The Electrochemical Society
Interface

FEATURED ARTICLES

From Hydrogen Manifesto, through Green Deal and Just Transition, to Clean Energy Act

To cite this article: Plamen Atanassov *et al* 2021 *Electrochem. Soc. Interface* **30** 57

From Hydrogen Manifesto, through Green Deal and Just Transition, to Clean Energy Act

by Plamen Atanassov, Vito Di Noto, Stephen McPhail

On December 17, 2020, just before stepping out to a very different COVID-19 scarred Christmas holiday season, all European Union countries signed a short, page-and-a-half document: *Manifesto for the Development of a European "Hydrogen Technologies and Systems" Value Chain.* The governments of kingdoms and republics as large as the Federal Republic of Germany and as small as the Grand Duchy of Luxembourg committed themselves to leading the transition to a hydrogen economy by establishing the 4th European *Important Project of Common European Interest* (IPCEI) framework for funding green hydrogen at a scale larger than anywhere else in the world.

This agreement came just three days before the European Commission adopted a revision to its 2013 regulation on *Trans-European Networks in Energy* (TEN-E), on December 20, 2020. The TEN-E regulation establishes the European Union cross-border energy infrastructure and lays out the process for selecting *Projects of Common Interest* (PCI). These PCIs are infrastructure projects critical to moving toward common goals of the European Union and its member states in the field of energy and play a central regulatory "push" role in promoting renewable energy. This new, revised 2021 TEN-E regulation will align closely with the ambitious climate neutrality objectives of the *European Green Deal*,[1] which is a central piece of the European legislation following the currently implemented *Recovery and Resilience Facility*.[2] The European Green Deal is currently being debated and refined, while the European Commission is preparing the groundwork for the third massive initiative that will shape the future of the continent in terms of well-being and competitiveness: the *Just Transition Platform*.[3]

What is clear is that decarbonization of society holds a central place in these three major legislative packages. The latter are practical implementation steps of the *Hydrogen Strategy*, the general framework for the development of a hydrogen ecosystem in Europe by 2050.[4] This set of agreements makes a policy shift toward clean/renewable energy central for the European economic space and highlights the role of hydrogen technologies as a means of decarbonization of the transportation and industrial sectors. A unique attribute of these EU arrangements is the focus on hydrogen—an energy carrier that integrates electric power with energy utilization, mobility with connectivity, and manufacturing with food production and supply—as critical for European energy security and independence.

The revised 2021 TEN-E regulation updates the infrastructure categories eligible for support with an emphasis on decarbonization and adds a new focus on offshore electricity grids, hydrogen infrastructure, and smart grids. It announces a new "taxonomy" for hydrogen, establishing the legal use of the terms "green hydrogen" (derived from renewable sources), "blue hydrogen" (off-setting the CO_2 footprint with emission savings at least equal to those incurred during its synthesis), and "gray hydrogen" (non-zero CO_2 emissions associated with its synthesis and use). Given the size of the European hydrogen market, even if measured in its almost 300 current demonstration projects, this taxonomy will have a global meaning. What is omitted is discussion of the color of nuclear electricity-synthesized hydrogen or hydrogen (potentially) derived via carbon capture technologies. Those "colors" have not yet been universally recognized (see this issue's Chalkboard for a more in-depth look at the many proposed colors of hydrogen).

This summer, the European Council (EC) decided to end its support for new natural gas and oil projects and to introduce mandatory sustainability criteria for all current and future projects sponsored by the EC, and by virtue of subsequent preparation through individual states' legislations, by the entire European Union. The EC established a transitional period until the end of 2029, during which gray hydrogen derived from natural gas can be still used. For this limited period of eight years, it is allowable to transport or store a blend of hydrogen with natural gas or biomethane. There is an envisioned set of strategic projects that will be deployed to demonstrate how, by the end of this transitional period, these hydrogen/gas blends will be replaced with clean hydrogen, dislodging natural gas from the economies of the EU member states. This policy clearly supports the standing EU policies for ending the extraction and use of coal across the member states by 2030. This drive toward green hydrogen is a hallmark of the EU hydrogen strategy. The EC aims to create a hydrogen market for Europe and hence to help the European Union to meet its commitment to achieve carbon neutrality in 2050 by proposing the development of a dedicated hydrogen grid and the creation of multiple hydrogen clusters across the EU.

On the specific green hydrogen production path, the European Union aims for the scale-up of electrolyzer technology to 6 GW in 2024 and subsequently to 40 GW by 2030. This scaling up corresponds to moving from 1 million tons of green hydrogen produced from renewable sources in 4 years to a target of **10 million tons in 10 years**.[5] Such ambitious goals are supported by substantial dedicated funding by the member states of more than 40 billion Euro, representing the sum of the financial support provided for the different hydrogen strategies of European member states.

(continued on next page)

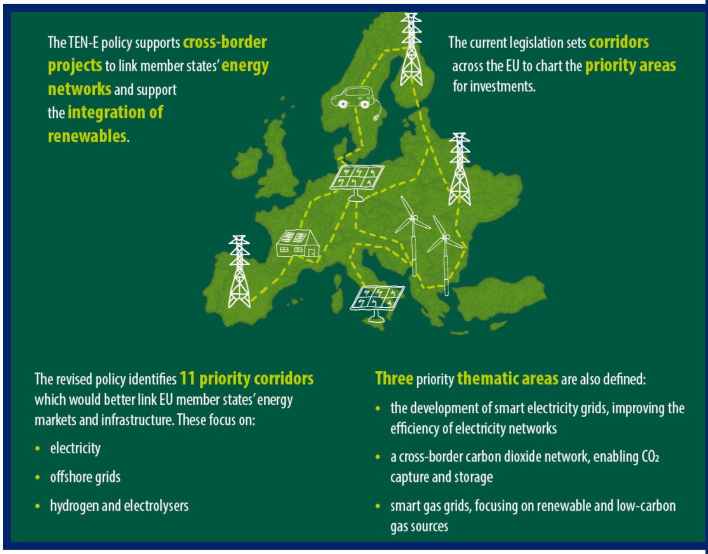


FIG. 1. *TEN-E Europe's energy corridors. Reproduced from Ref. 5.*

Massively increasing the EU production capacity of green hydrogen is also one of the main objectives of the *European Clean Hydrogen Alliance*, a forum bringing together industry, national and local public authorities, civil society, and all other possible stakeholders to establish a comprehensive inventory of European players that are involved in the energy transition.[6] The *European Clean Hydrogen Alliance* was launched by the European Commission simultaneously with the *Hydrogen Strategy* in July 2020. The scope of the activities of the European Clean Hydrogen Alliance is much broader than the production of green hydrogen, as it plans to identify and develop a pipeline of viable investment projects along the entire hydrogen value chain, extending to mobility, industry, heat, and power applications. The activities of the *European Clean Hydrogen Alliance*, framed in the European Union "*Hydrogen Strategy*," are aiming toward the development of a **clean hydrogen market** for the green transition, providing a key contribution to growth and jobs.

At the same time, the financial framework *Next Generation EU* foresees clear funding instruments to enhance a faster deployment of the transition to a hydrogen economy as a critical component of the decarbonization strategy. The ultimate target is CO_2 emissions by 2030 to be reduced by 55% compared to 1990 (the reference year). To achieve this highly ambitious goal, the planned investments (covering both public and private contributions) until 2030 will be massive. Hydrogen production will attract a total 220 billion Euros, and hydrogen infrastructure and applications will receive 120 and 90 billion Euros, respectively, for a grand total of 430 billion Euros in financial volume for the onset of hydrogen economy deployment. These figures refer to the EU as a whole, and do not take into account the additional resources provided by the various member states in their individual state budgets. The latter can be significant, on the order of 5–15 billion Euros per member state covering the years until 2030. For example, Germany has planned an investment of 9 billion Euros from its internal programs.[8]

The *European Green Deal* and the forthcoming *Just Transition Platform* aim to establish Europe as leading in hydrogen technology at the intersection of legislation and public acceptance, financial and industrial practices, codes and standards, workforce development, research and development, and education. In all framework documents, the EC systematically moves hydrogen into the center stage of the transition to decarbonized economy. The *Fit for 55 Package* is a unique and much advanced vision for an EU-wide framework for the development of a clean hydrogen economy. It is developed by *Hydrogen Europe*, the most established and influential group of industry and research organizations in Europe in terms of lobbying, defining, and steering the implementation of the European budget for research and innovation. Hydrogen Europe is the successor of the *Fuel Cell and Hydrogen Joint Undertakings*, a series of two consecutive public-private partnerships which shaped the way EU member states and their businesses develop the hydrogen economy.[9] This visionary program elaborates on multiple aspects of technology transition, including road transport and maritime, under the singular vision of hydrogen and electrified mobility. It forecasts deep restructuring of energy taxation by reducing fossil fuel subsidies, eliminating double taxation, and providing fiscal rewards to those investing in clean energy technologies. This *Fit for 55 Package* vision is central to establishing a robust carbon reduction system capable of reaching the ***goal of cutting CO_2 emissions by 55% in less than a decade!***

The research on hydrogen technologies in the EU plays a crucial role in achieving such an ambitious goal. The R&D activities are very diverse, and are funded by a broad variety of players, including the European Commission, the governments of the member states, regional bodies, and private companies. A significant number of supporting business associations and initiatives gravitate around the implementation of the hydrogen strategy in Europe, such as the *European Clean Hydrogen Alliance* (described above) and the *European Energy Research Alliance* (EERA), built as the carrier of the research agenda.[10] The EERA aims to capture the holistic nature of the energy transition and constitutes 18 so-called *Joint Programs*

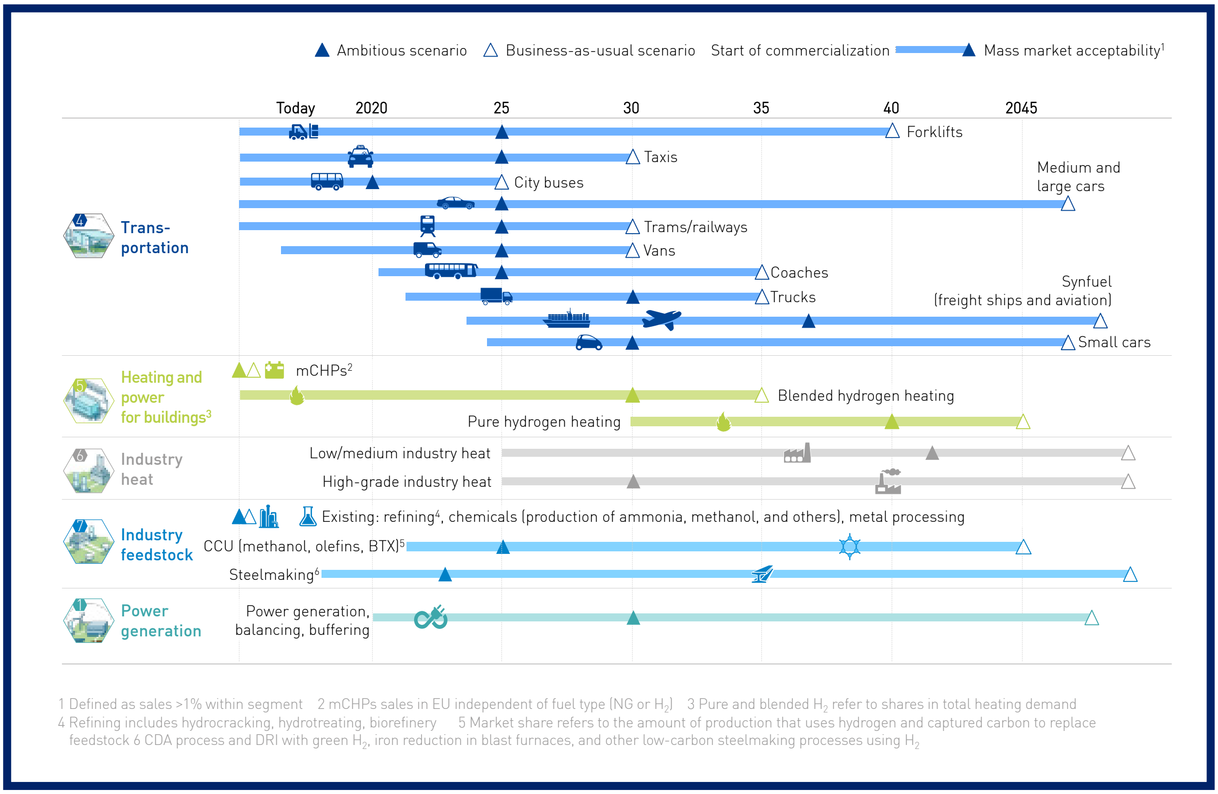


FIG. 2. *A survey of the applications of hydrogen technologies, including their expected deployment timeline. Reproduced from Ref. 7.*

reflecting both the technology fields and the social aspects of a clean energy transition. The *Joint Programme on Fuel Cells and Hydrogen* (JP FCH)[11] includes many important representatives of the European research community and academia within a platform of discussion and exchange on scientific topics and R&D strategies and priorities, providing important pathways for collaboration. JP FCH aims to contribute actively to the development of tools and events that support science-based policy decisions and actions.

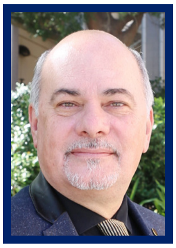
The total portfolio of research projects on hydrogen technologies is extremely large and covers the entire value chain. As a representative example, the *European Institute of Technology for Raw Materials*[12] has funded the project *ALPE*,[13] which aims to minimize the loading of platinum in proton-exchange membrane fuel cells (PEMFCs). This goal is a major steppingstone toward the reduction of EU dependency on imported platinum, whose primary sources are located outside of the EU. The EU commission has also included hydrogen research as one of the topics of the *Graphene Flagship*, a major EU effort meant to bring closer to the market innovative products and devices enabled by graphene and graphene-related materials.[14] Here the research focuses on the implementation of graphene and related materials at the electrodes of fuel cells and electrolyzers with the purpose of raising their performance and durability. The hydrogen research is also involving important companies such as ALSTOM, which developed the fuel cell hydrogen train Coradia iLint™.[15] Another example is SYMBIO, a company that specializes in the development of fuel cell packages to extend the range of battery-powered vehicles; the research here led to the Pininfarina H2 Speed, a fuel cell car capable of going from 0 to 100 km/h in a record 3.4 seconds![16]

In conclusion, the strong political will of the EU and its member states, coupled with important investments from both the public and the private sectors, is paving the way toward a prominent role of Europe in the full-fledged implementation of hydrogen technologies in a future that is no longer a far promise but a societal commitment.

Acknowledgments

Plamen Atanassov is not funded by any EU instrument. Vito Di Noto would like to acknowledge financial support from: (a) the European Union's Horizon 2020 research and innovation program under grant agreement 881603; (b) the project *"Advanced Low-Platinum Hierarchical Electrocatalysts for Low-T Fuel Cells"* funded by EIT Raw Materials. Stephen McPhail is the Coordinator of the Joint Programme on Fuel Cells and Hydrogen (JP FCH) of the European Energy Research Alliance – EERA.

About the Authors



Plamen Atanassov, Professor, Departments of Chemical & Biomolecular Engineering, Materials Science & Engineering and Chemistry, National Fuel Cell Research Center, University of California, Irvine, CA, U.S.

Education: PhD in Chemistry/Electrochemistry (Bulgarian Academy of Sciences, Sofia, Bulgaria)

Research Interests: Electrocatalysts for fuel cells: Non-platinum electrocatalysts and nano-structured catalysts for PEMFC and AMFC; Biological fuel cells based on enzyme-catalyzed electron transfer and microbial fuel cells; Functional nanomaterials, rational materials design and biomimetic/bio-inspired approaches in materials design.

Pubs + Patents: 430+ publications in peer-reviewed journals, 20+ book chapters and one edited book, 57 issued US Patents, h-index 88, 31,000+ citations.

Awards: Fellow of the National Academy of Inventors (2017), Vice President of the International Society of Electrochemistry (2015–2017), Fellow of the International Society of Electrochemistry (2020).

Work with ECS: Fellow of The Electrochemical Society (2107), ECS Energy Technology Division Research Award (2018), Member-at-Large, Physical & Analytical Electrochemistry Division and Energy Technology Division, Multiple symposia and workshops, Finance committee service, Member 20+ years

Websites: https://engineering.uci.edu/users/plamen-atanassov https://scholar.google.com/citations?user=CPilx4wAAAAJ&hl=en&oi=ao

https://orcid.org/0000-0003-2996-472X

Vito Di Noto, Professor of Electrochemistry for Energy and Solid-State Chemistry, Department of Industrial Engineering, University of Padova, Italy

Education: PhD in Chemistry (University of Padova, Italy).

Research Interests: Electrode materials and electrolytes for energy conversion and storage devices: anion-exchange membrane fuel cells (AEMFCs), proton exchange membrane fuel cells (PEMFCs), high-temperature proton exchange membrane fuel cells (HT-PEMFCs), direct methanol fuel cells (DMFCs), PEM electrolyzers and redox flow batteries (RFBs). Polymer electrolytes and electrode materials for secondary batteries based on alkaline and alkaline-earth elements (e.g., Li, Mg, Na, Ca). Study of the electric response of ion-conducting, electric and dielectric materials by Broadband Electrical Spectroscopy (BES).

Work Experience: 30+ years of experience in R&D of advanced functional materials for electrochemical energy conversion and storage devices, including primary and secondary batteries running on alkaline and alkaline-earth elements. In the late 1990s, pioneered the secondary magnesium ion battery and devised breakthrough approaches for the synthesis of electrolytes and electrode materials. He also provided seminal contributions to the understanding of the mechanisms of ion conduction in condensed phases.

Pubs + Patents: 312 published papers (263 peer-reviewed papers, 10 book chapters), 30 patents (13 international and 17 national, 13 were sold) and 10 papers in proceedings. 296 meeting contributions. h-index: 49 Google Scholar, 45 (SCOPUS + ISI). 7780+ citation.

Awards: Special Prize "Alessandro Volta" (2000); Japan Society for the Promotion of Science Fellow (since 2002); Premio "Amministrazione, Cittadini, Imprese" (Prize "Public Administration, Citizens, Enterprises") (2018); President of the Italian Electrochemical Society (since 2020).

Work with ECS: Member since 2003; ECS Fellow (2019); Past Member, Executive Committee of the Energy Technology Division (ETD); Currently Member-at-Large, Executive Committee, Energy Technology Division and Physical and Analytical Electrochemistry Division. Organizor/co-organizer of 35+ thematic sessions of ECS; Member and later President of the committee for the assignment of the ETD Srinivasan Award (2014–2017; 2021); Member, ETD Graduate Student Award committee (2014–2017; 2021).

Websites: https://www.dii.unipd.it/category/ruoli/personale-docente?key=1D56F2193C0F237DDD04C70DF3C19F02
http://wwwdisc.chimica.unipd.it/lab_DiNoto/

https://orcid.org/0000-0002-8030-6979

Stephen J. McPhail, Coordinator of the Joint Programme on Fuel Cells and Hydrogen, Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA)

Education: MSc in Mechanical Engineering, PhD in Thermal Fluid Dynamics

Research Interests: High-temperature fuel cells and electrolyzers, Cell and system characterization.

(continued on next page)

(continued from previous page)

Work Experience: Researcher at ENEA since 2007. He is coordinator of the EERA (European Energy Research Alliance) Joint Programme on Fuel Cells and Hydrogen and the Italian member of the Technical Collaboration Programme (TCP) on Advanced Fuel Cells of IEA. He has coordinated 4 EU funded projects (FP7 and H2020) and participated in a further 9 EU funded projects. He is member of several international committees on fuel cells and hydrogen (IEC, mission innovation, etc.).
Papers + Patents: Coauthor of 58 papers on the topic, h-index 17.
Awards: Winner of 2 IEC "1908" Awards.
Websites: www.enea.it, www.eera-fch.eu
https://orcid.org/0000-0003-3045-0945

References

1. https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en
2. https://ec.europa.eu/info/business-economy-euro/recovery-coronavirus/recovery-and-resilience-facility_en
3. https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/finance-and-green-deal/just-transition-mechanism/just-transition-platform_en)
4. https://ec.europa.eu/energy/sites/ener/files/hydrogen_strategy.pdf
5. https://www.consilium.europa.eu/en/infographics/ten-e-energy-infrastructure/
6. https://www.ech2a.eu/
7. https://www.fch.europa.eu/sites/default/files/Hydrogen%20Roadmap%20Europe_Report.pdf
8. https://www.bmwi.de/Redaktion/EN/Publikationen/Energie/the-national-hydrogen-strategy.pdf?__blob=publicationFile&v=6
9. https://www.hydrogeneurope.eu/wp-content/uploads/2021/06/Hydrogen-Europe-Position-Paper-on-the-Fit-for-55-Package.pdf)
10. https://www.eera-set.eu/
11. www.eera-fch.eu
12. https://eitrawmaterials.eu/
13. https://www.alpe-kic.eu/
14. https://graphene-flagship.eu/research/work-packages/work-package-11-energy-generation/
15. https://www.alstom.com/solutions/rolling-stock/coradia-ilinttm-worlds-1st-hydrogen-powered-train
16. https://www.symbio.one/en/pininfarina-h2-speed-et-greengt-h2-2/