2024

ENERGY SOLUTIONS

How Europe can accelerate electrolyzer deployment to boost its green hydrogen production

Numerous 100MW+ electrolyzer projects are under preliminary studies either in Europe or for imports to Europe. However, for most of them, the final investment decisions are delayed for extra CAPEX or project risks reasons.

We at P3 energy solutions are involved daily to support stakeholders of the green hydrogen value chain to overcome challenges from project ideation to final business plant and investment decision.

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Introduction

At the heart of the challenge of deploying green hydrogen at scale, lies one issue: build profitable electrolyzer plants.

Green and low-carbon hydrogen can be massively produced via the electrolysis process, which consists of using electricity produced from a renewable source, like wind or solar, or nuclear power, to split water into hydrogen and oxygen. The electricity is converted into hydrogen that can be then used in industrial processes, as an energy source, or, in turn, converted into derivatives like ammonia, methanol or e-kerosene: a transportation vector or a liquid fuel. The water electrolysis process takes place in the electrochemical cells, fitting a membrane in between electrodes in the presence of an electrolyte, which can be stacked and range in size. It relies on different technologies, the most mature being alkaline and PEM (Proton Exchange Membrane).

Manufacturing and deploying these units are essential to decarbonize the existing hydrogen sectors like refineries or fertilizers but also abate carbon in other sectors like steel, cement, glass industry, transport or APU (Autonomous Power Units). Countries around the world are busy trying to figure out how best to increase their electrolyzer capacity. As part of its REPowerEu plan - ambitioning to produce 10 million tons of renewable H2 within the EU territory by 2030 and importing 10 million more from outside - the European Union is aiming to install 100 GW of electrolysis by 2030 — which means multiplying by 10 in the next three years the bloc's manufacturing capacities of electrolyzers.

This is a very ambitious goal given that the EU production capacity is estimated today at around 3 GW/year.

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Increasing production capacities entails many challenges

The electrolyzer OEMs shall first develop performant and reliable solutions. This can be only achieved with operational experience, deploying, and operating first units, solving technical problems, and improving safety. Endurance tests in both steady state and stop & go modes are also key to qualifying power efficiency degradation on the long run.

Then, with a sufficient level of maturity, OEMs can standardize and industrialize their products, to be manufactured in large series. Manufacturing processes like cell stack assembly will be progressively streamlined and automated to reduce costs and reach higher repetitiveness. Large production volumes are the only way to dramatically reduce costs. This is what Chinese have started to do, positioning them already at the forefront on the most competitive solutions.

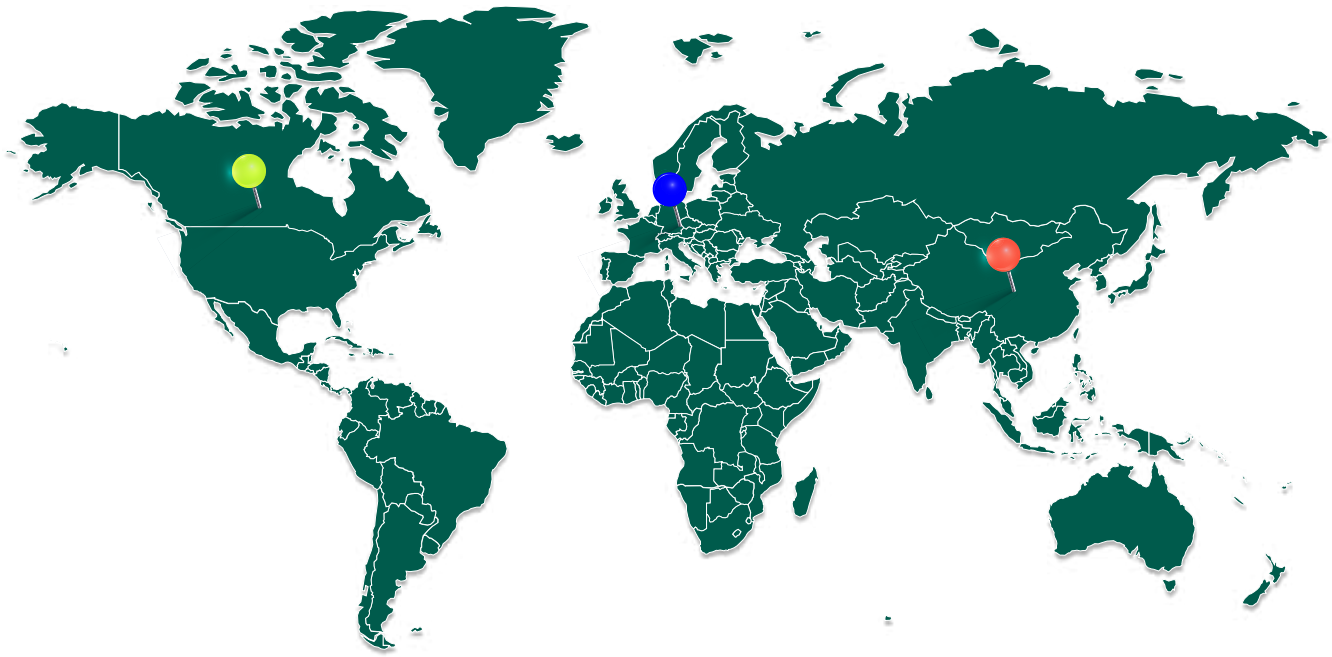
Based on our experience of the automotive and batteries serial production processes, we support electrolyzer OEMs to shift to large production batches together with standardized products and stabilized configurations.

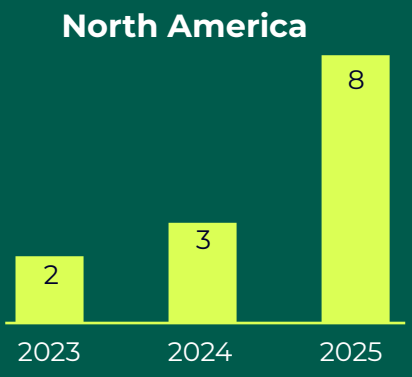
The complete supply chain such as membranes, electrodes + catalysts, gas diffusion layers, power rectifiers, and many other equipment suppliers shall also develop dedicated products and optimized manufacturing processes to support these goals. The concentration of rare metals in the catalysts, shall be progressively reduced. Research is much mobilized on the topic for many years already. Stacks refurbishment with precious metal recycling will also bring large benefits, especially for the PEM technology.

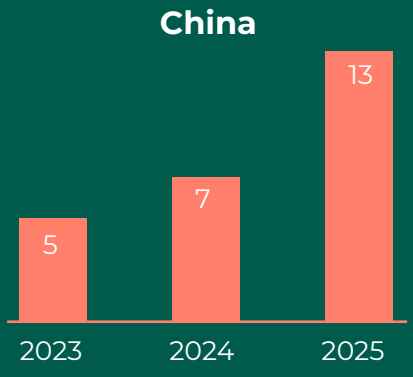
We support equipment suppliers not yet involved in the field to better understand the requirements and expectations of this emerging market.

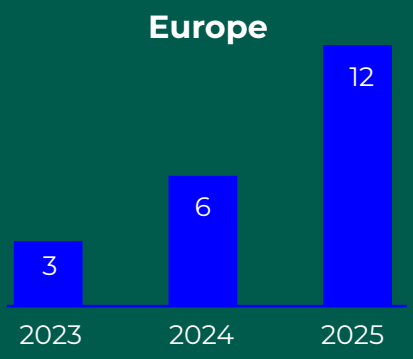
All these efforts shall be concomitantly managed, in a way to make these investments and projects bankable. Indeed, electrolyzer giga factories and large production plants cannot be funded without the support of finance and banks. Access and conditions to public support, bridging the economic gap with fossil-based solutions, shall be understandable and effective to trigger investment decisions towards the hydrogen value chains.

Planned electrolyzer production capacity by region in GW/year









List of OEMs

- Accelera
- Hydrogen Pro
- Plug Power
- Nel

- Accelera
- Elogen
- Green hydrogen systems
- H-TEC Systems
- Hydrogen Pro
- ITM Power
- John Cockerill EU
- McPhy
- Nel
- Nucera
- Siemens
- Sunfire

- Hydrogen Pro
- John Cockerill
- Longi
- Peric
- THE
- Sungrow

*Capacity announced by manufacturers, not demonstrated

Engineering and construction tasks often underestimated.

Numerous studies have been published about green hydrogen costs and electrolyzers CAPEX (k€/MW). But it's still difficult to find robust turnkey costs including all the EPC (Engineering, Procurement and Construction) costs. This includes the balance of plant, the grid connection and power transformation, the other utilities such as water and nitrogen supply for example, the civil work, the installation and start-up costs. With the turnkey responsibility of the plant born by the EPC contractor, a provision for the electrolyzer procurement risks is commonly factored in the price too.

Breaking down the turnkey costs of an electrolyzer plant, up to 50% can be associated to these EPC costs, that are at stake to match competitive hydrogen prices.

> *We coordinate exhaustive risk analysis and mitigation plan, to reduce overall insecurity, hence lowering contingencies as most of the risks are reflected and incorporated by the EPC.*

The EPC companies shall develop their competencies and blueprint solutions to integrate electrolyzers at the cheapest costs. Reliable balance of plant shall be designed to harvest intermittent electricity while matching downstream processes constraints. Affordable hydrogen storage solutions shall be also developed, like underground storage or using the variable pressure of the pipeline as a buffer.

Permitting can complexify the development process. To secure the project, both in terms of planning and feasibility, permitting submission shall be engaged early in the project development. Requiring a mature definition of the solution, based on a electrolyzer solution, early negotiation shall be completed to down select the right product and supplier. This can put the project at risk, if later-on, the selected supplier encounters difficulties or delays in the execution of its development roadmap. By increasing their track record of large plant operation and OEM+EPC executed projects, the front runners in the field should be progressively in position to propose robust pre-engineered solutions, mature enough to submit a permitting file.

Secure hundreds of MW of power connection can be long and expensive task with the Transport System Operator (TSO). TSO usually process the demand only after a formal request has been issued. By anticipating the relevant locations to integrate power "buffers" into the grid, TSO could proactively design conditions for investor to get a preferred access to the grid in specific locations, with an accelerated ad 'hoc process.

> *We provide extensive pre-work studies to optimize the power supply configuration improving the project as grid connection aspects are often underestimated.*

Water supply should not be forgotten. Requiring nine liters of demineralized water for one kilo of hydrogen produced, a 100 MW electrolyzer will consume around 16 cubic meters per hour. Moreover, the demineralization process consumes more tap water, a portion being wasted and the cooling system, if not in a close loop, can also consume large quantities of water. In location where water is rare, sea water with a desalination unit can be contemplated.

EU position in this race for hydrogen production capacity

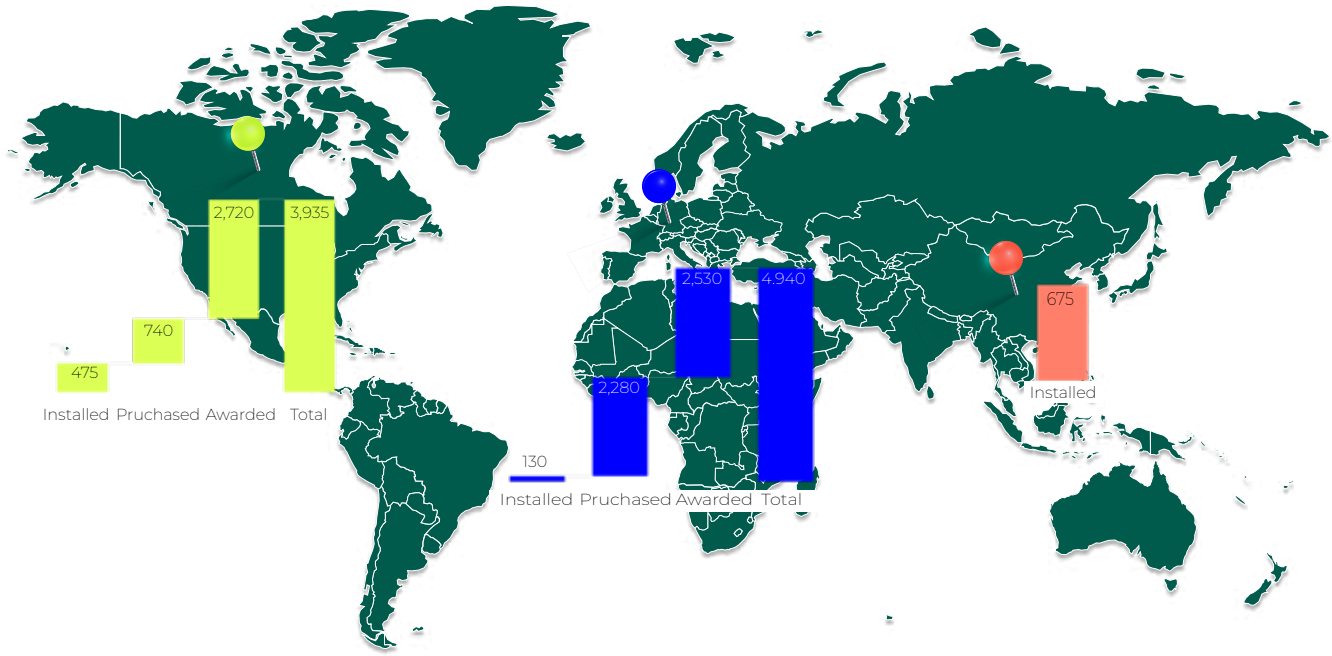
From the complexity of public incentives streams to the intricacies of the regulations between renewable and low carbon features and the need for large new renewable electricity sources that shall not be detrimental to nature preservation, several challenges are impeding the building and expansion of new electrolyzers in Europe.

China and Europe are the two largest markets, accounting for over half of electrolyzer worldwide demand this decade, but Beijing has already moved ahead in accelerating the manufacture of very cheap units. Biden, with the “inflation reduction act” is attracting hydrogen investors from all over the world. In this world race, Europe needs to design a strategy for catching up, taking advantage of its innovative domestic players, retaining a “made in Europe” clean technology, boosting hydrogen unit deployments, and meeting the objectives of energy sovereignty, decarbonization, and reindustrialization.

The most advanced Chinese players have already shifted into gigafactories production, benefiting from serial production savings to achieve cheaper costs. Even so, Europe cannot delay its investments, risking delaying the energy transition in fields where decarbonized hydrogen is a key enabler.

Many of the first 100 to 200 MW projects under execution or in the pre-engineering phase are based on European technologies. They are thus of utmost importance to pave the road for large production plants at scale, based on an integrated European Industry, and unlocking other investment decisions with similar setups.

Status of electrolyzer projects larger than 10MW in 3 key regions Q1 2024 MW



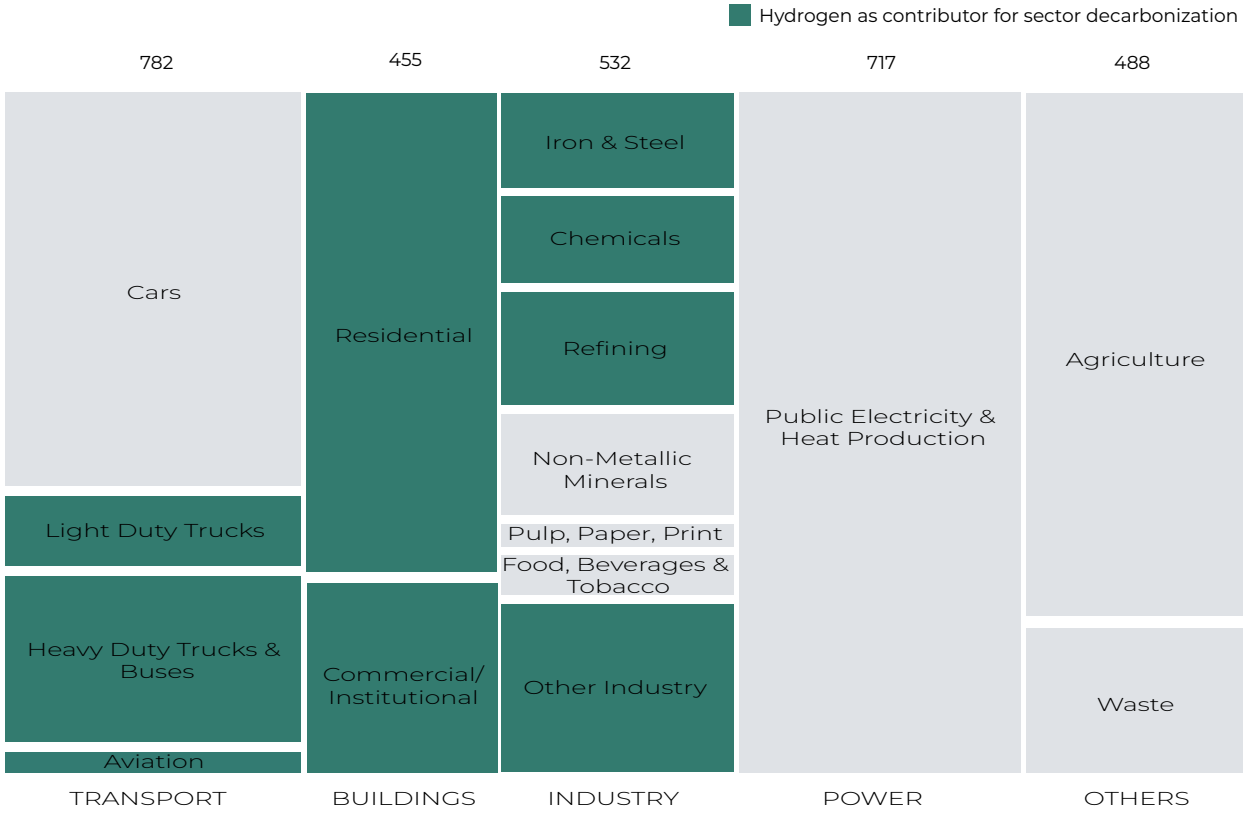
**Awarded means a supplier has been selected but FID is pending*

We enable investors to select the right electrolyzer partner and OEMs to improve their positioning in the competitive landscape by constantly monitoring the electrolysis market. Our mapping covers PEM, Alkaline, AEM and SOEC technologies providers at global level from top tier player to start ups. We factor the technical and cost performances as well as attractivity parameters as for example contractual commitments, or project execution track record allowing a 360° analysis and informed selection.

Decarbonizing hard-to-abate sectors

Beyond industrial sectors consuming hydrogen today, such as fertilizers and refineries, which shall shift to non-fossil-based hydrogen, steel, cement industry or maritime and road transport are among other, hard-to-agate sectors, that should resort to low carbon hydrogen for their energy transition.

Greenhouse gas emission, Mt CO_2 equivalent, 2021



SOURCE: UNFCC GHG inventory 2021

With around 75% energetic efficiency, the electricity-to-hydrogen conversion presents a higher yield than most of the incumbent energy conversion processes. However requiring an additional energy conversion, it's of course less efficient than the direct use of electricity. Which is why hydrogen is not expected to compete with electric-based solutions including batteries, but to complement them. Hydrogen will address the sectors that require either the chemical properties of the hydrogen or its high energy content feature, bringing for example more energy storage capacities than batteries. This is relevant for onboard vehicles requiring high autonomy such as long-haul road or maritime transport, non-electrified rail, or aviation. Together with the long autonomy, the possibility to refuel rapidly is another advantage of hydrogen solutions.

Hydrogen volumetric energy density remains low, requiring high pressure tanks in vehicles, from 350 to 700 bar. More prospectively, cryogenic liquid hydrogen is being demonstrated, for aviation or trucks. But as a transitional solution, conversion of hydrogen into e-fuels with carbon sequestration is considered, including e-kerosene for aviation or e-methanol for maritime.

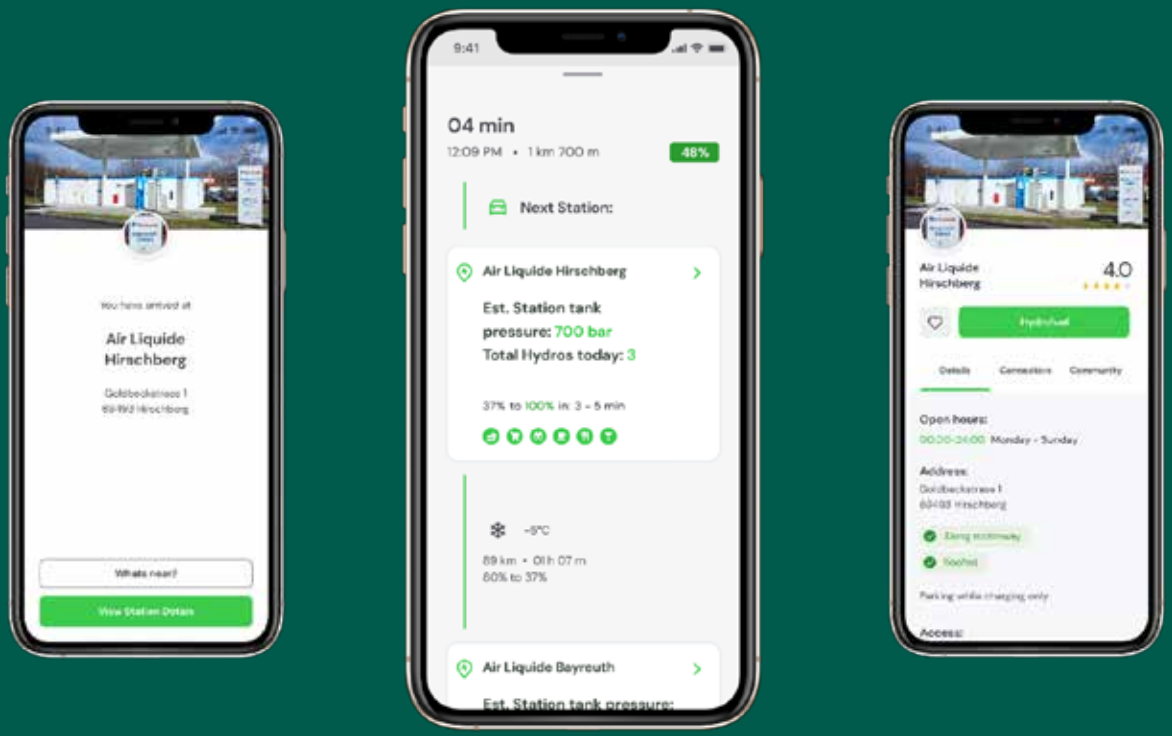
We are involved in both compressed gas and cryogenic liquid value chains supporting for example leading funds and companies investing in hydrogen distribution infrastructures for mobility for fuel-cell buses, trucks, or taxi fleets.

E-ammonia could also be qualified as a fuel for maritime transport, used in an internal combustion engine with a pilot fuel. However, its toxicity leads to preferring e-methanol, at least in the short term.

Our due diligence dealing with large e-ammonia projects has already been instrumental to an investment conclusion. We continue supporting power-to-X investors in different geographies of the world.

For the steel industry, green hydrogen can serve a dual purpose, the fuel for heat production and the reductive environment making it suitable to replace coke and thus abate dramatically GHG emissions. Car OEMs are among the first clients for green-steel.

In the cement industry, the decomposition of limestone to produce clinker releases significant amounts of CO2. Hydrogen can be used as a fuel for the high-temperature process but also as a raw material in the clinker production.



Derived from our interactive map for battery electric vehicles, we propose a cell-phone app. for hydrogen-vehicle drivers.

Build energy bridges between gas and electricity networks; balance the power grid

The progressive deployment of the hydrogen pipeline network in the EU (ref. EU H2 backbone) will make it even more relevant to use large electrolyzers at power grid bottlenecks, linking the power grid with the H2 gas network. Especially at locations where the lack of grid capacity to absorb new wind and solar sources, the addition of new high-voltage overhead lines would otherwise be required. In terms of neighborhood and landscape preservation, buried pipelines are more desirable than overhead HV lines.

Electrolyzers are also expected to play an important role in balancing the electricity grids in Europe. Intermittent electricity production peak times often mismatch consumers' peak times. The grid balancing insurance provided by TSOs, will become more and more difficult to guarantee, assuming an increasing penetration of intermittent power. Electrolyzers can play a role in absorbing production peaks in excess of demand, producing hydrogen as storable energy, rather than curtailing this excess of renewable production. For instance, nowadays, during windy nights or in the middle of a summer day, excess power is often wasted.

> *Our teams have developed grid simulation tools that allow to simulate the electrical grid behavior and identify the power storage like in the predesign of the NEOM island grid.*

Installing electrolyzers at the future power grid bottleneck locations, coupled, when possible, with underground hydrogen storage caverns, will allow to both avoid new high voltage lines investments and provide massive energy storages capacities for grid balancing services. These units being mainly operated during intermittent peaks, are only viable with lower CAPEX, to remain competitive. Grid balancing services are expected to progressively complement the revenue streams. But considering present CAPEX and lack of grid service revenues, more intensive operation shall be targeted, mixing renewable and low-carbon sources to complement off-peak times.

> *Our electrolyzer economic model has been used by several investors to simulate and optimize their project and OEMs to improve their offering. Our approach factors power supply and operation strategy together with reliability and redundancy strategy enhanced by concrete field experience.*

Hydrogen from water electrolyzis as a green energy vector for massive importation

Europe must simultaneously replace Russia's fossil imports and accelerate its clean energy deployment. This cannot happen by relying only on energy sobriety, energy efficiencies, and new renewable energy power sources. The limitation of land usable for wind turbines and PV plants, in particular, cannot be easily tackled without damaging areas where nature is still preserved.

The use of green hydrogen, liquefied or in the form of its derivatives like ammonia, should be considered as the new energy vector to import massively green energy from the outside of the EU.

The geographies gathering a good combination of wind and solar, large regions that can fit renewable power production without damaging nature, and stable governments and institutions, will become the new El Dorados for green hydrogen production plants. Assuming that this imported hydrogen compliance with the European low-carbon hydrogen regulation, it will be supplementing domestic production. These additional volumes of hydrogen contribute to abate greenhouse gas emitions in all the industrial and transport sectors already mentioned and make the energy transition in the EU an executable roadmap.

We bring our customers methodologies from best-in-class companies practices and insights based on expertise and experience to down select the best projects, considering all the aspects that make a project bankable.

Europe is also considering to be connected by pipelines: under the Mediterranean sea to connect North Africa and possibly, on the longer run, with Middle East. Middle East countries gather all the ingredients to become large producers: sun, wind, large deserts, massive available capital, and the vital need to shift from fossil to low carbon.

Ammonia as a liquid carrier requires ammonia cracking at destination that is energy intensive. Liquid hydrogen for maritime transportation was tested at scale by Kawasaki and turns out to remain complex and expensive.
Alternative liquid carriers are also considered, such as the methyl-cyclo-hexane / toluene cycle, but they are not mature today.
Consequently, pipelines remain the most effective way to transporting hydrogen, in its original production form: gas.

We make projections of required hydrogen price to reach revenue targets based on local hydrogen consumers mapping, including clients supplied by future forecasted pipeline or by road.

Key message:

Matching the European net zero targets requires hydrogen from water electrolysis produced with renewable and low carbon electricity. This molecule will play four key enabling roles:

- Contribute to decarbonize hard-to-abate industrial sectors such as steel or cement.
- Complement electric batteries for use cases requiring high autonomy, such as maritime, long-haul road transport or aviation.
- Stores large quantities of energy from intermittent power sources in to support the grid balancing services and avoid curtailments.
- Provide a decarbonized energy vector, transportable, storable, and tradable, to progressively replace fossils, for intercontinental energy exchanges.

It's now well understood all over the world, that hydrogen will play a key role in the energy transition and therefore, that the most advanced countries in deploying hydrogen productions capacities and hydrogen solutions to abate GHG, will become the best positioned to export their technologies and to reach net zero targets. At the heart of this deployment, water electrolysis, that bridges power and gas networks, is the technology brick that makes it possible.

European low carbon energy future in intimately linked with large electrolyzers plants El Dorados deployments, both domestically but also in the future green hydrogen El Dorados, especially the ones interconnectable by pipeline with Europe.

'P3 energy solutions is proud to be involved daily with the hydrogen value chain actors for enabling this shift towards green hydrogen deployments at scale.'

P3 group

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