



HAL
open science

Low-carbon hydrogen production in the EU: are 2030 targets achievable?

Boigontier Thomas, Gregory de Temmerman, Robin Girard, Julien Lamarque-Lacoste, Manon de la Motte Saint Pierre, Anouck Dubois

► **To cite this version:**

Boigontier Thomas, Gregory de Temmerman, Robin Girard, Julien Lamarque-Lacoste, Manon de la Motte Saint Pierre, et al.. Low-carbon hydrogen production in the EU: are 2030 targets achievable?. Zenon Research; MINES paris; PERSEE; IHEIE. 2023. hal-04158824

HAL Id: hal-04158824

<https://hal.science/hal-04158824v1>

Submitted on 11 Jul 2023

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



PSL 

Zen n
Research

ARCHERY
STRATEGY CONSULTING

THE HYDROGEN SERIES – PART 2
REPORT
JUNE 2023

LOW-CARBON HYDROGEN PRODUCTION IN THE EU: ARE 2030 TARGETS ACHIEVABLE?

In part 1 of our Hydrogen Series, the great variety of hydrogen production routes and technologies were presented and compared based on their maturity and performances.

Around the world and particularly in developed countries such as the EU, there is a strong support for the development of hydrogen produced by water-electrolysis and powered by renewable electricity as it is one of the most mature and clean hydrogen production routes.

This second part is dedicated to the analysis and comparison of 2030 EU's targets in terms of renewable hydrogen production with the pipeline of projects. It will also explore the possibility of using other low-carbon hydrogen production technologies than water electrolysis.

CONTENTS

EU TARGETS AND POLICIES ON HYDROGEN	3
LIMITING FACTORS FOR RENEWABLE HYDROGEN PRODUCTION SCALE-UP	5
NATURAL GAS WITH CARBON CAPTURE: A COMPLEMENTARY (BUT LIMITED) SOLUTION	17
BIBLIOGRAPHY	23
FOOTNOTES	24

EU TARGETS AND POLICIES ON HYDROGEN

Hydrogen (H₂) can be qualified as **low-carbon** when the CO₂e emissions associated to its production are **lower than a threshold based on current fossil fuel production routes**. According to the latest EU delegated acts, the condition for hydrogen to be considered low-carbon is that the emissions of the production life-cycle must be lower than 3.38 kg CO₂e/kg H₂, which is at least 70% lower than the fossil fuel reference of 11.3 kg CO₂e/kg H₂ (production from natural gas without CCUS)¹.

As shown in the part 1 of this series, the most mature low-carbon hydrogen production technology at an industrial scale is water electrolysis powered by low-carbon electricity. When this electricity originates from renewable sources, it is differentiated and labelled as **renewable hydrogen** (or green hydrogen).

Today, at a global scale, low-emission hydrogen production comes mostly from fossil fuels with carbon capture. With a mere 1 Mt produced in 2021, it represents a fraction (0.7%) of the global annual production of 94 Mt. Similarly, and although alkaline (ALK) and proton exchange membrane (PEM) electrolyzers are mature technologies, global hydrogen production via water-electrolysis (from renewable and non-renewable electricity) was only 35 kt in 2021, which is less than 0.04% of the global hydrogen production².

In the EU region, the landscape is quite similar. From a total hydrogen demand of **8.7 Mt in 2020**, 90% was produced by the **reforming of natural gas** without carbon capture. By then, water electrolysis only accounted for around 0.1% of the total hydrogen production capacity of 11.5 Mt (including hydrogen as a co-product)³. Hence, scaling up H₂ low-carbon production capacities to abate meaningfully the carbon intensity of the current H₂ production processes will be a **long process given the volume required**.

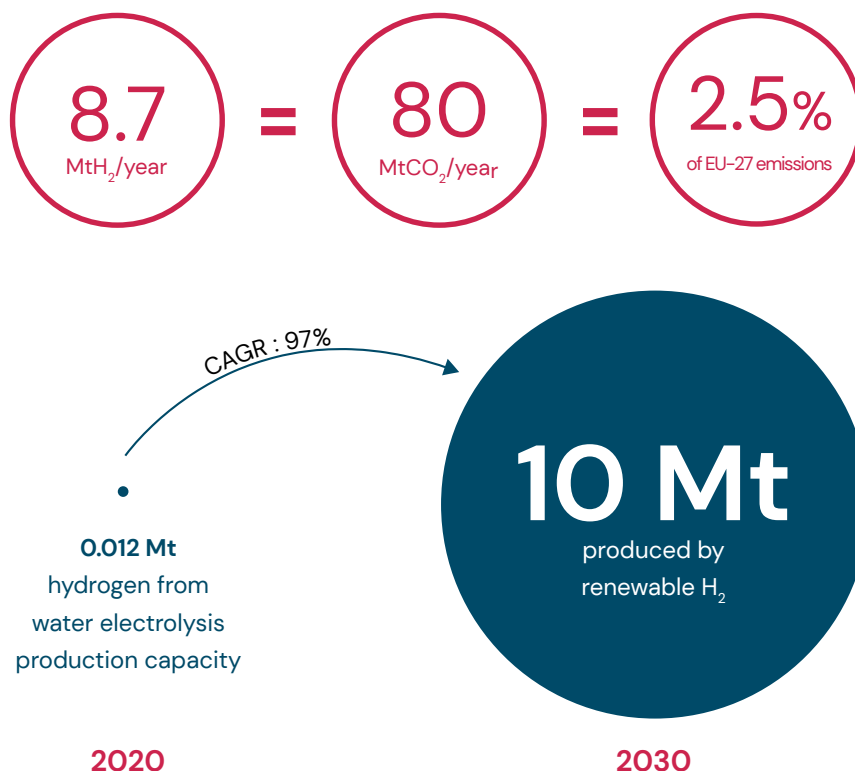


Figure 1. 2020 renewable hydrogen production in Europe, and 2030 production target

So far, Europe efforts have been mostly focused on boosting the production of **renewable hydrogen**. Key EU policy initiatives such as the European Green Deal, the EU Hydrogen Strategy and more recently the REPowerEU plan have set a final target of **10 Mt of renewable hydrogen production in 2030** along with an additional 10 Mt to be imported from outside the EU. This aims at accelerating its decarbonisation pace as well as limiting its fossil fuel dependence on Russia^{1,4,5}.

More recently, the European Commission (EC) has also approved two **Important Projects of Common European Interest (IPCEI)** dedicated to the development of hydrogen sector:

“IPCEI Hy2Tech” released up to 5.4 billion euros of state funds intended for innovative technologies of the hydrogen value chain focused on end-users in the **mobility sector**. This could incentivize private investments to join and for which another 8.8 billion euros of private funds are expected. Currently, 35 European companies are developing 41 projects aiming at establishing a real hydrogen market in Europe⁶.

“IPCEI Hy2Use” will provide up to 5.2 billion euros of public funding for research and innovation programs as well as “the first industrial deployment and construction of relevant infrastructure in the hydrogen value chain”. This could also foster private investments and attract another 7 billion euros of private funds. As part of this second IPCEI, 29 European companies including small and medium-sized enterprises (‘SMEs’) and start-ups will take part in 35 projects⁶.

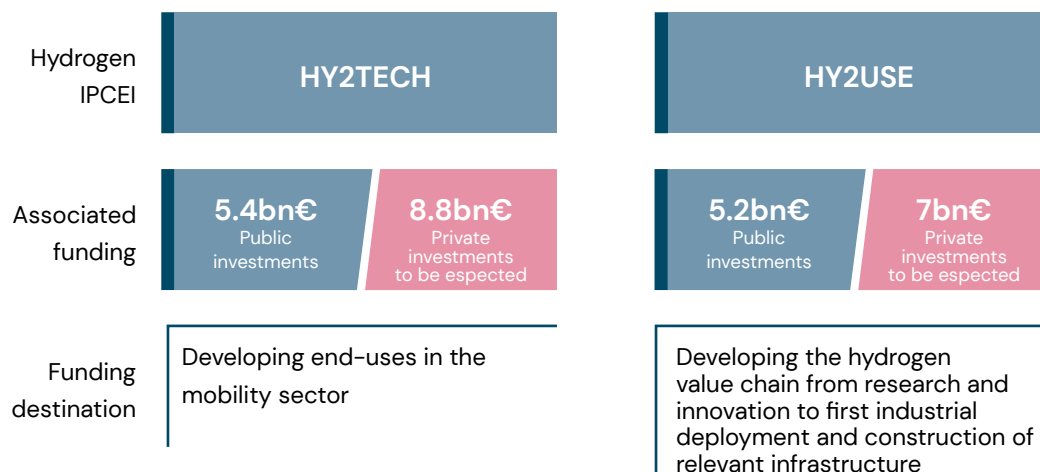


Figure 2. Details on the IPCEI dedicated to the development of H₂ value chain (source: European Commission⁴)

When looking at all the European projects dedicated to the production of hydrogen supported by these two IPCEIs, **449 out of 490 projects** kick-starting from 2023 onwards, will use water-electrolysis process, which illustrates the strong momentum of this technology⁶.

Overall, while the objectives are clear and ambitious, the road ahead is challenging. The purpose of this study is to understand their implications in terms of technological deployment rate, renewable electricity capacity and to consider the potential of additional low-carbon hydrogen production processes.

FACTORS LIMITING THE RENEWABLE HYDROGEN PRODUCTION SCALE-UP

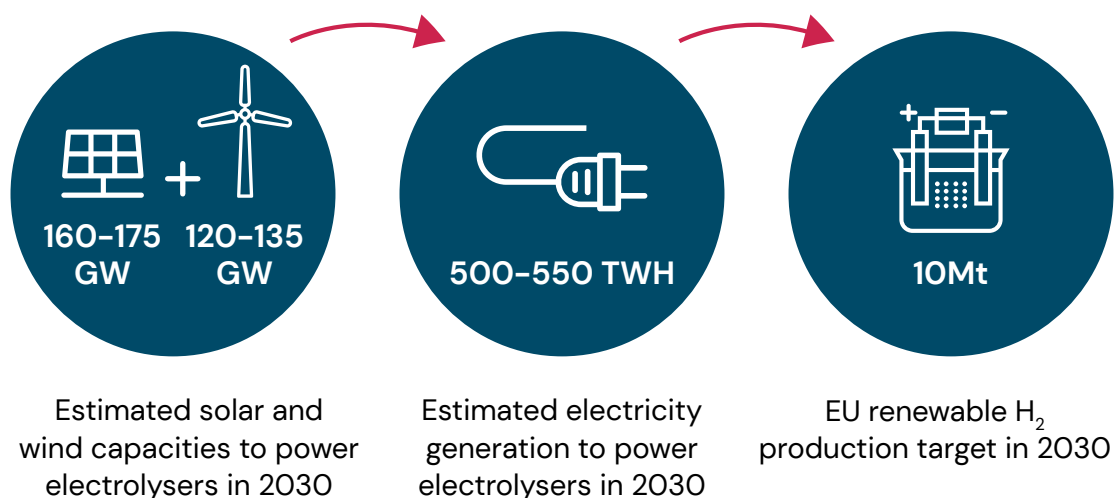
Reaching the target of 10 Mt of renewable hydrogen produced in 2030 will require the European **production capacity to nearly double every year**. In the short to medium term, the **two limiting factors** of this growth are the availability of renewable electricity and electrolyzers. The aim of the following sections is to analyse what has been planned or announced on these two topics and to create a perspective with the resources needed to reach the EU's 2030 targets.

Renewable electricity supply

500–550 TWh of renewable electricity is needed to produce 10 Mt of renewable hydrogen by 2030.

In its latest delegated acts, the EC has set out the rules to credit the hydrogen produced as renewable¹. Hydrogen producers will need to prove that their monthly hydrogen production matches with their consumption of renewable electricity originating from their “bidding zone”^A until 2030, thus enforcing a **temporal and spatial correlation** criterium. If the electrolysis installation is in a country where the carbon intensity of the electricity from the grid is **lower than 65 g CO₂e/kWh**, it can consume it directly, providing that the hydrogen producer buys renewables PPAs^B at least equivalent to the amount of electricity claimed as fully renewable. These rules ensure that every kg of renewable hydrogen produced is matched with the same amount of renewable electricity and is indeed low-carbon and mitigating global warming.

To produce 10 Mt of green hydrogen domestically by 2030, the EC estimates that **500 to 550 TWh of renewable electricity** is needed, which translates into a 61% to 67% electrolyser LHV efficiency^{5C} (consistent with current electrolysers performances). Considering the EU additionality principle on renewable, this leads to capacity additions of **159–175 GW for solar** and **123–135 GW for wind** to be deployed in Europe by 2030 to power electrolysers:



A. “Bidding zone” means the largest geographical area within which market participants are able to exchange energy without capacity allocation as defined in Article 2, point (65), of Regulation (EU) 2019/943 of the European Parliament and of the Council for Member States.

B. Power Purchase Agreements.

C. Lower Heatin Value (LVH). Consistent with the performances of current technologies (cf. Part 1).

Renewable electricity generation needs to double to meet ambitious levels of demand from both hydrogen and power generation sectors, thus creating potential conflicts of use if renewables do not ramp up fast enough.

As renewable electricity will also be needed to decarbonize several end-uses such as transportation and heating, potential **conflicts of use** for this energy could emerge if its demand is greater than its production.

The EU has recently re-evaluated its renewable electricity targets via its REPowerEU plan published in May 2022, raising the **renewable energy share** in the electricity ('RES-E') sector to **69% by 2030** (72% in gross electricity generation) compared to the previous target of 65% (69% in gross electricity generation) from the FF55^c package published in July 2021^{8,9}. This is a sharp increase in comparison to the historical share of **38% in 2020**. Translated into production volume, this means that **gross renewable electricity generation needs to more than double between 2020 and 2030**, from 1048 TWh to 2583 TWh according to REPowerEU⁸.

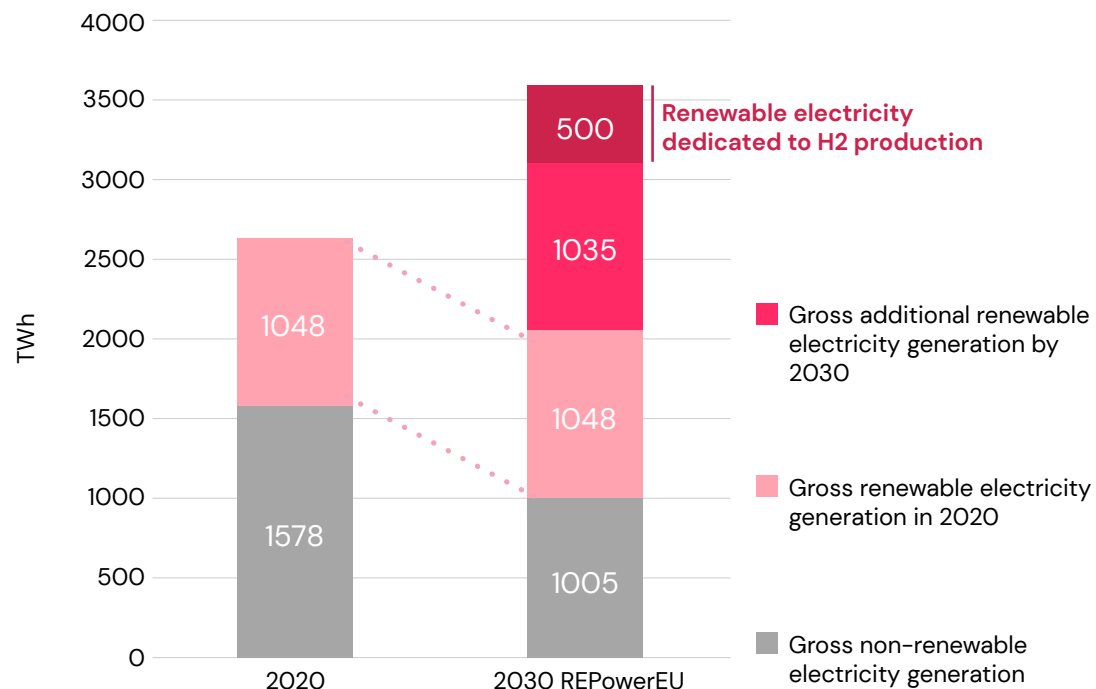


Figure 3: Renewable and non-renewable electricity generation in 2020 and in 2030 based on REPowerEU modelling⁸

From a renewable electricity production standpoint, the 500 to 550 TWh required to produce 10 Mt of renewable hydrogen in 2030 represents **33% to 36% of the additional renewable electricity generation** projected in the REPowerEU scenario (which is a far greater share than what was expected in previous EU plans). It is noteworthy that, while hydrogen production is meant to absorb more than a third of the additional renewable electricity which was first dedicated to direct electrification, it is only expected to constitute **~3% of the final energy consumption**.

This raises the following question: will the installed capacity in renewable electricity develop fast enough to reach both renewable hydrogen production and power generation decarbonization targets?

To reach enough renewable electricity generation by 2030, Europe must accelerate the deployment of wind capacity and at least maintain the same growth rate for solar capacity.

The expected increase in the share of renewables in electricity consumption will be mainly provided by the deployment of wind and solar PV capacities as well as a **reduction of fossil-fuel based electricity consumption**.

These renewable electricity targets are ambitious and require a **strong acceleration** of wind and solar PV electricity generation in the years to come. To illustrate this, Figure 4 shows the historical cumulative installed capacity of wind and solar in the EU and compares the average growth rates observed during the last three years with those needed to reach REPowerEU targets.

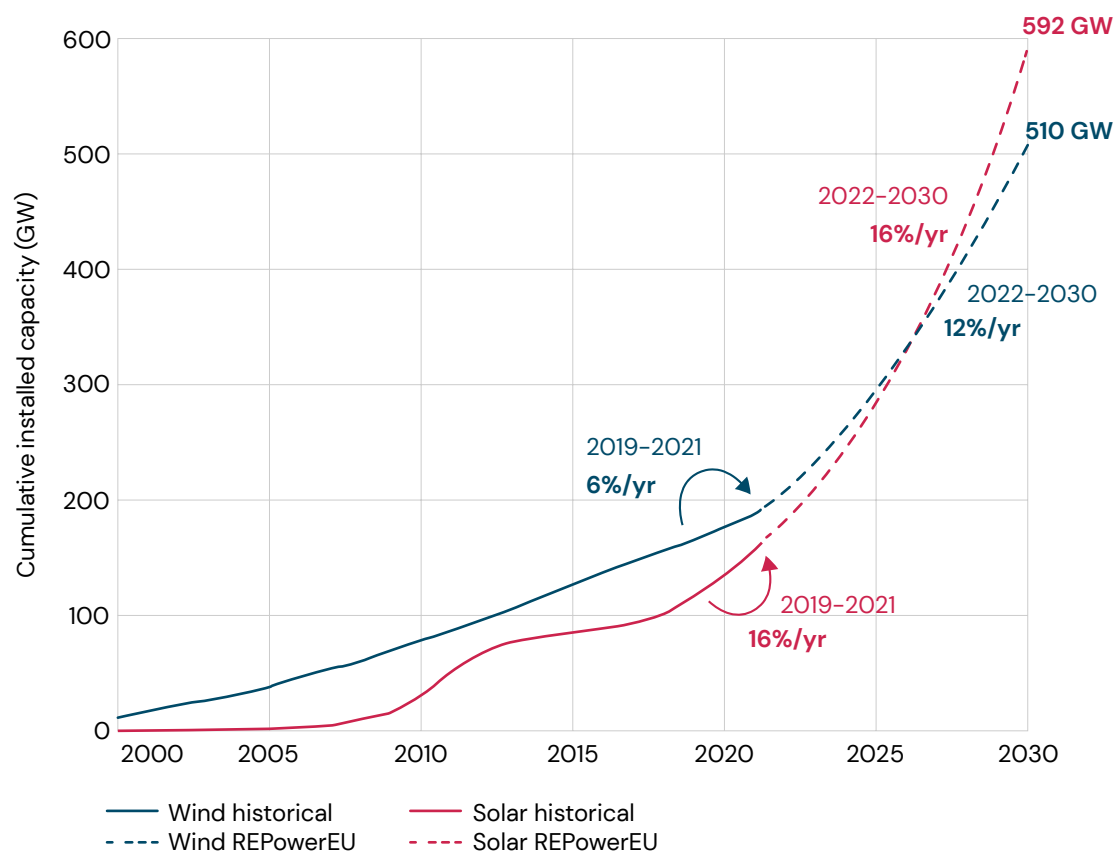


Figure 4: Comparison between historical growth rate for wind and solar capacity in the EU and the required rates to reach REPowerEU targets¹⁰

On one hand, **solar capacity should maintain the same growth rate as it did during the last three years** (2019 to 2021) to achieve REPowerEU target of 592 GW in 2030. It still represents a challenge for the supply chain to be able to provide 4 times more of new installed capacity than today (+22 GW/year between 2020 and 2021; +80 GW/year expected between 2029 and 2030).

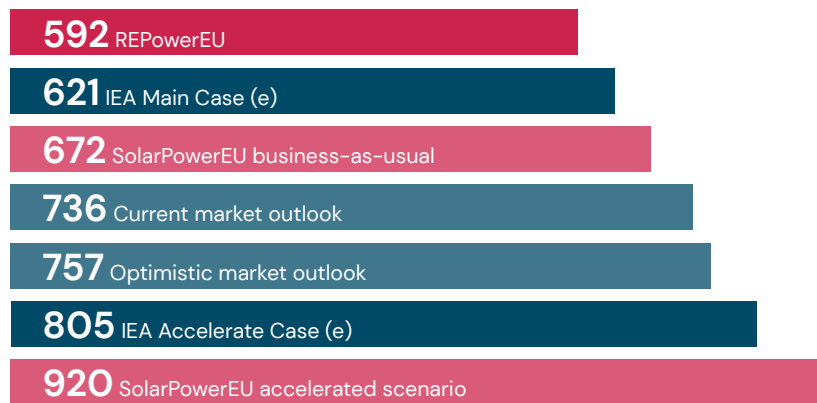
On the other hand, **the installation rate for wind power must double** to reach a 16% annual growth, compared to the 6% growth rate observed over the same period, leading to an increase of annual installed capacity from 11 GW/year today to 53 GW/year in 2030.

Hence, this calls for intensifying efforts toward the installation of new renewable capacities in Europe, otherwise the scarcity of renewable electricity is likely slow down electrification efforts and hydrogen uses.

Recent market outlooks indicate that such growth rates are achievable. Were they not, the arbitration between allocating additional renewable electricity generation to the power sector or/and to the hydrogen sector would have to be considered.

All market outlooks and projections expect solar capacity to exceed REPowerEU targets, including those of the IEA which are known to be rather prudent. However, wind capacity objective is higher than all projections.

Projected solar PV capacity in 2030:



Projected wind capacity in 2030:

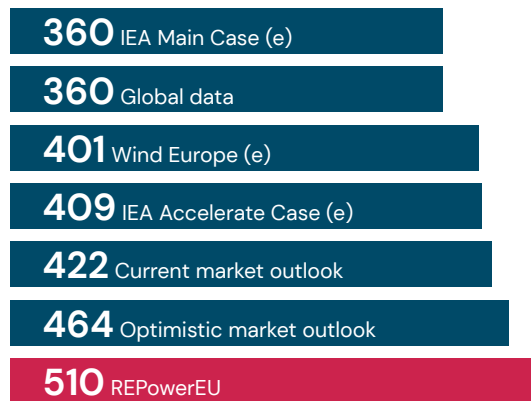


Figure 5: Projected photovoltaic capacity (first chart) and wind capacity (second chart) in 2030 in the EU-27, according to different scenarios^{11 12 13 14}

NB: IEA and Wind Europe projections in 2030 have been estimated based on 2023–2027 official projections (drawing from average growth rate during this period)

For example, **Ember** projects that **onshore wind installed capacity will not exceed the FF55** targets of 361 GW (nor REPowerEU target of 510 GW) and only reach a range of 311–353 GW in 2030 (extrapolation of Wind Europe’s 2023 market outlook and IEA Renewables 2022 figures).

However, **offshore wind is expected to partially fill up the gap** as projects under development already represent 70.5 GW, more than the 66 GW expected in FF55¹¹.

Indeed, the deployment of new wind power capacity has recently hit roadblocks due to **increased duration of permitting processes**. At the end of 2022, more than 80 GW of wind projects were still stuck in permitting procedures across Europe¹⁵. On December 30th 2022, a **temporary emergency regulation** came into force to accelerate the development of renewables and stimulate the energy transition¹⁶. Whether this emergency regulation will be effective enough remains to be seen.

Several actors have highlighted the key challenges to overcome for achieving REPowerEU goals ^{15 17}:

Secure supply chain ramp up consistently across the whole value chain to avoid bottlenecks.

Provide stable and long-term visibility to investors through an adapted market design resilient to market turbulences.

Reduce permitting lead time for all projects (greenfield / brownfield, new / already submitted), through administration simplification and improved local acceptance.

Reinforce existing power transmission and distribution networks, reduce lead time for grid connection and develop new grid connection model for offshore.

In any case, the use of renewable electricity to power electrolyzers will have to be done in coherence with the primary objective: reducing GHG emissions as fast as possible.

As the main goal of the EU is to abate its GHG emissions by 55% by 2030, public policies ought to make sure that powering electrolyzers with renewable electricity **does not come at the expense of decarbonising the power generation sector**. Indeed, reaching EU ambitions for 2030 translates into an electricity carbon intensity of 110 to 118 g CO₂e/kWh (vs. 265 g CO₂e/kWh in 2020), which makes it a priority for many European countries¹⁸.

Considering the target of 10 Mt of imported renewable hydrogen, the EU should make sure that the renewable electricity capacity needed to produce this hydrogen in third countries is effectively **in excess of their domestic demand** to decarbonize their own power sector. If not, displacing new renewable hydrogen production to a country where electricity generation is dominated by fossil fuels would result in an **increase of global GHG emissions**. This would contradict the primary objective of the EU as the reduction brought by renewable hydrogen use in the EU would be cancelled by the fact that the carbon intensity in the third country would not decrease. This bias is not currently considered in PPAs conditions to ensure that “green” hydrogen bought to the third country is effectively low-carbon on a global perspective¹⁹.

Electrolyser capacity

Reaching 100 GW of installed electrolysis capacity in 2030 equals a growth rate of more than 80% per year, starting today.

The second factor that could limit renewable hydrogen production in the coming years is the **deployment rate of electrolysers**.

EU announcements are very ambitious: from a 135 MW of operational electrolyser capacity in 2021, Europe plans to reach **6 GW by 2024**, and to attain at least **100 GW in 2030 required to produce 10 Mt of H₂**. Beyond this horizon, ambition of 500 GW is set to 2050⁵.

Reaching 100 GW in 2030 would imply an average 83 % growth rate/year. When looking at historical trends, such growth rates have only been achieved for a **very limited number of energy technologies** in Europe, such as solar PV during its boom years (2004, 2005, 2008)¹⁰.

Could electrolyser capacity grow as fast or even faster than solar capacity in its most prosperous years?

Two arguments are put forward to bring credibility to such an acceleration: the political will to develop this industry and the “modular” nature of electrolysis technology, characterized by fast adoption and learning curves.

The electrolysis industry benefits from a strong political support, which lead to many projects announcements.



Arrival of the first electrolyser modules RWE 10 MW ALK green hydrogen facility in Lingen, Germany (April 2023, Courtesy of RWE)

Electrolyser technologies currently benefit from a **strong political support** around the world considering the urgency of the climate crisis, having many countries including hydrogen production targets in their Nationally Determined Contributions (NDC)^{D 20}.

For the EU in particular, the war in Ukraine has triggered a **phase out of natural gas** and many member countries see hydrogen as a low-carbon substitute. The fact that part of the current fossil fuel infrastructure can be repurposed for hydrogen and e-fuels is also the reason why many companies are willing to invest in the molecule. **Regions where renewable energy is abundant and cheap** will be the primary places where hydrogen will be produced, benefiting from less densely populated areas, thus alleviating local oppositions.

So far, this political support has materialized into a great number of projects announcements. Based on the current pipeline of projects under development, EU electrolysis capacity could reach 58,6 GW in 2030 with 33 projects announced so far⁷.

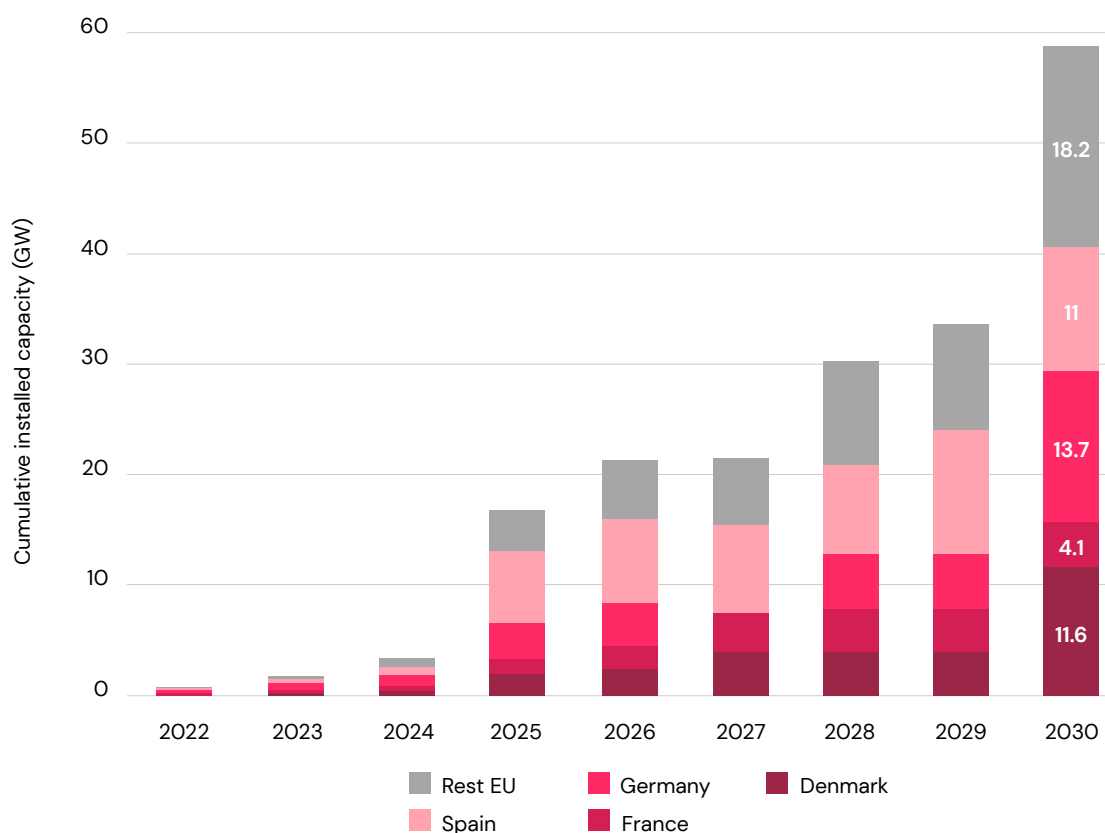


Figure 6: EU electrolyser announced projects capacity by country⁷ (HyDeal ambition excluded)

E. A NDC is a climate action plan to cut emissions and adapt to climate impacts. Each Party to the Paris Agreement is required to establish an NDC and update it every five years (UN definition).

However, **more than 75% of these projects are still at the concept stage**, which does not give any certainty on their effective realisation.

In the years to come, **additional projects could be announced** to be operational by 2030 and thus contribute to reach the 100 GW target. **The HyDeal Ambition** for example (excluded from figure 3), is a consortium of 30 industrial companies whose aim is to boost renewable hydrogen production in the Iberian Peninsula by installing 67 GW of electrolyzers powered by 95 GW of solar PV by 2030²¹. While it is not yet clear how this ambition will turn into projects, it could well make EU targets realistic.

Being modular by design, electrolyzers share common features with highly standardized and mass-produced technologies like solar photovoltaic (PV) that demonstrated fast adoption rates.

Electrolyzers are considered as a **modular technology** as they are composed of small modules that can be assembled to create higher power systems, like solar modules making up solar farms. Modular technologies are usually adopted more quickly and have a **faster learning curve**, as they can be mass produced and thus become accessible for all types of users.

Moreover, some technologies (mostly non-energy ones) have sometimes seen unconventional growth rates **greater than those of solar capacities**. This is usually experienced in specific contexts such as wartime efforts (World War II US aircraft or liberty ships), massive public investment and central coordination (nuclear power in France or high-speed rail in China) or of market-driven deployment of highly modular information technology innovations with low coordination requirements (internet hosts or smartphones)^{23 24}.



Enapter world's first megawatt-class AEM electrolyser composed of 420 modules (450 kg H₂/day), North Rhine-Westphalia, Germany, May 2023 (Courtesy of Enapter)

Many studies have found that the characteristics of a technology (design complexity, need for customization, etc.) can impact its learning rate²². For example, solar PV modules are **highly standardized systems** containing 36 to 72 solar cells connected in series. Their modular interfaces are also defined by **industry standards** so much that they can be installed and used practically everywhere. Moreover, while the characteristics of solar irradiation can vary across contexts, it has no impacts on the design and operating principles of the modules.

In a similar fashion, electrolyzers are also modular systems composed of multiple cells assembled to form a stack. From kW scale modules, stacks can reach powers in the hundreds of kW and can even be installed in series with other stacks. The operating and design conditions of electrolyzers are also the same across contexts and the overall systems are all composed of the same units such as a storage tank, a power supply, a separator and other components making the balance of the plant. Technologies like solar PV modules, LEDs or batteries have benefitted from **cumulative experience gained from deployment in large, global markets** and new knowledge has often been globally applicable, allowing them to scale up across multiple contexts with relative ease. Hence, electrolyzers share the characteristic features common to highly standardized and mass-produced technologies which could be deployed on large scales.

Hence, comparing historical cost reductions of solar/wind and electrolyzers can give an insight on the modular nature of electrolyser technology and its future learning rate. Historically, **Power-to-X (or P2X)^E** has seen cost reductions with an average of 7.4%²⁴. Comparatively, wind energy costs have decreased on average by 5.2% and solar energy costs by 12.5%. However, P2X useful energy production has increased very quickly by 88% per year compared to wind and solar energy with 17% and 40% respectively, as shown on Figure 8.

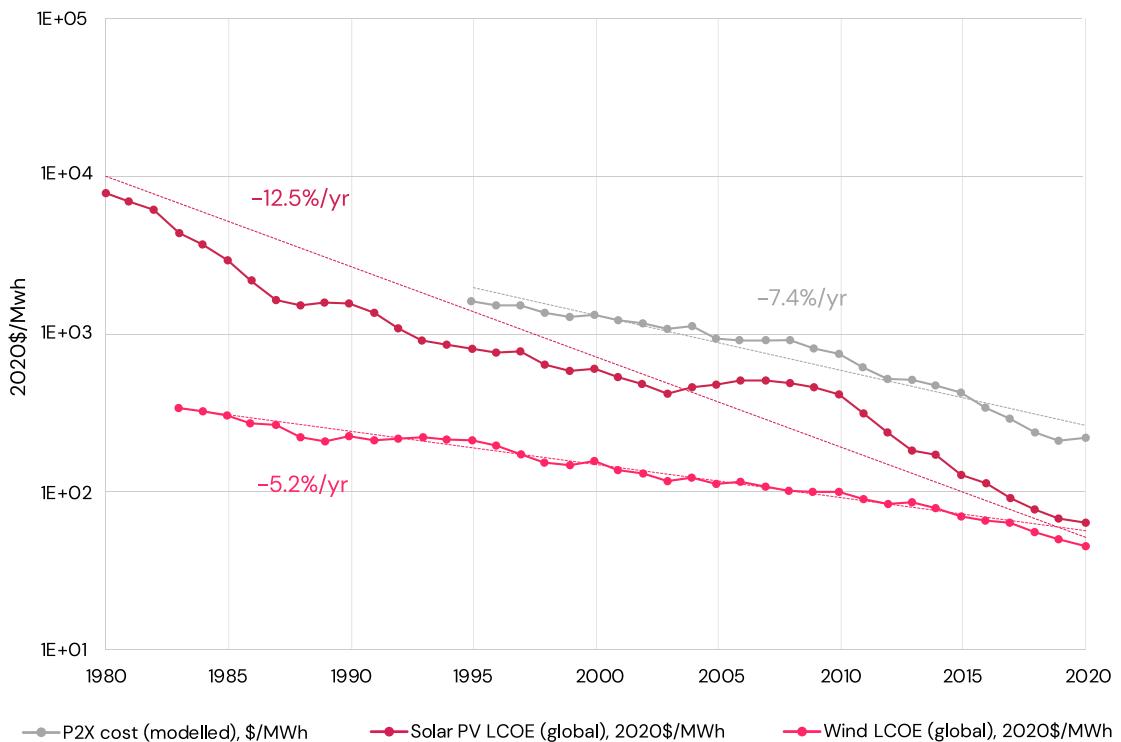


Figure 7: Historical reduction of costs in \$/MWh of useful energy for solar PV, wind and P2X²⁴

F. Power-to-X designate technologies that convert electricity into low-carbon fuels such as hydrogen, synthetic fuels, chemicals...

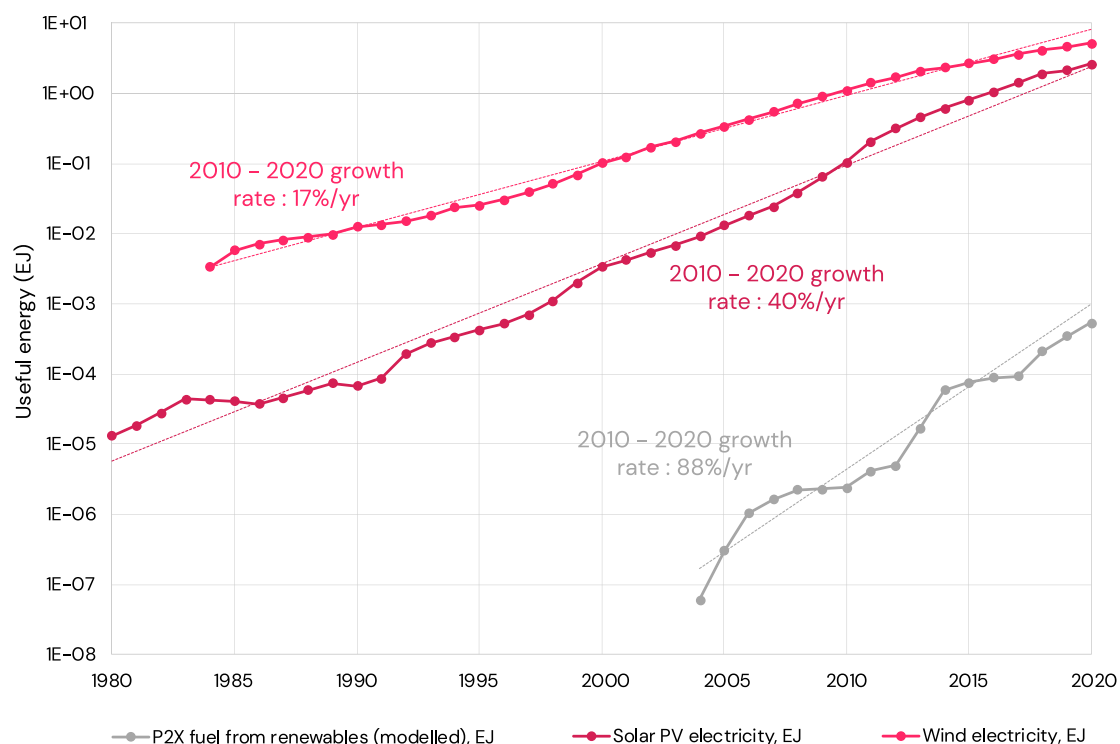


Figure 8 : Historical growth in useful energy production from solar PV, wind and P2X²⁴

Hence, the useful energy^F produced and the installed capacity seem to follow a **similar or even greater growth than solar**. However in terms of costs reductions, electrolyzers are slightly faster than wind but still slower than solar, thus questioning if they could indeed experience the same adoption rates as solar power.

Nevertheless, to reach 100 GW by 2030, the electrolysis industry would have to outpace the best photovoltaic growth rates ever achieved.

Using the IEA Hydrogen projects database, we find that 640 MW of electrolyser capacity were expected to be operational by the end of 2022⁷. As this estimated capacity is similar to the 2003 EU solar PV capacity, it is an interesting proxy to estimate the electrolyser capacity in 2030. During the 8 years from 2003 to 2011, solar PV grew most rapidly in Europe, starting at ~600 MW with an **average growth rate of 76%**¹⁰. During its best 3 years, growth rates for solar PV electricity generation in Europe reached on average 98%, compared to 68% for the best 3 years for nuclear power generation in France²⁵. To put matters into perspective, the nuclear power deployment in France is often considered as “the most successful scaling up of a complex and capital-intensive energy technology system in the recent history of industrialised countries”²⁶.

It is interesting to compare these growth rates with those needed for electrolyzers to reach the 100 GW/10 Mt targets in 2030. As the EU considers that 100 GW of electrolyzers will be enough to produce 10 Mt of hydrogen annually, we apply a 1/10 factor to obtain the projections for the production through 2030:

G. Useful energy is last step of the energy system. Useful energy provides the energy service required by the consumer. End-uses technologies such as motors, heaters, A/C... convert final energy (natural gas, electricity...) into the desired useful energy (heat, drive power...).

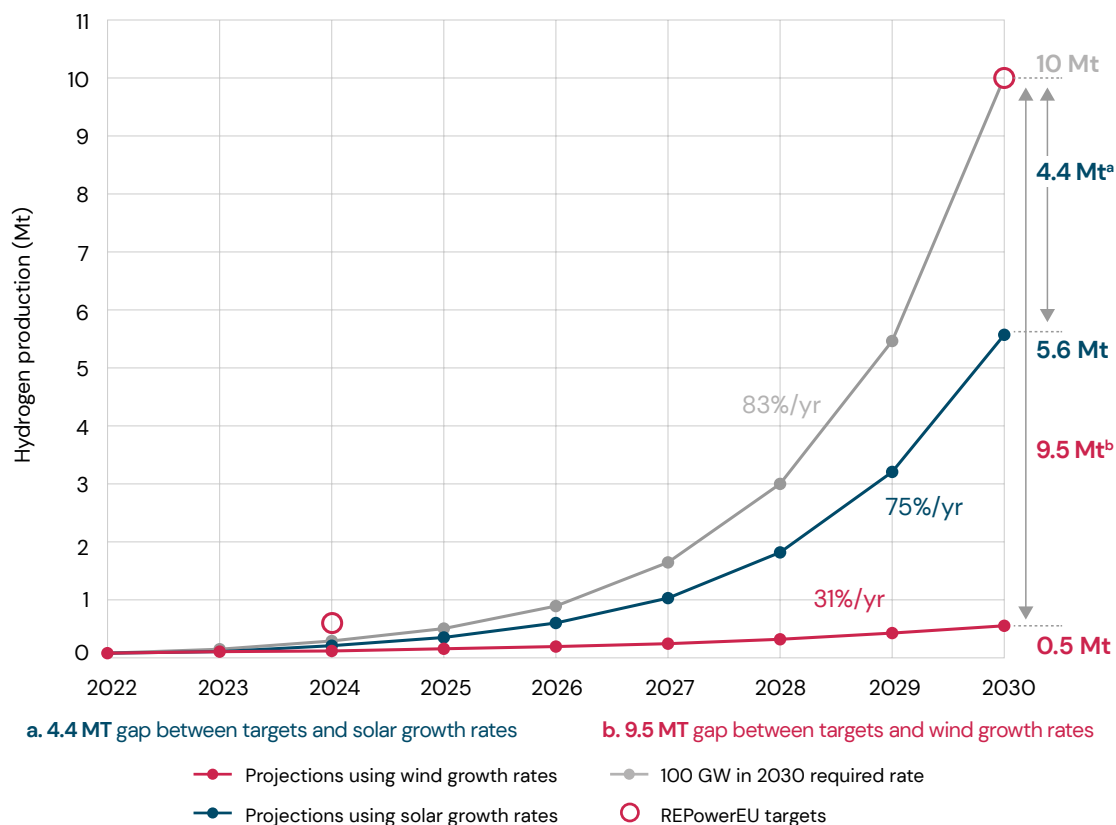


Figure 9: Comparison between projections for renewable hydrogen production using solar PV or wind growth rates and the required rate to reach REPowerEU target of 10 Mt in 2030

Should electrolyser capacities follow the same growth as solar PV in Europe during its 8 consecutive most successful years, renewable hydrogen production would reach around **~5.6 Mt by 2030, which is 4.4 Mt short of the REPowerEU target of 10 Mt**. Taking a growth rate similar to the one of wind, the gap would be even wider as only 0.5 Mt would be produced in 2030. Hence, in order to meet the targets in terms of renewable hydrogen production, electrolyser capacity growth rates would have to be **greater than those of solar during its eight best consecutive years**.

Considering that renewable hydrogen produced by water electrolysis is expected to provide for most of the EU future demand, scaling up electrolysers as well as renewable electricity capacity will require **unprecedented efforts**. Fortunately, other low-carbon hydrogen production technologies could be considered in addition to fill the remaining gap in case electrolysers and renewables deployment is slower than expected.

NATURAL GAS WITH CARBON CAPTURE (NG + CCUS): A COMPLEMENTARY (BUT LIMITED) SOLUTION

NG+CCUS is the most mature technology to complete the development of renewable hydrogen production in the short to medium term, but it relies on more gas consumption.

Looking at Technology Readiness Levels (TRL), the **current most mature technologies** are thermochemical processes with carbon capture (NG+CCUS), dark fermentation and plasma pyrolysis.

Although **dark fermentation** has some advantages (use of waste as a feedstock, simple design of reactors, low energy needs...) it still suffers from **low process efficiency and yield** compared to biomass pyrolysis or gasification and it also generates CO₂ emissions reaching up to 8.6 kg CO₂/kg H₂ depending on the feedstock²⁹.

Plasma pyrolysis also has clear advantages (valuable co-product, high efficiency, low to negative CO₂ emissions...) but has **only been demonstrated at commercial scale by one company** in the US (Monolith) for which hydrogen is not their main product. In Europe, there are only companies focused on the technology-as-a-product (TRL 3 to 8) and not hydrogen-as-a-product, thus no commercial project has been announced for the moment.

Natural gas processes such as steam methane reforming (SMR) or autothermal reforming (ATR) combined with carbon capture are the only other low-carbon hydrogen production technologies that are mature enough to produce significant quantities by 2030. Also, carbon capture applied to SMR and ATR has the advantage of relying on existing production facilities with production patterns adapted to consumers (e.g. uninterrupted hydrogen supply). Biomass gasification is also mature but is likely to remain marginal due to potential conflicts of use around the limited resource (biofuels, bioenergy...). Other fossil fuel-based hydrogen production routes are not being considered as they constitute a very limited share of the current hydrogen production in Europe and/or cannot reach a carbon intensity lower than the level imposed by the latest delegated acts and thus be qualified as low-carbon.

Construction of a CCUS facility of the hydrogen production unit at Preem oil refinery in Sweden (courtesy of Aker solutions)



Moreover, producing hydrogen from natural gas with carbon capture also means consuming more natural gas while REPowerEU's aim is also to reduce the EU fossil fuel dependence to Russia. On average, adding a carbon capture unit to a SMR plant reduces its overall efficiency by 5% to 14%, **increasing natural gas consumption by 3% considering 56% capture rates, and by 10% considering 90% capture rates**^{27 28}. To provide an order of magnitude, producing 10 Mt of hydrogen with this technology would consume 50 bcm of natural gas, that is about 12% of the EU natural gas demand in 2021 (421 bcm)³⁰. This is in contradiction with the EU directive requesting that natural gas demand should be reduced by 141 bcm (or 33%) by 2030 compared to 2021⁶. Having said that, **this technology shouldn't drive an important increase in natural gas consumption as no new SMR or ATR facility is expected to be built**. Moreover, by progressively replacing some of the natural gas by biogas, it is expected to decrease and bring down the emissions of the hydrogen production.

Considering typical construction duration, new NG+CCUS hydrogen production projects could only account for 600 kt of hydrogen production by 2030.

Based on the 2022 IEA Global hydrogen projects database, **14 NG + CCUS hydrogen production projects have been announced in EU member countries**⁷. Among them, only 6 projects defined an operation starting date and a projected hydrogen production (excluding ammonia) representing **less than 600 kt of hydrogen produced by 2030** (cf. Figure 10). The carbon capture rate for all these facilities is at least 84% (H2morrow project), thus qualifying for low-carbon hydrogen as it is better than the threshold imposed by the EU, except for the Port Jerome project in France which has been operating since 2015 (23% capture rate). Moreover, being all at the feasibility study or concept stage, **none of these projects have reached a final investment decision yet**, questioning the number of projects that will effectively come to operation.

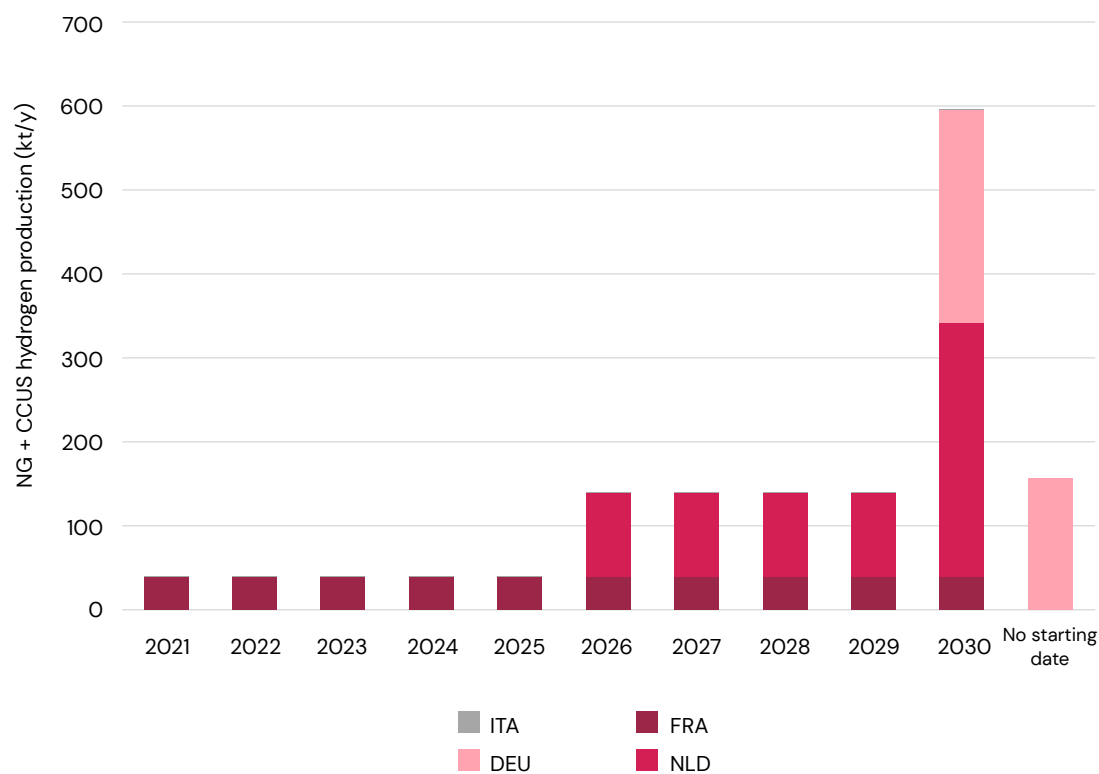


Figure 10: Announced hydrogen production from natural gas with CCUS projects⁷. Status of projects given as of 2022

H. When taking into account FF55 proposals, higher long-term gas and oil price paths and the impact of REPowerEU measures.



The H-vision project aims to produce 300 kt of hydrogen per year by 2030 to feed the additional demand of industrial processes in the port of Rotterdam (Netherlands) using the ATR with carbon capture technology – Courtesy of TNO

Nevertheless, **more than 600kt of NG + CCUS hydrogen production could be expected by 2030.**

Firstly, **new announcements about the 14 projects registered in EU members** could refine the expected production by 2030. Indeed 9 did not specify their expected hydrogen production outputs, 8 how much CO₂ they plan to capture, and 5 other projects do not have a planned starting date yet. So, possibly the NG + CCUS hydrogen production could be more than 600 kt by 2030 and thus complete renewable hydrogen production.

Secondly, countries like Norway and the United-Kingdom which are not part of the EU, are **some of the most advanced in CCUS** thanks to political support and have recently unlocked public funding for several projects³¹. Indeed, these countries have historically benefitted from natural gas and other fossil fuels reserves from the North Sea and thus aim at **taking advantage of their existing infrastructure as well as potential CO₂ storage sites** in the North Sea. Hence, most of the low-carbon hydrogen projects using or planning to use CCUS are in these countries. This gives rise to hubs and clusters generating economies of scale, lowering costs, and reducing the commercial risks of deployment. If all the projects in the pipeline become operational (currently 14 projects in feasibility study in the pipeline), they would account for 3.1 Mt of low-carbon hydrogen production by 2030⁷.

Thirdly, **lead-time of CCUS projects should be shortened** to increase the number of operational projects by 2030. According to the CCS Institute, it currently takes on average 6–8 years for new CCUS projects to progress from concept study through feasibility, to design, construction then operation³¹. Nevertheless, a positive industrial dynamic **shortening lead times of future CCUS projects and lowering costs through economies of scale** could materialize with a greater number of projects. Such trend has yet to be observed given that the number of new operational projects has been stable over the last ten years. It seems that specific political support and appropriate regulatory framework are required to impulse such dynamic.

At the regulatory level, **high CO₂ price** would help to tip the scale in favor of investors, especially for projects which remaining lifetime of NG process is substantially longer than their payback duration. Besides, setting targets for the volume of CO₂ to be captured and defining European action plans could provide industrials with more visibility.

While such targets have not been set yet, the **EU innovation fund** has started to provide financial support to CCUS solutions: 2 projects targeting hydrogen production with CCUS and 4 projects focusing on CCUS out of a total of 65 eligible projects were selected in 2021 for a subsidy during the expression of interest for large-scale projects, which is encouraging for industrials³¹. Moreover, 2 other expressions of interest for large-scale projects and small-scale projects have been made in 2022, which could again provide subsidies to other CCUS projects.

Last challenge to face to increase the number of NG+CCUS hydrogen production is to increase the **"survival rate" of CCUS projects**. Over the last decade, the overall trend has been a **decline in the size of the project pipeline**, with only three projects per year and 37% of projects still in the pipeline in 2020. But this has been **improving over time**, as projects announced since 2010 have a higher survival rate than those already in development at the start of the period (59% and 21% respectively). Between 2018 and 2020, the number of projects announced also exceeded the number of projects exiting the pipeline. Projects are also **more likely to survive when in their construction phase** (80% remain in the pipeline) compared to their development phase (37% survival rate)³¹.

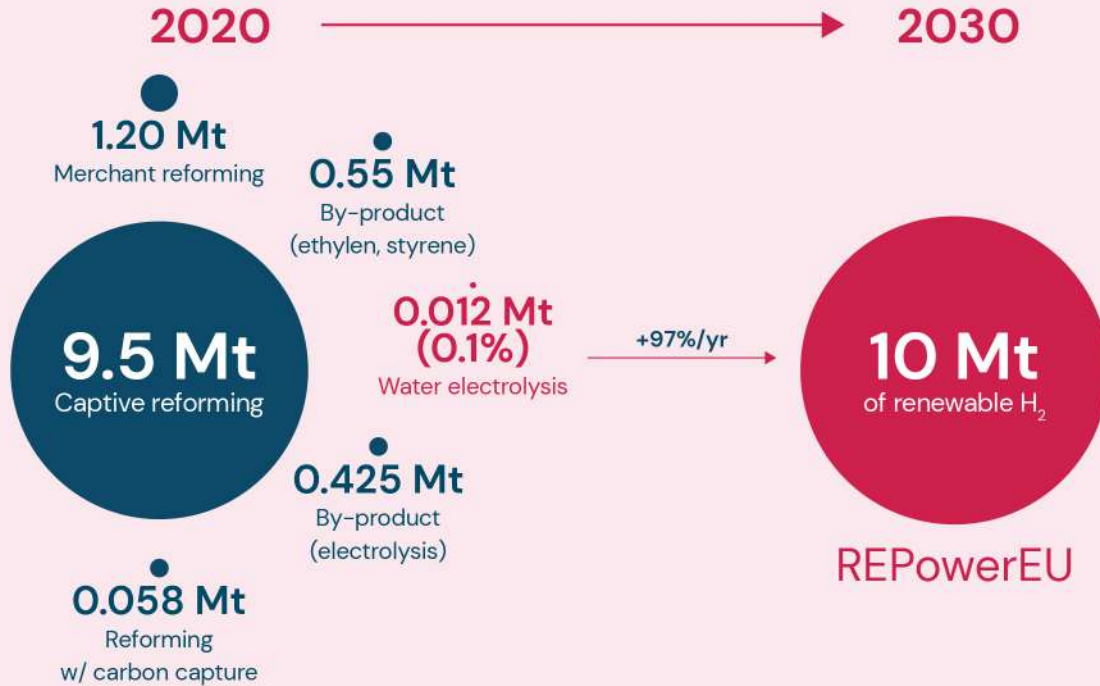


Neste's Porvoo refinery in Finland, where the SHARC project funded by the EU Innovation fund and aiming to produce hydrogen from natural gas with CCUS (along renewable hydrogen from water electrolysis) will be built (courtesy of Jobsite)

Hence, it is still uncertain whether all the projects announced will indeed materialise and if other projects not yet unveiled today could become operational before 2030. Political and industrial support for the NG+CCUS technology need to gain traction in the coming months to enable significant share in low-carbon hydrogen production by 2030.

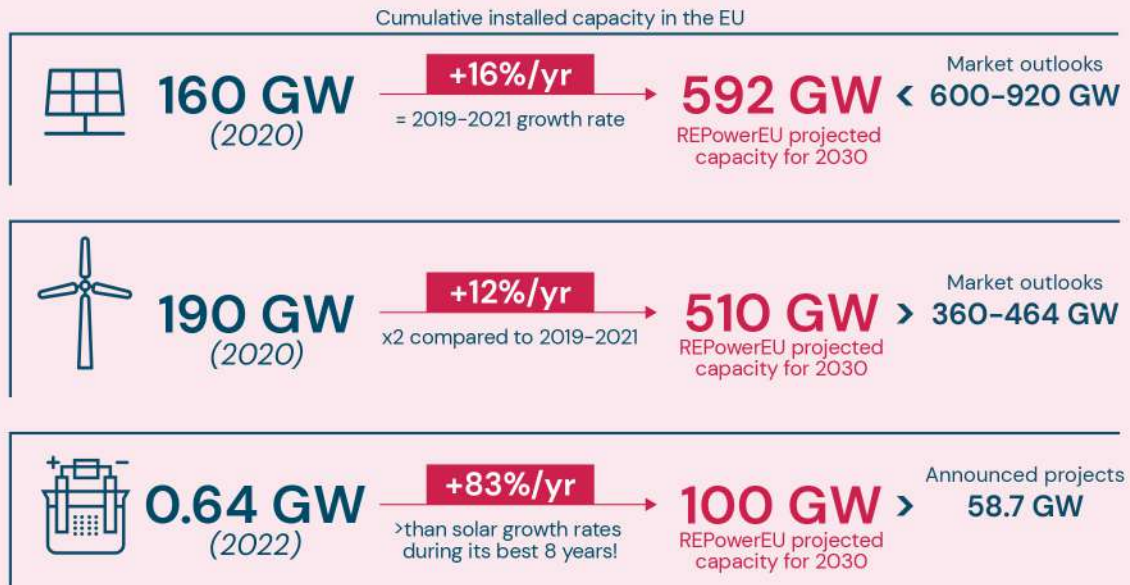
THE HYDROGEN SERIES – PART 2 VISUAL SUMMARY

HYDROGEN PRODUCTION CAPACITY



The EU is very ambitious on renewable hydrogen: water electrolysis capacity would need to double every year to reach REPowerEU targets of 10 Mt in 2030. But important Projects of Common European Interest (IPCEI) dedicated to the development of hydrogen value chains could help the technology take off, as 449 out of 490 projects (H₂ production) concerned by these IPCEI are based on electrolysis.

RENEWABLE ELECTRICITY AND ELECTROLYSERS



NATURAL GAS WITH CARBON CAPTURE IN THE EU 27



Low-carbon hydrogen production from natural gas with carbon capture would need more support to play a significant role as it currently faces many barriers: uncertainty of current projects, 6-8 years from concept to operation, low survival rate...

CONCLUSION

1

There is no debate on the fact that **low-carbon hydrogen will be key to reach net-zero**. First, it is necessary to decarbonize the current demand (8.7 Mt in 2020). And thereafter, it can be a vector for other sectors where emissions are hard to abate or where there is no other alternative (at least in the short to medium term) like the steel industry. Producing large quantities of low-carbon hydrogen will **reduce its production costs** and will also **trigger the development of end-use technologies** based on hydrogen, thus increasing the emission reduction potential of the molecule. But in the short to medium term, reaching a sufficient renewable hydrogen production to meet the highly ambitious REPowerEU targets will prove to be challenging.

2

The targets set by REPowerEU on hydrogen are **highly ambitious** and will undoubtedly call for a strong acceleration in the deployment of new renewable electricity capacity. Current growth rates will have to be **sustained or even surpassed until 2030**, and electrolysers growth rates will need to be greater than those of solar during best 8 years of growth in Europe.

3

Considering that neither hydrogen production from electrolysis nor via NG + CCUS are likely to be sufficient on their own to meet the targets by 2030, the **low-carbon hydrogen production in 2030 should come from a combination of both technologies**. Completing renewable hydrogen with NG + CCUS would release the pressure on new renewable electricity capacity, at least in the short to medium term where it is likely to be scarce. But for this to happen, NG+CCUS need more financing and should be included in national and European strategies so industrial companies can have a solid regulatory framework to develop new projects.

4

Beyond these considerations, is the switch to low-carbon hydrogen economically viable? And if not, when will it be in the future and what are the enabling factors that could change the paradigm? These aspects will be covered in the third and last report of our hydrogen series.

BIBLIOGRAPHY

- 1 Commission sets out rules for renewable hydrogen. European Commission – European Commission https://ec.europa.eu/commission/presscorner/detail/en/ip_23_594.
- 2 GlobalHydrogenReview2022–Analysis.IEA<https://www.iea.org/reports/global-hydrogen-review-2022>.
- 3 Europe, H. Hydrogen Europe. Hydrogen Europe <https://hydrogeneurope.eu/clean-hydrogen-monitor2022/> (2022).
- 4 Powering a climate-neutral economy. European Commission – European Commission https://ec.europa.eu/commission/presscorner/detail/en/ip_20_1259.
- 5 REPowerEU. European Commission – European Commission https://ec.europa.eu/commission/presscorner/detail/en/IP_22_3131.
- 6 State Aid. European Commission – European Commission https://ec.europa.eu/commission/presscorner/detail/en/ip_22_5676.
- 7 Hydrogen Projects Database – Data product. IEA <https://www.iea.org/data-and-statistics/data-product/hydrogen-projects-database>.
- 8 RED non-paper additional modelling (20/06/2022) https://energy.ec.europa.eu/system/files/2022-06/2022_06_20%20RED%20non-paper%20additional%20modelling.pdf
- 9 Fit for 55 – The EU’s plan for a green transition – Consilium. <https://www.consilium.europa.eu/en/policies/green-deal/fit-for-55-the-eu-plan-for-a-green-transition/>.
- 10 Renewables Data Explorer – Data Tools – IEA. <https://www.iea.org/data-and-statistics/data-tools/renewables-data-explorer>.
- 11 Fit for the future, not Fit-for-55. Ember <https://ember-climate.org/insights/research/fit-for-the-future-not-fit-for-55/> (2023).
- 12 EU Market Outlook for Solar Power 2022–2026 – SolarPower Europe. <https://www.solarpowereurope.org/insights/market-outlooks/eu-market-outlook-for-solar-power-2022-2026-2>.
- 13 Renewable electricity – Renewables 2022 – Analysis. IEA <https://www.iea.org/reports/renewables-2022/renewable-electricity>.
- 14 Wind energy in Europe, Scenarios for 2030. WindEurope <https://windeurope.org/about-wind/reports/wind-energy-in-europe-scenarios-for-2030/> (2017).
- 15 Dixon–Declève, S. It takes longer to permit a wind farm than to build it. www.euractiv.com <https://www.euractiv.com/section/energy-environment/opinion/it-takes-longer-to-permit-a-wind-farm-than-to-build-it/> (2023).
- 16 Enabling framework for renewables. https://energy.ec.europa.eu/topics/renewable-energy/enabling-framework-renewables_en.
- 17 Is the European Union on track to meet its REPowerEU goals? – Analysis. IEA <https://www.iea.org/reports/is-the-european-union-on-track-to-meet-its-repowereu-goals>.
- 18 Greenhouse gas emission intensity of electricity generation – European Environment Agency. https://www.eea.europa.eu/data-and-maps/daviz/co2-emission-intensity-12/#tab-googlechartid_chart_11
- 19 Schmidt, J., Regner, P., Turkovska, O. & Wehrle, S. The European green hydrogen strategy risks increasing CO2 emissions globally. Preprint at <https://doi.org/10.31224/2834> (2023).
- 20 Liebreich: The Unbearable Lightness of Hydrogen. BloombergNEF <https://about.bnef.com/blog/liebreich-the-unbearable-lightness-of-hydrogen/> (2022).
- 21 HyDeal Ambition. <https://www.hydeal.com/hydeal-ambition>.
- 22 Malhotra, A. & Schmidt, T. S. Accelerating Low-Carbon Innovation. *Joule* 4, 2259–2267 (2020).
- 23 Odenweller, A., Ueckerdt, F., Nemet, G. F., Jensterle, M. & Luderer, G. Probabilistic feasibility space of scaling up green hydrogen supply. *Nat Energy* 7, 854–865 (2022).
- 24 Rupert Way et al. (2022) Empirically grounded technology forecasts and the energy transition: *Joule*. <https://doi.org/10.1016/j.joule.2022.08.009>.
- 25 Statistical Review of World Energy | Energy economics | Home. bp global <https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html>.
- 26 Energy Technology Innovation: Learning from Historical Successes and Failures. (Cambridge University Press, 2013). doi:10.1017/CBO9781139150880.
- 27 Hermesmann, M. & Müller, T. E. Green, Turquoise, Blue, or Grey? Environmentally friendly Hydrogen Production in Transforming Energy Systems. *Progress in Energy and Combustion Science* 90, 100996 (2022).
- 28 IEAGHG Document Manager. IEAGHG Document Manager <http://documents.ieaghg.org/index.php/s/HKtMncfw2vaBxl>.
- 29 Lee, K. The Potential Role of Biohydrogen in Creating a Net-Zero World. Center on Global Energy Policy at Columbia University | SIPA <https://www.energy-policy.columbia.edu/publications/the-potential-role-of-biohydrogen-in-creating-a-net-zero-world/> (2023).
- 30 World Energy Outlook 2022 – Analysis. IEA <https://www.iea.org/reports/world-energy-outlook-2022>.
- 31 Scaling up the CCS Market to Deliver Net-Zero Emissions. Global CCS Institute <https://www.globalccsinstitute.com/resources/publications-reports-research/scaling-up-the-ccs-market-to-deliver-net-zero-emissions/>.



AUTHORS

Zenon Research
Mines Paris PSL, IHEIE

- Thomas Boigontier
- Greg De Temmerman
- Robin Girard

Archery Strategy Consulting

- Julien Lamarque-Lacoste
- Manon de la Motte Saint Pierre
- Anouck Dubois

This note should be cited as:

Zenon Research, Archery Strategy Consulting (2023),
Low-carbon hydrogen production in the EU: are 2030
targets achievable?

ARCHERY
STRATEGY CONSULTING

www.zenon.ngo
www.archeryconsulting.com



© Voestalpine AG