical optimization has been used ModeFrontier. The use of software such these, do not imply high cost of licences and high requests of expertise inasmuch in the last years the market offer of these software has increased reducing the costs and the software developers have focus a lot of attention to develop simplified modular interfaces that permit to the users to use the software reducing the need to insert specific programming code. The OES2 method identifies three possible areas of application of SEDM module to improve life cycle performance of the organizations. The first one is related to the improvement and optimization of life cycle processes of the organization in order to reduce identified hotspots. One of the most relevant example is the optimization of supply chain in order to improve and support decision making processes related to suppliers and to support decision making related to products delivery stage. This application can be very strategic for multisite organizations that can optimize the localization of their production processes reducing environmental impacts and economic costs. The second application identified is related to support the identification of optimal solutions relating to decisions on ecodesign specifications of the different alternatives assessed. This approach recommended by OES2 method is according to ISO/TR 14062. The third application is related to support the improvement of ecoeffciency at product and process level providing approaches and solutions able to guide the organization in the improvement of ecoeffciency of its processes. An example of this application is IWEE with the IPLE that has been elaborated using statistical approach (statistical discriminant analysis). The OES2 method, introducing the SEDM module and therefore supports and recommends the use of these decision making tools, responds to the development directions defined a part of scientific community that have identified in the use of these tools the most promising solution to find compromise decisions for conjugate environmental performance objectives with economic performance objectives considering the set of constraints to which each organization is subject.
Interesting results emerged from industrial implementation of OES2 method (test 5). The application of OES2 method has allowed to understand to San Benedetto the importance to assess use decision making tools for strategic decision processes. The SEDM module has been applied two times during the tests in San Benedetto. The first time, to support the development of IPLE and the second one to solve a multiobjectives problems related to the selection of PET supplier mix in order to respect given economic performance, minimizing impacts on climate change and water scarcity. The results shown as the use of specific decision making tools provides interesting opportunity of improvement. In the test a reduction of the -3,8% of the GHG emissions related to PET suppliers mix has been obtained. This result permits a reduction of -1,2% of the whole GHG emissions of the San Benedetto PET Italian Mineral Water Sub Division.

4.3.6. Results discussion – Strategy & Management (6)

Focusing on methodological results on strategy & management the OES2 method applying the methodology according to the new revision of 14001:2015 permits to introduce managerial and strategical aspects. Focusing on the management of aspects related to life cycle environmental performance although the use the EMS in the already existing methods for multiple EMTs use is diffuse (table 87) the OES2 method introduces respect to the other methods, a new procedural tool in order to solve gaps related to environmental strategy definition (table 86). The Environmental Sustainability Strategy Model, in this new procedural tool introduced for the first time in a method for multiple EMTs use by OES2 method, that permits to support and test preventively the environmental strategy in order to identify and take corrective actions before approved the strategy (table 87). This model, internalizing the concepts introduced by Jouneault et al. (2016) and other authors, permits to develop the two components of environmental strategy: the ecoefficiency strategy component related to manufacturing initiatives on ecodesign and ecoefficiency; and the ecobranding environmental strategy component related to marketing and communication initiatives. This aspect is very useful because permits to avoid the issue related to unbalanced strategy that often is too pushed on the ecobranding component without support actually the communication activities with real activities of life cycle environmental performance improvement. Furthermore, the test of consistency between the planned activities and the fixed objectives by the organization (performance objectives in the case of ecoefficiency strategy component and communication objectives in the case of ecobranding strategy component), permits to reducing the risk of divergence between the intended strategy and the realized strategy in both cases of the two strategy components. This result is very useful for companies that are exposed on the market with communication processes on life cycle environmental performance to stakeholders. Furthermore, the ESSM supports the increasing of the link between ecodesign and EMS as required by the new ISO14001 revision, focusing the attention on the ecodesign and ecoefficiency activities as levers to improve life cycle environmental performance of the organization. Another important result related to the ESSM is its sustain to communication processes on life cycle environmental performance over the time or on eco-friendly initiatives and projects perform by the organization. In fact, it supports communication and information to stakeholders, consumers, investors, authorities, and the general public. One of the most relevant objective of these communication processes could be to increase the organization' reputation on the market and give evidence of its environmental sustainability where applicable. Other important communication processes supported by OES2 is related to labels and environmental claims according to ISO14021-24-25. The method is able to provide results on environmental performance in order to obtain product labels related to Product Environmental Footprint (PEF), the new European framework for environmental performance evaluation of products. The model is also compatible with Environmental Product Declaration (EPD) scheme and with the Organizational Environmental Footprint (OEF), offering a wide choice of communication tool to use. Furthermore, the OES2 method, providing a performance tracking at organizational and product level, permits to the company of to claim its performance achieved over the time with specific claims that can be inserted on the products or in other communication supports (e.g. materials for B2B communication). Finally, the ISO 14001 has an important role, supporting: consolidation of leadership role, change planning, communication, increasing of commitment of top management and employees, staff training, definition of roles and responsibilities, availability of financial and human resources requested for the application of the method, the functionality of the method.

Interesting results emerged from industrial implementation of OES2 (test 6). The application of OES2 method has allowed to understand to San Benedetto the importance to define an environmental strategy and to create a structure able to manage the method. In this sense, San Benedetto has created a new Sustainability Team in order to manage the OES2 method assuming and training three people coordinated by a project manager and a director. The definition of roles and responsibilities has been fundamental to incorporate in the culture of the organization the OES2 method. San Benedetto has decided to certify ISO14001:2015 all the Italian Group by 2020 in order to consolidate the OES2 method application that has been definitively choice by San Benedetto as its new reference method for environmental management. Regarding the strategy definition, the ESSM has been positively applied in order to test the environmental strategy of the product line ecogreen that envisages an environmental objective to reduce the GHG emissions more than 20% by 2020. The consistency check of ecoefficiency strategy component has been conducted through the assessment of the potential improvement contributions of all planned eco design and ecoefficiency projects regarding the ecogreen products. The results shown that the global potential improvement exceeds the environmental objective permitting a greater GHG emissions reduction. This aspect has permitted to San Benedetto to reduce the risk of divergence between intended environmental strategy and the realized strategy. According to this results communication processes has been established in order to communicate the achieved environmental performance using product claims according to ISO14021. This strategy has increased the reputation level of San Benedetto that in the world ranking of Reputation Study 2017 elaborated by RepTrak has achieved the first place in the alcohol-free beverage industrial sector.

4.4. SWOT analysis

Every method has strengths and weaknesses and it is important to discuss the improvements introduced by the OES2 method identifying also potential weaknesses. In this way, a SWOT analysis has been performed. In the following table have been identified: the strengths, the weaknesses, the opportunities and the threats related to environmental management.

Strengths (S)	Weaknesses (W)
1. Multiscale life cycle assessment 2. Comprehensive life cycle environmental management approach 3. LCA applied to all product portfolio, supporting identification of new hotspots 4. High operative support with STEMs 5. Life cycle performance evaluation and performance tracking at product and organizational scales 6. Support the reduction of industrial costs 7. Favour new market opportunities 8. High time saving for life cycle inventory data collection 9. Support strategic decision making introducing robust methodologies (mathematical and statistical techniques) 10. Support definition and approval of the environmental strategy introducing improvement objectives 11. Full support to external communication	1. The organization must have a good expertise with EMTs 2. Require high competence of employees that manage the method application 3. Increase of the cost for EMTs implementation (required software, potential certification, etc.) 4. Increase cost of measurement tools (e.g. to measure energy consumptions)
Opportunities (O)	**Threats (T)**
1. Industry 4.0 and technological evolution of measurement systems 2. Market awareness on environment 3. Establish relationships with institutional organisms (e.g. Environmental Minister)	1. More restrictive environmental laws 2. Market awareness on environment 3. Shocks of raw materials and energy prices 4. Benchmarking with competitors

Table 88 SWOT analysis applied to OES2 method

Considering the strengths of the OES2 method it is possible to notice how the method is able to face the threats to which the organization is potentially exposed. In fact, point S11 covers point T2, point S2 covers point T1, points S3,5,10 cover points T4,3. Relating to weaknesses and opportunities is interesting to see how point O1 would reduce costs related to point W4. Regarding strengths and weaknesses, the reduction of industrial costs through eco design and ecoefficiency (point S6) should widely cover costs related to EMTs implementation (point W3). The other strengths (points S1, 4, 7, 8, 9) in a costs/benefits perspective cover widely the effort request by the organization to improve its competence on environmental management through specific training activities. This last point, has been demonstrated in this work, where the PhD student has trained three newly recruited human resources to constitute a new team for Eco Sustainability. These resources are able to manage OES2 method. Globally the OES2 method looks suitable for complex industries exposed to operative, compliance, financial and reputation risks related to environmental management and that face important strategic decisions.

CHAPTER FIVE: CONSLUSIONS & FUTURE PERSPECTIVES

Highlights:

- **Contributions of the research**
- **Validation of the research**
- **Future perspectives**

Environmental sustainable development topic is increasingly at the centre of international interest. During the last decades, environmental issues have evolved from pollution and depletion of natural resources towards global issues such as climate change. In this global context, industries need of a robust Environmental Strategy for improving their competitiveness and proactively manage related risks and opportunities. In the last years, the concept of life cycle environmental management has increased its importance stressing the need of organizations manage all the environmental impacts generate by their activities and products along all values chains with a life cycle perspective. However, different criticalities on life cycle environmental management are faced by organizations and they are circumscribable in six different critical areas: 1. environmental impact assessment, 2. inventory resources consumptions assessment, 3. performance evaluation & performance tracking, 4. ecoinnovation (Eco Design, Eco Efficiency), 5. strategic decision making and 6. strategy & management. Many Environmental Management Tools (EMTs) have been developed by scientific community. The combination of different tools is needed to ensure all environmental aspects are appropriately identified and managed. However, no methodological framework for EMTs combination has been already proposed in order to face in a holistic way all criticalities identified on life cycle environmental management. Different methods for multiple EMTs use have been developed from the scientific community and they are circumscribable in five different types in function of the EMTs selected: 1. LCA + EMS; 2. LCA + EMS + Ecodesing; 3. LCA + EMS + Ecodesign + Communication & Labels; 4. EMS + EPE and 5. EMS + Ecodesign. However, these methods have some limitations that affect company competitiveness. In fact, they are not able to respond to a set of environmental management barriers that currently limit the capacity of companies to perform the management of life cycle environmental performance. These limitations are related to: lack of environmental impact assessment at organizational level, technical difficulties in large data management, correlation between product and organizational scale does not considered, issues during ecodesign and investments assessment, lack use of life cycle performance assessment and performance tracking, lack use of decision making tools (optimization, statistical techniques, etc.), lack use of ecoefficiency assessment, issues in strategy definition and balancing. These limitations do not allow companies to have a robust and complete management of its life cycle environmental performance and therefore limit the opportunity to develop strategies that reduce the environmental impacts of the organization and its products.

In this framework took place the activity of this PhD research. It focused on the development and application at industrial level of a new method to combine environmental management tools (EMTs) to improve the life cycle environmental performance of industries. The specific objectives of the research were:

1. The develop of a new method to combine EMTs and solve identified criticalities on life cycle environmental performance management at level of 1. environmental impact assessment, 2. inventory resource consumptions assessment 3. performance evaluation & performance tracking, 4. ecoinnovation (Eco Design, Eco Efficiency), 5. strategic decision making and 6. strategy & management;
2. Test the applicability of the developed method in a real industrial case study and its effectiveness in overcome the identified criticalities on life cycle environmental performance management.

To develop the new method for multiple EMTs, the recent evolution in ISO standards with the revision of ISO 14001:2015 and the born of ISO/TS 14072 for Organizational Life Cycle Assessment (OLCA) have been considered. The Organizational Environmental Sustainability System (OES2) method has been based on the combination of seven EMTs and eight STEMs. In fact, the combination of EMTs have been required the development of STEMs (Supportive Tools to Environmental Management) that support operatively the implementation of EMTs and permit to overcome the criticalities emerged during EMTs implementation. The introduction of STEMs is an innovation of OES2 method to increase the operative support to the users, aspect that has not never considered from already published methods for multiple EMTs use. The combination method has been choice because is the most flexible and comprehensive. The flexibility deriving from the fact that the combination method permits of to concentrate on individual solutions. In fact, it permits, to the organization, to decides of primarily apply one EMT and, as a second step of to introduce, the other EMTs following a problem oriented perspective.

5.1. Contributions of the research

Criticalities related to environmental impact assessment (1) and inventory resource consumptions assessment (2) have been solved introducing OLCA and LCA methodologies according respectively to ISO/TS 14072 and ISO 14040-44, and three STEMs: Multiscale LCA (MLCA) model, Environmental Inventory Database (EID) and Environmental Results Database (ERD) interfaces (see table 86). The OLCA and LCA permit to consider all requirements to perform the life cycle environmental impact assessment and the inventory analysis respectively at organizational and product scale. The introduction of OLCA permits to achieve a comprehensive assessment of the environmental impacts of the organization along its life cycle considering all process and all products. The introduction of OLCA permits to solve potential contradiction on the fact that the good performance of some products does not imply a good performance of an organization. No method for multiple EMTs use published in literature has applied the OLCA (see table 87). The introduction of MLCA model has allowed to develop only one model that at the same time is able to perform the environmental impact assessment and the inventory analysis for all the assessment scales: organization, division, sub division, single sites, product family, single products and specific life cycle processes. The MLCA model permits to solve the problem of the lack of correlation measurement between performance at organizational scale and performance at product and process scales. The use of a multiscale approach provide by MLCA model is necessary in order to assess real hotspots at processes, products and site levels. The multiparametric mathematical formulation of MLCA model, developed with SimaPro programming language, has allowed to consider very large product portfolio permitting to perform single LCA for each product. This result has been previously considered in the literature ambitious. No model published in literature has performed complete LCA according to all standard requirements of large product portfolio (almost 300 products), certifying by third the results (see table 87). The MLCA model has undergone two third party verifications by a certification body accredited by ACCREDIA the Italian accreditation body. The introduction of EID has been fundamental to make feasible the operative functionality of MLCA model, permitting to automatize the inventory data collection and elaboration from the business informatic systems and to automatize the process of data feed to MLCA model. The EID constitutes an important centralized database of all primary inventory data of the organization for all production sites and all produced products, considering: supplier transports, products bills, auxiliary material consumptions, specifications on production processes and technologies, energy consumptions, wastes and other emissions generated, and delivery transports. It is an enormous knowledge baggage that besides support the analysis of life cycle environmental performance can support other assessment needs of other organization functions. The ERD interface, complete the process of automatization, automatizing the management of results returned by MLCA model at inventory level and impact assessment level. In the complex the combination of MCLA, EID and ERD permits a high saving of time and human resource to perform the analysis of life cycle environmental impacts of organization and its products.

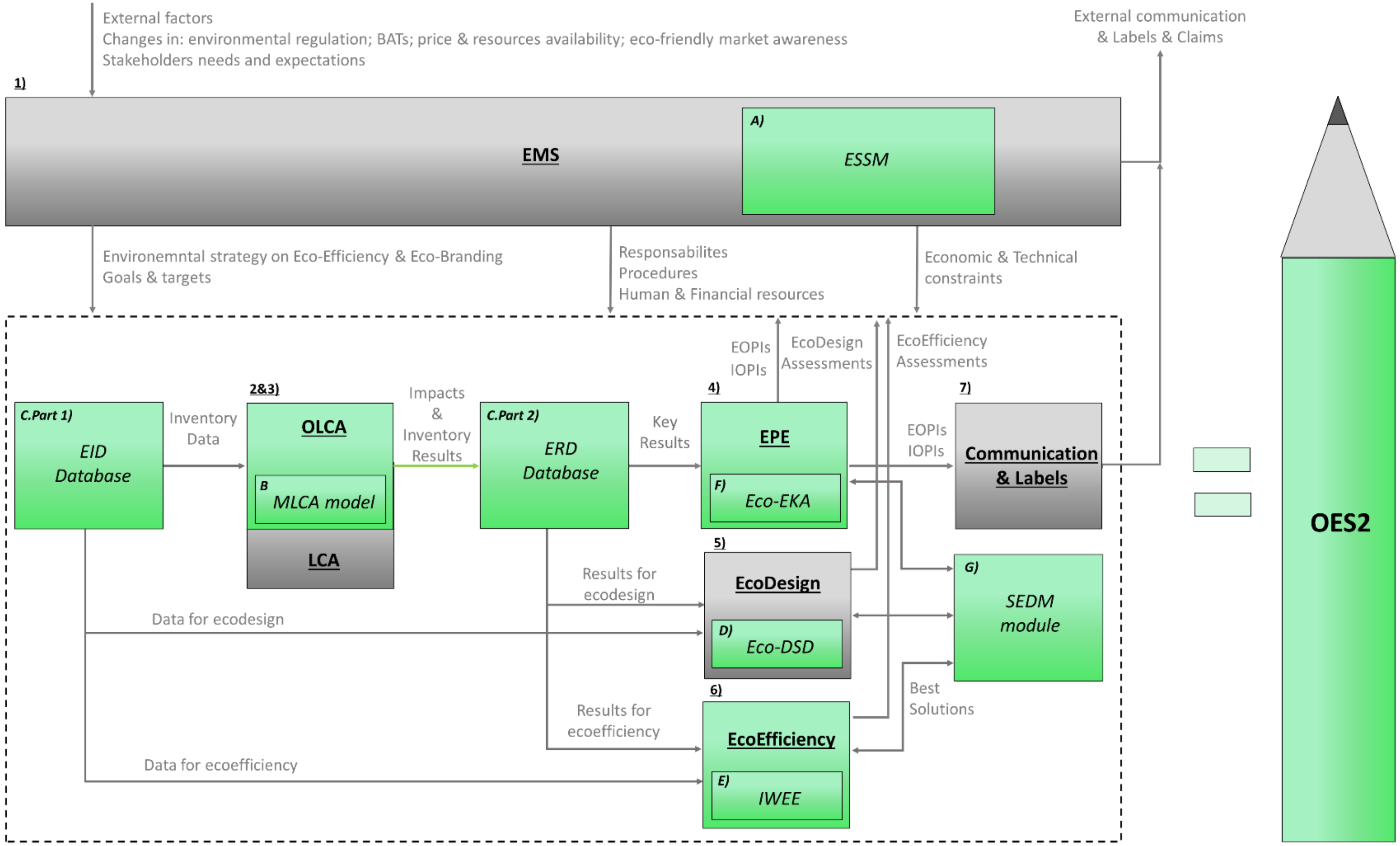
Criticalities related to environmental performance evaluation & performance tracking (3) have been solved introducing Environmental Performance Evaluation methodology according to ISO 14031 and one STEM: Eco Environmental Key performance Analyzer (Eco-EKA) (see table 86). The introduction of the concept of environmental performance is fundamental to establish correctly an evaluation framework that permits the performance tracking over the time and the comparison of the performance of the elements that characterize the different assessment scales (e.g. production sites, products, processes, etc.). The introduction of Eco-EKA has simplified the operative evaluation of life cycle environmental performance at organizational and product level. It has automatized the calculation of EOPIs and IOPIs and permitted the analysis with a smart dashboard. In order to correctly understand the trend of EOPIs the use of IOPIs and SOPIs in important. The SOPIs gives fast information on indirect variables that can perturbate the environmental performance.

Criticalities related to ecoinnovation (Ecodesign and ecoefficiency) (4) have been solved introducing Ecodesign and Ecoefficiency methodologies according respectively to ISO/TR 14062 and ISO 14045, and two STEMs: Eco Design Simulation Dashboard (Eco- DSD) and Indicator of Work Environmental Efficiency (IWEE) (see table 86). The ecodesign and ecoefficiency are the two most important levers for ecoinnovation that the organization can use. No method for multiple EMTs use published in literature has applied the Ecoefficiency (see table 87). The first one permits the develop of new eco-friendly solutions while the second one can be exploited to increase the efficiency of already existing processes and products. The new concept of Organizational eco design has been introduced shown a new possibility, according OLCA, to modify organizational structure to reduce environmental impacts. The modification of organizational structure can be determined for example by new production site acquisition and from productive process delocalization between already existing productive sites. According with MLCA model, each ecodesign project performed into a scale, generates effects on the other scales that are important to assess. This perspective is according to the new revision of ISO 14001:2015 that identifies the product eco design as a lever to improve the organizational environmental performance. The introduction of Eco-DSD has permitted to solve the criticality related to the absence of a work space where to simulate and compare the different ecodesign alternatives. Furthermore, the representation of the results in a smart dashboard improve the communicability to top management simplifying the operative process of assessment of the ecodesign project results. The introduction of ecoefficiency in this case permits to assess how much the current performance are different from a reference performance. In fact, with the introduction of IWEE a new indicator to assess ecoefficiency of industrial processes has been introduced with a complementary assessment perspective respect the OEE that is the most used indicator to assess process efficiency in the manufacturing industrial sector. The IWEE as well as to assess efficiency to use of energy, auxiliary materials and raw materials is able to give important feedback on how improve the process efficiency thanks the use of IPLE index. The IPLE index permits to discriminate configurations of productive variables that encourage ecoefficiency from configurations that discourage it.

Criticalities related to strategic decision making (5) have been solved introducing one STEM: Strategic Environmental Decision Making module (SEDM module) (see table 86). The SEDM module is a procedural tool that requires the use of tools for decision making such as statistical approach, mathematical optimization. The introduction of SEDM module increase the use of decision making tools increasing the robustness of strategical decisions. No method for multiple EMTs use published in literature has integrated tools for decision making through statistical and mathematical approaches (see table 87).

Criticalities related to strategy & management (6) have been solved introducing the EMS according to ISO 14001, Communication tools according to ISO14021-24-25 and one STEM: Environmental Sustainability Strategy Model (ESSM) (see table 86). The application of ISO 14001 requirements especially relating to roles & responsibilities, training, leadership, etc are very supportive to the management of life cycle environmental performance. Although for the management of life cycle environmental performance are not required, the full certification it is recommended in order to ensure other relevant aspects related to environmental management such as legal compliance. The introduction of ESSM permits to test environmental strategy assessing the consistency between environmental objectives and planned activities. Furthermore, it permits to verify the consistency between results in terms of environmental performance and the communication contents verifying the consistency and the balancing between ecoefficiency and ecobranding strategy components. The strategic use of communication tools permits to OES2 method to close the management of environmental performance of the organization, permitting their communication to stakeholders. Furthermore, the OES2 method, regarding LCA and OLCA part, has been developed for be compatible with PEF and OEF that are the most recent tool for communication developed by European Commission. In the following figure the contributions of the research are shown in terms of additionality respect to the most complete method for multiple EMTs use published (POEMS method). In green are shown the new contributions introduced by OES2 method while in grey are shown the parts of OES2 method that were already been implemented by published methods.

Concluding, the OES2 method being based on the concept of life cycle management, promotes a holistic management of life cycle environmental performance inasmuch it considers all the management perspectives. It provides full description of roles, functions and interactions between the EMTs. Being OES2 method based on EMTs developed by ISO it responses to the need of propose a framework for a complementary approach of ISO 14000 series, aspect that has been recognized important to promote a broader use of ISO 14000 series. Finally, this research shows as the combination of EMTs improves the life cycle management performance of the organization inasmuch makes the organization able to manage different criticalities on life cycle environmental management.



OES2 close loop cycle scheme

EMTs:
1) EMS = Environmental Management System (ISO 14001)
2&3) OLCA & LCA = Organizational Life Cycle Assessment & Product Life Cycle Assessment (ISO/TS 14072 ; ISO14040-44)
4) EPE = Environmental Performance Evaluation (ISO 14031)
5) EcoDesisgn = (ISO/TR 14062)
6) EcoEfficiency = (ISO 14045)
7) Communication & Labels = Environmental labels and declarations (Type I, ISO 14021; Type II, ISO 14024; Type III, ISO 14025);

STEMs:
A) ESSM = Environmental Sustainability Strategy Model
B) MLCA model = Multiscale LCA model
C part 1) EID = Environmental Inventory Database
C part 2) ERD = Environmental Results Database
D) Eco-DSD = EcoDesign Simulation Dashboard
E) IWEE = Indicator of Work Environmental Efficiency
F) Eco-EKA = Eco Environmental KPI Analyzer
G) SEDM module = Strategic Environmental Decision Making module

Figure 152 OES2 method vs best complete method for multiple EMTs use available published

NB: in green the innovations introduced by OES2 method respect to the most complete already published method for multiple EMTs use (POEMS method).

5.2. Validation of the research

The six tests have been performed in order to verify the applicability and effectiveness of OES2 method at industrial level, in the case of Acqua Minerale San Benedetto S.p.A. that is one of the most important player of the beverage sector in the world. The high sharing of results with the organization has permitted a continuous feedback on applicability of OES2 method. The six tests have been positively passed by OES2 method. Furthermore, the method has undergone two third-party audits in order to verify the most relevant methodological aspects and to permit the external communication of life cycle environmental performance. The external audits have been conducted by a certification body accredited by ACCREDIA the Italian body for accreditation.

As confirm of the good test at industrial level, San Benedetto has decided to adopt definitively the OES2 method as a new method for manage and improve its environmental performance. The company has constituted a new team for Environmental Sustainability of the industrial group assuming three new people that have been trained by the PhD student to manage the OES2 method. The organization on the push of OES2 method will complete the certification ISO 14001 of all Italian site by 2020 achieving an innovative more sustainable business model.

Finally, considering the high level of innovation of the OES2 method San Benedetto, has started to verify with UNI the possibility to build a "Prassi di Riferimento (PDR)" for the beverage sector on the life cycle environmental performance management.

5.3. Future perspectives

Results of this research open new research perspectives. First of all, future works should be related to verify the general applicability of OES2 method, applying the method to industries of other sectors and with different sizes.

The second perspective is related to the integration in the method of the other two components of the sustainability, the economic and the social sustainability components according with Triple Bottom Line model. In fact, OES2 method explores completely the environmental sustainability component, but in the future, following the currently scientific development trend related to sustainability, the integration of the other two components should be important and interesting.

The third perspective is related to the analysis of threats and opportunities related to different orders of EMTs implementation. In fact, OES2 method, on the base of the combination method leaves organization free to choose the order with which to implement different EMTs. The relevance of this perspective could be high for industries that have not already implemented EMTs.

The fourth perspective is related to the development of new specific communication tools in order to face completely the gap related to market differentiation inasmuch currently the organizations have not successes into highlight the differences in terms of environmental performance and ecodesign that characterize their products respect those of competitors. For example, San Benedetto, on the base of OES2 method, has started to verify the possibility to develop a new label according to ISO14024 to highlighting ecodesign and ecoefficiency performance of their products.

Finally, the last perspective proposed is related to the improvement of the informatic structure of some STEMs introduced by OES2 method. In fact, although the excel programming code is very useful, cheap, diffuse and well known the upgrade towards other informatic language could improve the stability, the security of the tools, and the usability introducing new features (e.g. smart visualization of the results, use of the tools on mobile devices, etc.).

Appendix (A)

1. Organizational Life Cycle Assessment (OLCA) & Product Life Cycle Assessment (LCA)

The LCA, according to ISO14040-44, is a methodology to address environmental aspects and potential environmental impacts (e.g. use of resources and the environmental consequences of releases) throughout a product's life cycle from raw material acquisition through production, use, end-of-life treatment, recycling and final disposal (i.e. cradle-to-grave). The OLCA, according to ISO/TS14072, expands the scope of the methodology to the organizational scale. Both methodologies are based on four different stages according to the following figure.

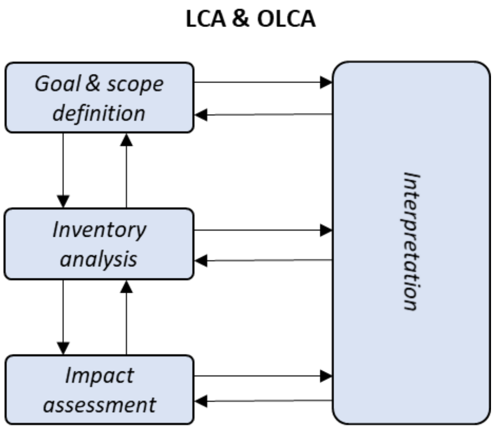


Figure 153 Methodological steps on which are based the OLCA and LCA, according to ISO/TS 14072 and ISO14040-44

The goals & scope stage, includes the definition of methodological aspects such as: system boundary functional and reporting unit, goal of the study, intended audience, environmental assessment method, limitations, etc.

The life cycle inventory analysis stage (LCI) is an inventory of input/output data with regard to the system being studied. It involves collection of the data necessary to meet the goals of the defined study.

The life cycle impact assessment stage (LCIA) is aimed at evaluating the significance of potential environmental impacts using the LCI results. In general, this process involves associating inventory data with specific environmental impact categories and category indicators, thereby attempting to understand these impacts.

Life cycle interpretation is the final phase of the LCA procedure, in which the results of an LCI or an LCIA, or both, are summarized and discussed as a basis for conclusions, recommendations and decision-making in accordance with the goal and scope definition.

For detailed information on these EMTs is recommended the reading of the ISO standards ISO14040-44 and ISO/TS 14072.

2. Environmental Performance Evaluation (EPE)

Environmental performance evaluation (EPE), according to ISO 14031, is a management process that uses key performance indicators to compare an organization’s past and present environmental performance with its environmental objectives and targets. It supports the dentification of strategic opportunities. This methodology is based on four stages shown in the following figure.

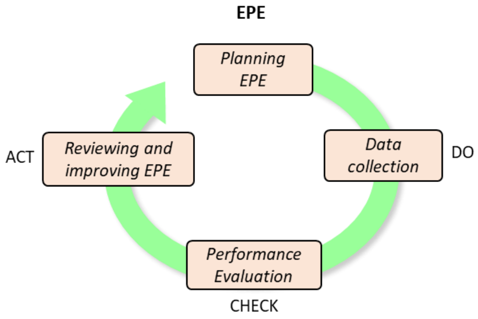


Figure 154 Methodological steps on which is based the EPE, according to ISO 14031

In the planning stage, the activities for EPE are planned and the indicators are selected.
In the second stage the data to performance EPE are collected.
In the performance evaluation stage, the indicators are calculated and the performance are assessed in detail identifying hotspots and improvement opportunities
In the last stage, the EPE can be modified in order to improve the application.
For detailed information on this EMT is recommended the reading of the ISO standards ISO14031.

3. Ecodesign

The Ecodesign, according to ISO/TR 14062, is an approach that aims to integrate environmental aspects into product design and development, where "product" is understood to cover both goods and services. This approach follows and integrates all the different stages of product design according to the following figure.

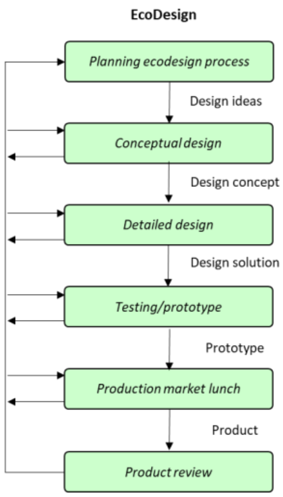


Figure 155 Methodological steps on which is based the Ecodesign, according to ISO/TR 14062

The objective of ecodesign is the development of new products or the improvement of already existing products considering the reduction of environmental impacts.

For detailed information on this EMT is recommended the reading of the ISO standards ISO/TR 14062.

4. Ecoefficiency

Ecoefficiency assessment, according to ISO 14045, is a quantitative management tool which enables the study of life-cycle environmental impacts of a product system along with its product system value for a stakeholder. The value of the product system may be chosen to reflect, for example, its resource, production, delivery or use efficiency, or a combination of these. The value may be expressed in monetary terms or other value aspects. This methodology is based on five stages shown in the following figure.

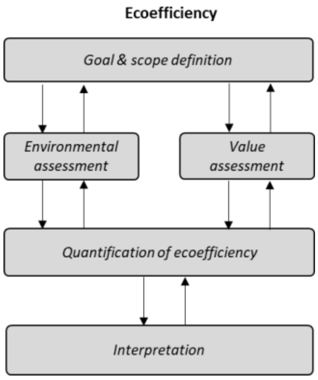


Figure 156 Methodological steps on which is based the Ecoefficiency, according to ISO 14045

The goals & scope stage, includes the definition of methodological aspects such as: system boundary functional, goal of the study, intended audience, environmental assessment method, value assessment method, limitations, etc.
The environmental assessment stage is aimed to perform the environmental impacts or the inventory resources consumptions assessment according to LCA methodology.
The value assessment stage is aimed to perform the assessment of the product system value.
The quantification of ecoefficiency stage is aimed to relate the results of the environmental assessment to the results of the product system value assessment, according to the goal and scope definition in order to assess the ecoefficiency.
The interpretation is the final stage and are summarized and discussed the results as a basis for conclusions, recommendations and decision-making in accordance with the goal and scope definition.
For detailed information on this EMT is recommended the reading of the ISO standards ISO14045.

5. Environmental Management System (EMS)

The Environmental Management System, according to ISO 14001, provides to organizations a framework to protect the environment and respond to changing environmental conditions in balance with socio-economic needs. It specifies requirements that enable an organization to achieve the intended outcomes it sets for improve its environmental performance. It introduces a systematic approach to promote the continuous improvement of environmental performance.
This methodology is based on four stages shown in the following figure.

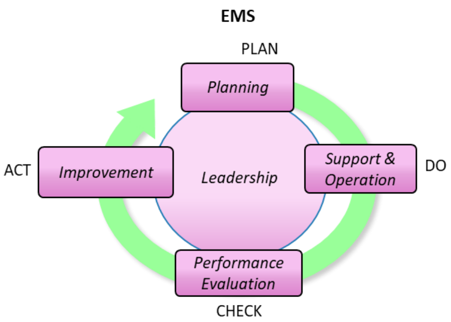


Figure 157 Methodological steps on which is based the EMS, according to ISO 14001

In the planning stage, the organization plans activities to address risk and opportunities related to environmental management considering its context and its objectives.

In the support & operation stage, the organization shall determine and provide the resources needed for the establishment, implementation, maintenance and continual improvement of the environmental management system, defines communication modalities, and establishes, implements, controls and maintains the processes needed to meet environmental management system requirements.
In the performance evaluation stage, the organisation monitors, measures, analyses and evaluates its environmental performance.
Finally, in the improvement stage, the organization determines opportunities for improvement and implements necessary actions to achieve the intended outcomes of its environmental management system.
For detailed information on this EMT is recommended the reading of the ISO standards ISO14001.

6. Communication & Labelling ISO tools

The ISO 14025 provides requirements, principles and procedures regarding Environmental labels and declarations (Type III environmental declarations). Type III environmental declarations present quantified environmental information on the life cycle of a product to enable comparisons between products fulfilling the same function. Type III environmental declarations are primarily intended for use in business-to-business communication, but their use in business-to-consumer communication is not precluded. It
The ISO 14021 provides requirements, principles and procedures regarding Environmental labels and declarations (Type II Self-declared environmental claims). It specifies requirements for self-declared environmental claims, including statements, symbols and graphics, regarding products. Finally, it also describes a general evaluation and verification methodology for self-declared environmental claims and specific evaluation and verification methods for the selected claims in this International Standard. Self-declared environmental claims may be made by manufacturers, importers, distributors, retailers or anyone else likely to benefit from such claims. Environmental claims made in regard to products may take the form of statements, symbols or graphics on product or package labels, or in product literature, technical bulletins, advertising, publicity, telemarketing, as well as digital or electronic media, such as the Internet.
The ISO 14024 provides requirements, principles and procedures regarding Environmental labels and declarations (Type I environmental labelling). It establishes the principles and procedures for developing Type I environmental labelling programmes, including the selection of product categories, product environmental criteria and product function characteristics; and for assessing and demonstrating compliance. It also establishes the certification procedures for awarding the label.
For detailed information on this EMTs is recommended the reading of the ISO standards ISO14025, ISO14021 and ISO14024.

List of tables

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