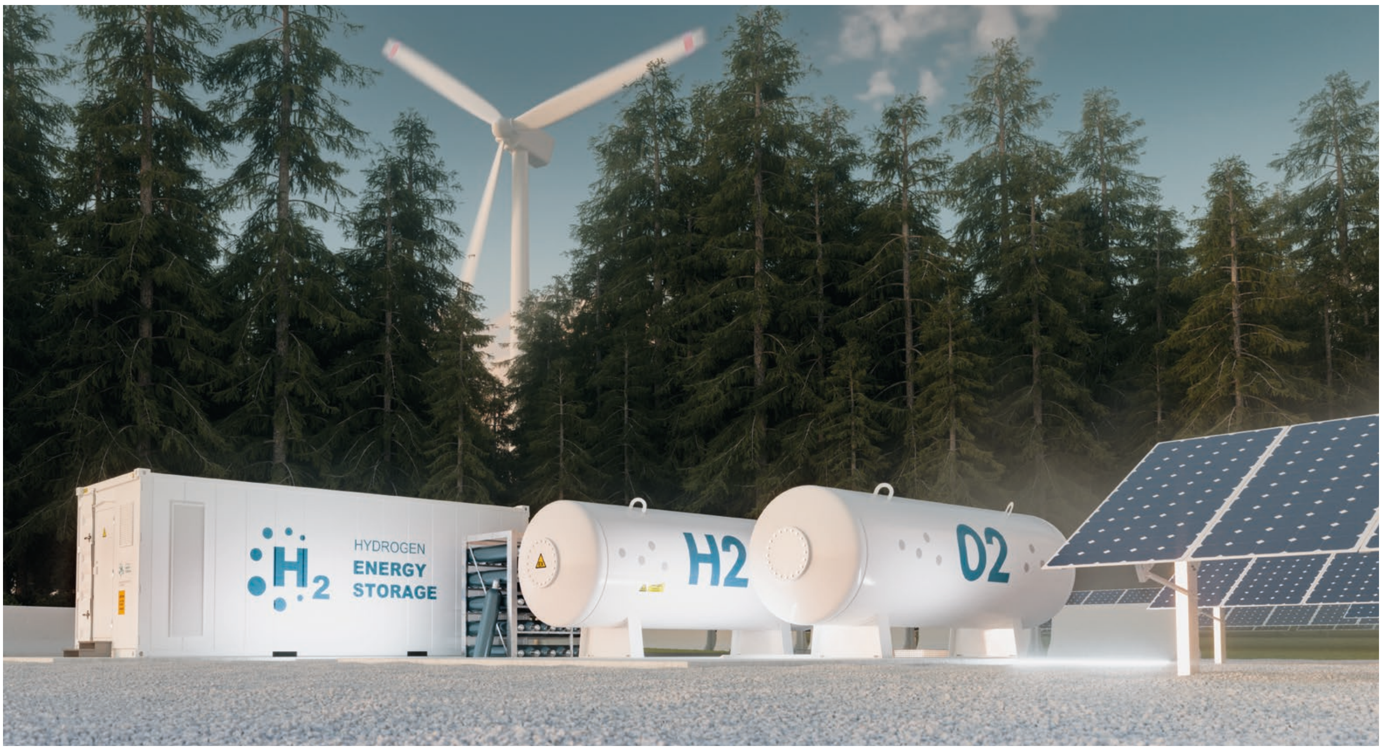

European Green deal - where green hydrogen becomes a reality!

For many of us hydrogen has always been an interesting point of discussion and we all remember the visionary author Jules Verne, who in 1874 wrote in the book 'The Mysterious Island' in which he said, "Water will one day be employed as fuel, that hydrogen and oxygen which constitute it, used singly or together, will furnish an inexhaustible source of heat and light, of an intensity of which coal is not capable".

147 years ago, Jules Verne set out a prescient vision that has inspired governments and entrepreneurs. But despite much hope and hype, hydrogen has always been considered as an anecdotal source of energy and mainly used as feedstock for industrial and agricultural applications (e.g., fertilizer, fuel refining, plastic, metallurgy).

As did Jules Verne, we have all dreamt about 'green hydrogen' but the reality today is that in practice it's more a case of 'brown and grey' rather than 'blue and green' hydrogen. Hydrogen production is almost entirely fuelled from fossil sources, and more than 70% of the global production comes from steam reformation of natural gas. In this process the methane reacts with steam, causing a reaction by which hydrogen and carbon dioxide are produced. As a consequence, the worldwide production of hydrogen is responsible for CO2 emissions of around 830 million tons of carbon dioxide per year, equivalent to the CO2 emissions of the United Kingdom and Indonesia combined.

That has been the situation for more than a century but things are changing and Europe is engaged in a process to develop a climate-neutral economy in which 'green and blue hydrogen' plays a major part.

Powering a climate-neutral economy
Part of the so called 'European Green Deal', the EU has laid out a strategy that will contribute to transform the European Union into a fair and prosperous society where there will be no net emission of greenhouse gases by 2050.

In line with the Paris agreement and the United Nations 2030 Agenda for sustainable development, on July 8, 2020 the European Commission issued a document (COM(2020) 299 final) describing the strategy for a clean energy system integration.

Taking into consideration all aspects of the various energy sectors, the strategy aims to reduce and eliminate CO_2 emissions but also to diversify Europe's sources of energy, making better, more efficient use of the energy produced within the EU.

This will require a fundamental transformation of the European energy system which today comprises: Fossil fuel (Solid, Petroleum, Gas) 72.4% ; Nuclear energy 12.9% ; Renewable 14.6% and 0.1% other.

The overall strategy to power a climate-neutral economy includes all aspects of the energy production system across multiple energy carriers, different infrastructures and consumption sectors, and the analysis of what is needed to achieve climate neutrality by 2050.

In this strategy, hydrogen has been considered an important part of the ecosystem and addressed in a specific sub-project: 'A hydrogen strategy for a climate-neutral Europe (COM(2020) 301 final)'. Making the production of hydrogen cleaner, and optimizing its utilization for transportation, energy storage, and many other areas have been addressed in this sub-project.

The European Hydrogen Strategy
Clearly too broad a subject to cover all aspects that it involves, but in summary the EU hydrogen strategy is aiming to use renewable hydrogen in industrial processes and heavy-duty road and rail transport, in synthetic fuel production from renewable electricity in aviation and maritime transport, or in biomass in those sectors where it has biggest added value.

Hydrogen 'in colors'
To begin, hydrogen is not a raw fuel and its production requires a certain chemical reaction that can result in significant CO_2 emissions. It is important to differentiate the different methods of production and their environmental impact. To make it easier to understand that relationship a de facto definition has been used within the industry, and four main categories have been defined (Image 1). The long term goal is to only use 'green hydrogen' though in the short and midterm, 'blue hydrogen' is needed to support the deployment of hydrogen in Europe, implying efficient carbon capture and storage (CCS) technology to reduce greenhouse emissions.

	**Brown hydrogen** In this method, the hydrogen is produced by gasification. The gasification processes convert brown coal into carbon monoxide, hydrogen, and carbon dioxide (Black coal using similar process). Gasification is achieved at very high temperatures, without combustion, with a controlled amount of oxygen and/or steam. In this process the carbon monoxide reacts with water to form carbon dioxide and hydrogen via a water-gas shift reaction. This is a highly polluting process since both CO_2 and carbon monoxide cannot be reused and released in the atmosphere.
	**Grey hydrogen** More than 70% of the hydrogen currently produced worldwide is so-called grey hydrogen. The most common production process implies Steam Methane Reforming (SMR). In this process high pressure steam (H_2O) reacts with natural gas (CH_4) resulting in hydrogen (H_2) and greenhouse gas CO_2. As for the Brown/Black hydrogen the greenhouse gases are not reused and released.

Image 01 – Definition of the hydrogen color classifications in relation to their environmental impact (PRBX)

	**Blue hydrogen** When the CO2 from the previous methods is captured and stored, the manufacturing process is less harmful for the environment though it is more expensive and less efficient than conventional methods. Blue hydrogen is considered as an important step in the energy transition and the vast majority of new production units strictly controlled in terms of environmental impact.
	**Green hydrogen** Despite, with less than 0.1% of dedicated hydrogen production globally coming from water electrolysis it is the most known technics that we all remember from the physics course at school. The hydrogen is produced by splitting H2O molecules into hydrogen and oxygen using electricity. In the case of green-hydrogen, the electricity is produced by renewable sources of energy. In that process the electrolyzers are the master piece and been used for decades with an average efficiency of 65%. Improving their efficiency is also a part of the EU project and new technologies such as Solid Oxide Electrolysis Cell (SOEC) expected to reach 90% and even more.

Image 01 – Definition of the hydrogen color classifications in relation to their environmental impact (PRBX)

Making green hydrogen a reality
As shown on Image 2, the EU strategy to develop renewable hydrogen is based on three phases with reasonable targets and goals. By 2050, the renewable hydrogen technologies are expected to have reached maturity and deployed on a large scale to contribute to decarbonize sectors where other alternatives are not feasible or of prohibitive cost. To reach this goal and to produce renewable hydrogen in volume will require a great amount of investment and strong cooperation between the different sectors, from research to end-user.

The strategy having been released in 2020, the European hydrogen research and initiative started much earlier and a number of projects have benefited from the €80 billion funding from the EU Research and Innovation program,

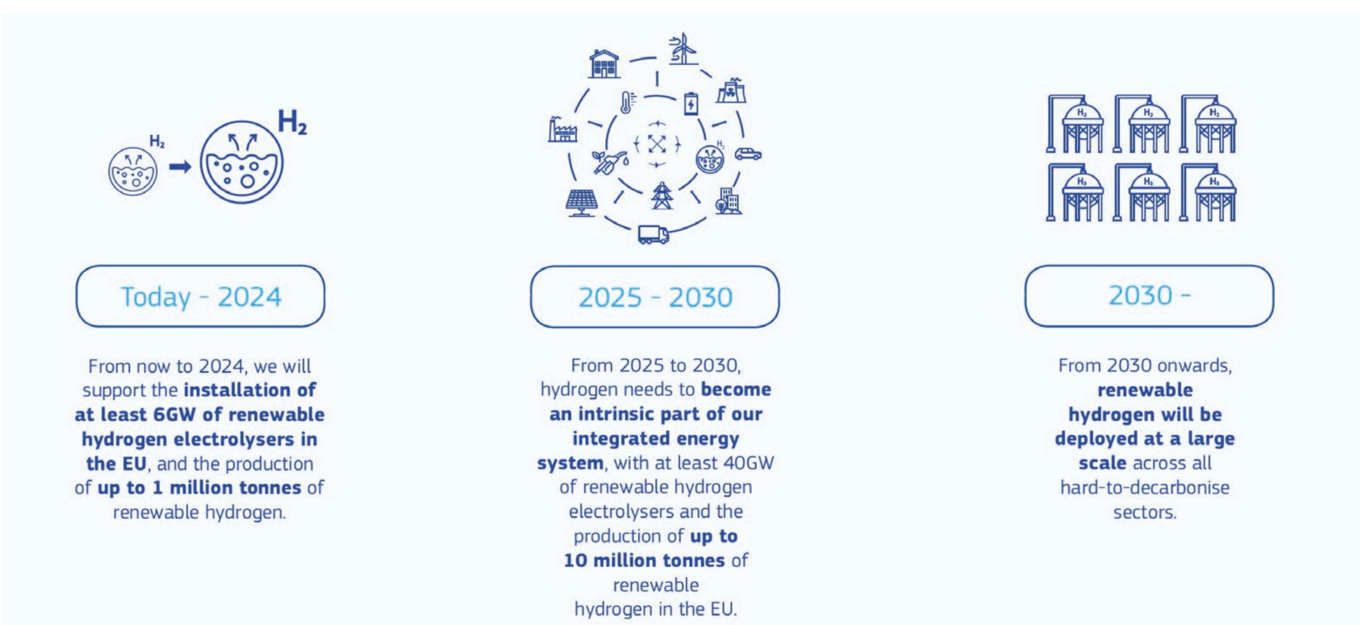

Image 02 – The three phases of the European Union renewable hydrogen strategy for a climate-neutral (PRBX/EU)

Horizon 2020. From 2014 to 2020 under this program an impressive number of projects have been conducted. More information can be found from the Horizon 2020 website but we would like to share one example of a project contributing to make the steel and heavy industry cleaner.

Due to the massive use of coal, the iron and steel industry is responsible for about 4% of anthropogenic CO2 emissions in Europe, and 9% worldwide. Replacing coal by hydrogen generated from renewable energy would make it possible to largely decarbonize this industry. The project H2FUTURE developed best practices to use the excess electricity from renewable sources to produce hydrogen from electrolysis. The hydrogen can be stored and used for fuel-cells to deliver power when needed. The project has focused particularly on deploying a large-scale electrolysis system operated for steel manufacturing. One outcome from this project is the demonstration of the increasing power of electrolyzers, highlighting their suitability for energy-intensive heavy industries.

Pilot Case

Engaged in a process to reduce its carbon footprint, the Austrian steel manufacturer VOESTALPINE set a goal to reduce its CO2 emissions by 80%. A large part of this reduction required them to change their way of working when manufacturing steel. The company research team investigated the practicality of using a hybrid technology to bridge the gap between the existing coke/coal-based blast furnace route and electric arc furnaces powered by green electricity partly generated using green hydrogen. It was obvious that hydrogen would make the deal and here started one of the European flagship projects for hydrogen.

Under the European Program Horizon 2020, after receiving EU agreement and a funding of €12 million, on 1st January, the **H2FUTURE** project began. As defined in the project, under the coordination of VERBUND (energy supplier), VOESTALPINE (steel manufacturer), and SIEMENS (PEM electrolyzers manufacturer) the goal was to install and demonstrate the ability of a 6MW electrolysis power system to deliver hydrogen to the VOESTALPINE Linz plant. The project also included competences from Austrian Power Grid, research partners K1-MET and Energieonderzoek Centrum Nederland (ECN).

Connecting such an installation to the grid presented many challenges. One important step has been to test PEM (proton exchange membrane) electrolysis technology on an industrial scale (6MW) and to simulate rapid load changes in electricity generated from renewable energy sources and from electric arc furnace steelmaking (grid balancing). This has been successfully completed and in November 2019 the kick-off of the largest green hydrogen facility took place (Image 03).

Image 03 – SIEMENS 6 MW Proton Exchange Membrane (PEM) electrolyzers (PRBX/ VOESTALPINE)

With a capacity of six megawatts and a production of 1.200 cubic meters of green hydrogen per hour, **H2FUTURE** has proven the ability of that technology, contributing to the European goal of becoming climate neutral by 2050. **H2FUTURE** is one amongst many projects initiated under the European Program Horizon 2020, setting the foundations for hydrogen to become an intrinsic part of the European Union's integrated energy system. The EU hydrogen strategy Phase ONE is just the beginning of a long journey of technical innovations to make dear old Jules Verne's vision, a reality.

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Note:
This paper was first presented, in 2021, in ASPENCORE - Power Electronics News and updated October 2022.
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About Powerbox
Founded in 1974, with headquarters in Sweden and operations in 15 countries across four continents, Powerbox serves customers all around the globe. The company focuses on four major markets - industrial, medical, transportation/railway and defense - for which it designs and markets premium quality power conversion systems for demanding applications. Powerbox's mission is to use its expertise to increase customers' competitiveness by meeting all of their power needs. Every aspect of the company's business is focused on that goal, from the design of advanced components that go into products, through to high levels of customer service. Powerbox is recognized for technical innovations that reduce energy consumption and its ability to manage full product lifecycles while minimizing environmental impact. Powerbox a Cosel Group Company.

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Chief Marketing and Communications Officer for Powerbox, Patrick Le Fèvre is an experienced, senior marketer and degree-qualified engineer with a 40-year track record of success in power electronics. He has pioneered the marketing of new technologies such as digital power and technical initiatives to reduce energy consumption. Le Fèvre has written and presented numerous white papers and articles at the world's leading international power electronics conferences. These have been published over 450 times in media throughout the world. He is also involved in several environmental forums, sharing his expertise and knowledge of clean energy.

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PRBX white paper 031 EN Rev A
2022-11-07