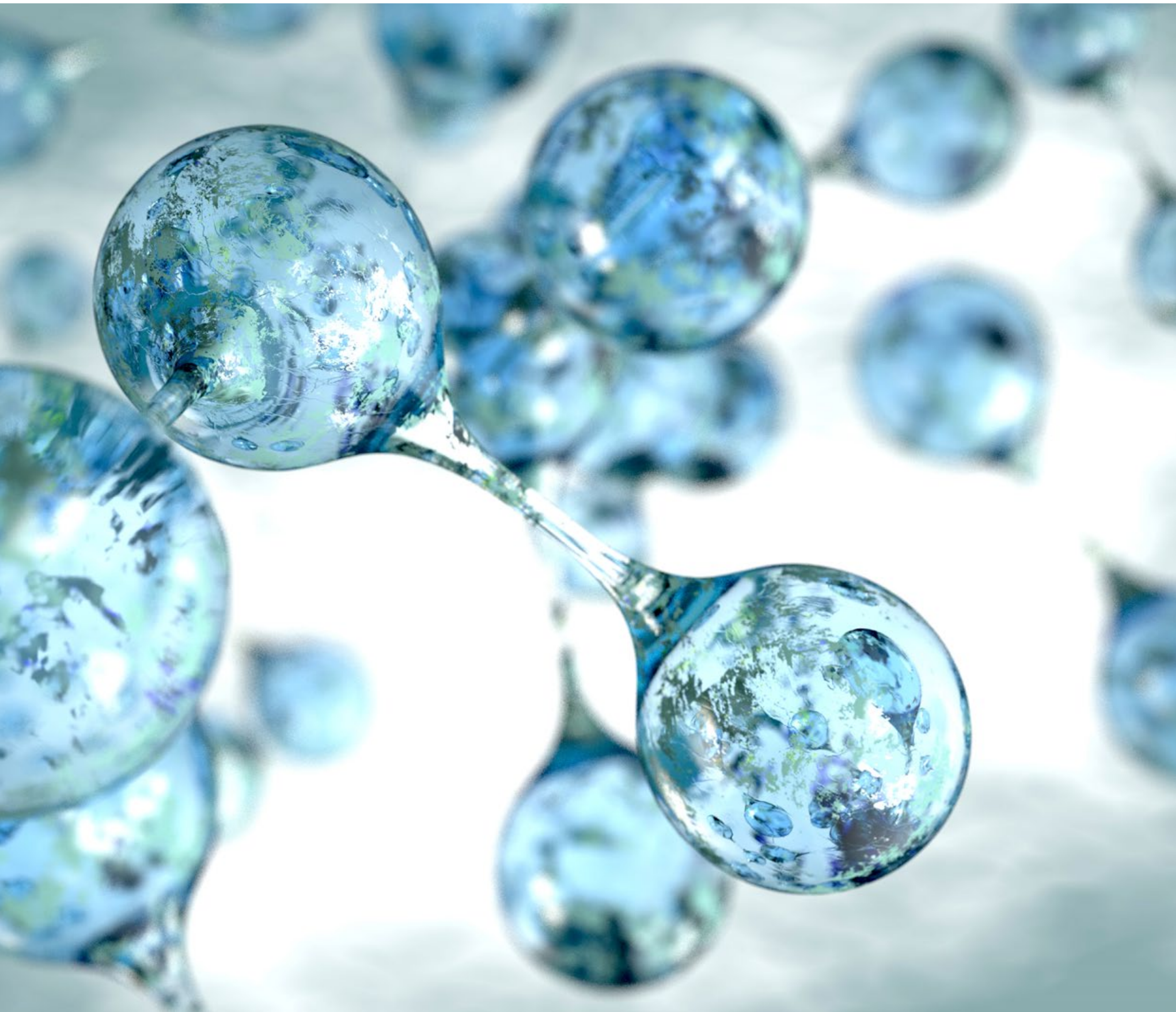
HYDROGEN AND RENEWABLE ENERGIES – THE KEY TO NET ZERO?



Abstract

Hydrogen is becoming a beacon of hope for economies striving for emission neutrality in the fight against climate change. Hydrogen offers the technological prerequisites to avoid emissions from sectors that are difficult to electrify and to enable the storage of fluctuating renewable electricity production. However, the economic viability of such applications and the investments required for them are still at the centre of the debate. In order to protect the climate effectively on a global level, it is essential to focus on cost efficiency, as the pursuit of prosperity is dynamically increasing global energy demand.

This paper therefore highlights the synergies and technological advantages of hydrogen. On the other hand, the economic viability of green hydrogen compared to fossil alternatives is examined under real conditions. The aim is to identify the hurdles in the existing environment and to develop specific options for overcoming them.

Analogous to the development in the renewable energy production sector, additional incentives are needed to move from technological maturity to market maturity and competitiveness. Whilst the focus is on the high energy demand for hydrogen production and the associated need to expand renewable energies, there are conflicting goals depending on the price of electricity that are difficult to overcome. High electricity prices create incentives to expand renewable generation capacities, but at the same time limit the economic viability of the production of green hydrogen, which is just as necessary to compensate for fluctuating generation.

However, there are possibilities to create a basis through technological progress and the use of economies of scale. The scenarios presented in this paper show the current situation and consider possible developments based on changing framework conditions.

Achieving green hydrogen competitiveness can mark a turning point in bringing the energy transition increasingly in line with reality.

Drawing on Aquila Capital's expertise in renewables and the energy markets, we will present a comprehensive and especially reality-based insight and outlook on the development of a European hydrogen economy.

Author:

Peter Schnellhammer
Investment Research Analyst
peter.schnellhammer@aquila-capital.com

Peter Schnellhammer is Investment Research Analyst at Aquila Capital. He has more than 6 years experience in Strategic Research and Alternative Investments. Prior to joining Aquila Capital in 2019, he focused on macroeconomic research of Real Estate markets. Peter Schnellhammer holds a master's degree in Economics from University Rostock.

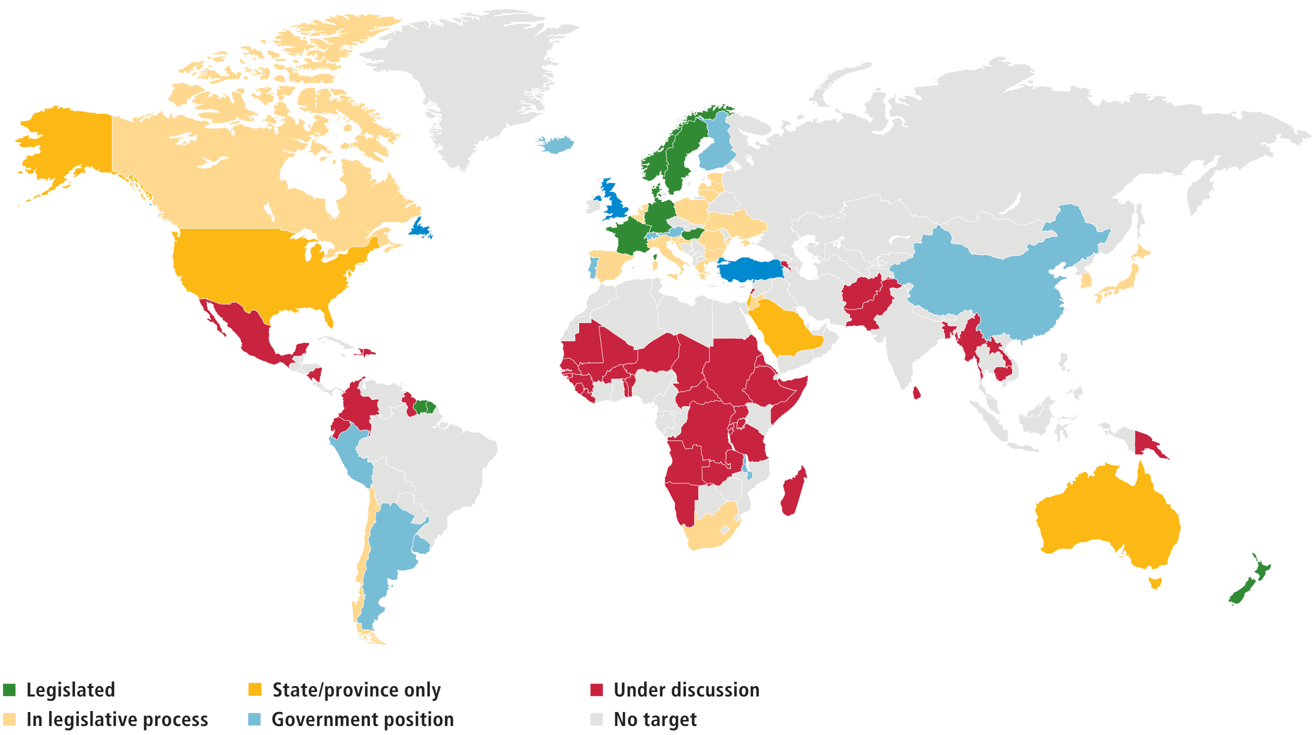
CONTENT

1. **Hydrogen – The Missing Link on the Road to Net Zero?** . . . p. 3
2. **Renewable energies – cornerstone of the energy transition** p. 6
3. **Technological readiness of hydrogen production** . . . . . . p. 8
4. **Green hydrogen – utopia or the future a scenario analysis** p. 9
4.1 Baseline scenario . . . . p. 9
4.2 Changing framework conditions. . . . . p. 10
4.3 Outlook . . . . p. 14
a) Baseline scenario Germany 2030
b) Hydrogen production Spain 2030
5. **Conclusion**. . . . . p. 16

1. Hydrogen – The Missing Link on the Road to Net Zero?

As global warming progresses, climate policy aspects are moving into the focus of global debates. Regulations as well as targets have been increasing since the Paris Agreement, but actual realisation still seems a long way off. Whilst more and more countries are declaring emissions neutrality as a goal, there are still numerous hurdles to overcome on this path. The technical prerequisites are there, but the technology maturity does not correspond to the stage of market readiness. Innovations and new concepts need to be developed to produce effective models that are economically attractive at the global level.

Figure 1: Intentions on emissions neutrality grow globally[1]

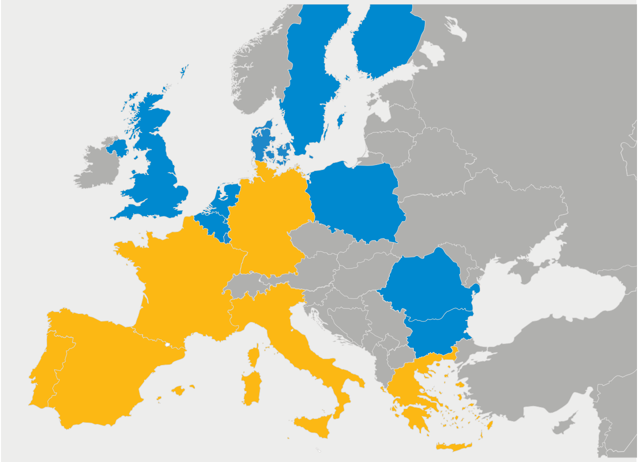


The first step has been taken. The global energy demand can be covered cost-effectively by renewable energies. Compared to conventional fossil thermal power plants, renewable technologies, especially wind and solar PV, show impressive competitiveness. Whilst grid parity has already been significantly exceeded, an increasing number of countries have an environment where the total cost of new wind and/or solar PV capacity is below the running costs of existing gas or coal-fired power plants.

[1] *BNEF (2021)*

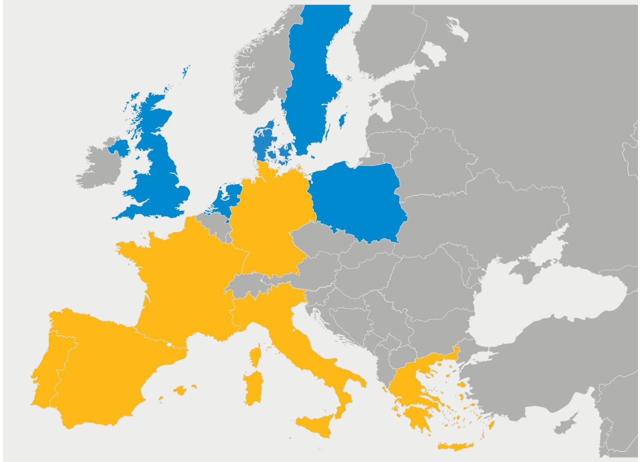
Figure 2: Tipping points from a competition perspective[2]

Inflection Point 1 – Renewables are the cheapest source of new generation capacity



Countries where wind and solar PV LCOE* < gas, coal LCOE

Inflection Point 2 – New renewable capacity is cheaper to install and operate to the running costs of existing fossil fuel plants



Countries where wind and solar PV LCOE is < operating costs of existing gas and coal plants**

■ **Wind** ■ **Solar PV**

**Levelized costs of energy, which represents the total cost of new generation capacity (including construction), divided by the total energy expected to be generated over the lifetime (in EUR/MWh).*

***Refers only to operating costs (e.g. fuel, EUAs) of an already existing plant and are thus significantly below the LCOEs of this plant type.*

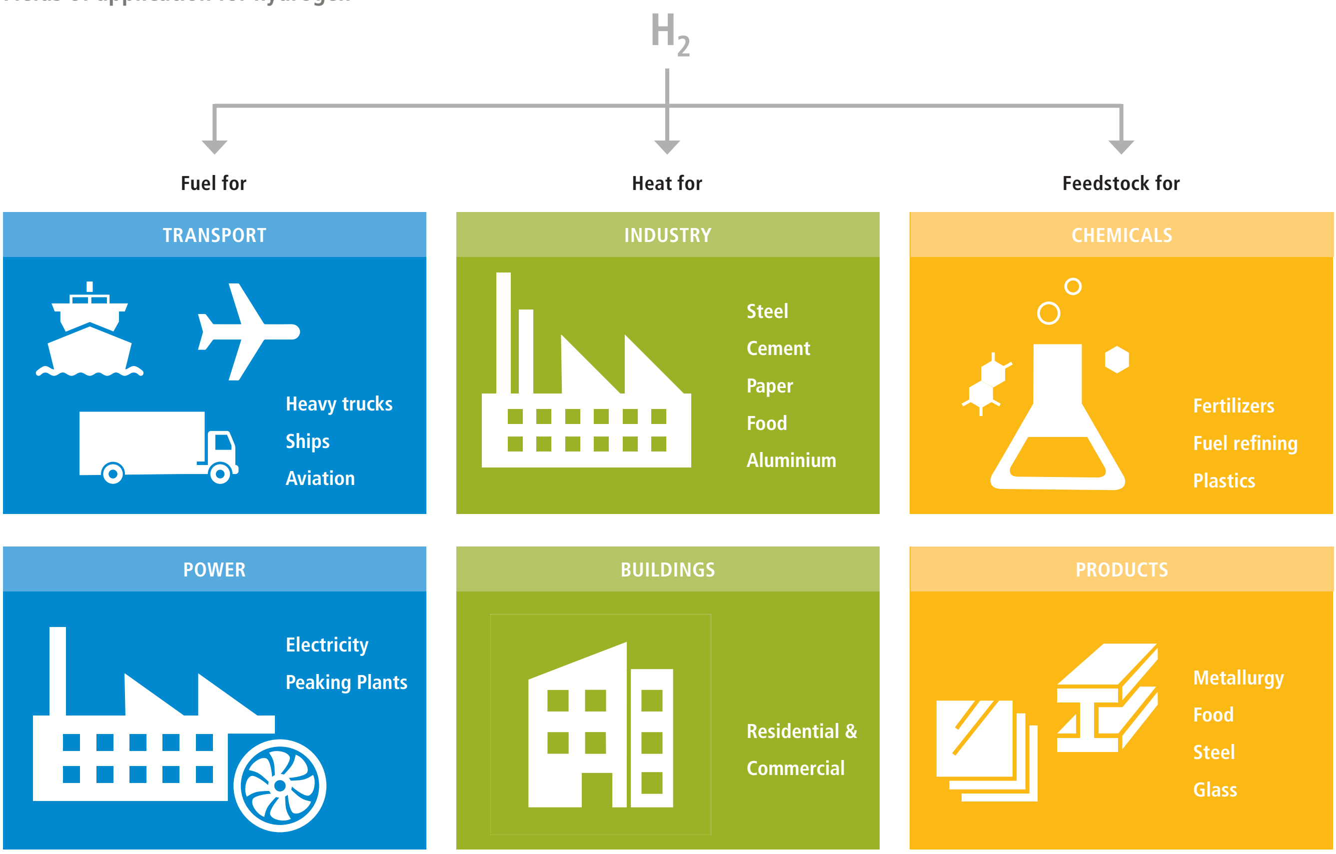
But further measures are needed to build on this development. The complexity of energy systems is both an opportunity and a challenge. Although there are numerous adjusting screws whose efficient networking offers opportunities, the complexity must be managed. In addition, solutions must guarantee energy security and also ensure affordability. The global problem of climate change can only be tackled if appropriate technologies are brought to market maturity and analogous to the development of renewable technologies, their economic viability is also proven in regions and countries with lower incomes.

Despite the possibilities available to electrify increasing sectors via renewable energies (sector coupling), to generate further progress in energy efficiency and to improve the flexibility of supply and demand with the help of digital technologies, further steps must be taken on the path to emissions neutrality. On the one hand, solutions for storage - beyond short-term battery options and limited pumped storage capacities - must be found. Secondly, there remain sectors that cannot be decarbonised through electrification.

Just looking at global energy consumption confirms the importance of a green molecule to sustainably limit emissions and, in particular, to accelerate the energy transition. The energy carrier hydrogen has properties that meet these requirements. Hydrogen produced from natural gas is already an important raw material whose demand is still largely determined by the chemical industry. However, it is technically possible to reorganise sectors that are difficult to decarbonise in a sustainable and emission-neutral way using hydrogen-based processes. In addition to replacing existing applications, steel production is one example where only indirect electrification with hydrogen can replace fossil fuels.

[2] *BNEF (2021)*

Fields of application for hydrogen



The technical feasibility, but also a global sales market for innovations, provide incentives for countries to achieve positive impulses for economic development and for combating climate change.

Figure 4: Coverage of the global economic volume with climate regulations[3]

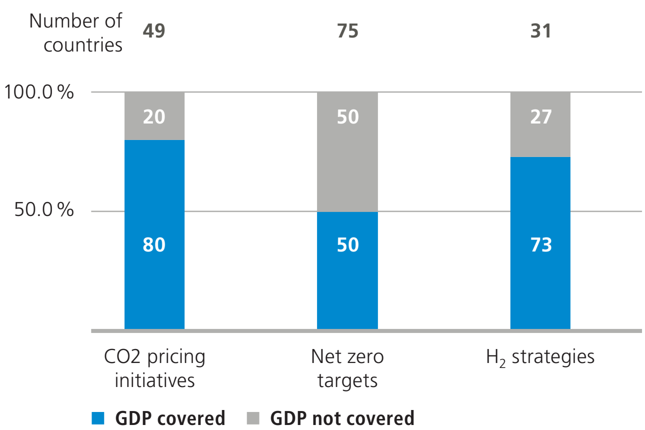


Figure 4 illustrates the high expectations for hydrogen strategies. Countries that are responsible for 73 % of the global economic volume have developed corresponding strategies.

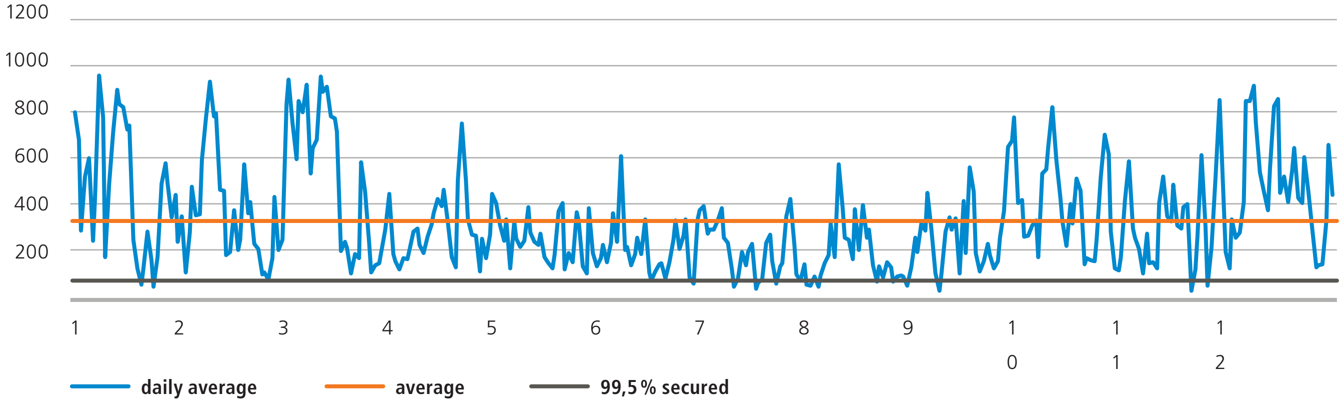
But the use of emission-free hydrogen applications requires the energy-intensive production to be covered by renewable energies. The resulting enormous energy demand must be accompanied by a significantly accelerated expansion of renewable capacities, but in return offers significantly positive interactions with the generation sector.

[3] *McKinsey (2021)*

2. Renewable energies – cornerstone of the energy transition

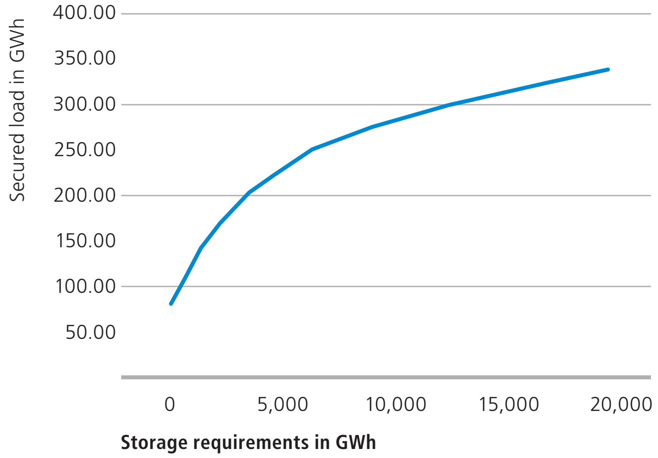
Wind power and solar PV are the basic pillars of the energy transition. The resource-conserving and, in particular, emission-neutral generation of electrical energy is indispensable for the modern world. The successful path from technology maturity to market maturity - characterised by innovations and economies of scale – offers a cost-effective option for sustainable energy systems today in an environment of strongly rising global energy demand. But everything good has its downsides. Due to the dependence on weather influences that cannot be influenced, energy generation fluctuates.

Figure 5: Wind power generation in Germany 2019 (in GWh) [4]



Lack of controllability of production is a problem for base load supply. Figure 5 illustrates that only a fraction of the energy produced can be considered secure over the year. Whilst a mix of technologies, more efficient use, smart grids as well as the integration of the European energy market improve these framework conditions, storage solutions are still needed to make the supply more flexible.

Figure 6: Secured power as a function of storage capacity (wind generation Germany) [5]



The higher the secured output approaches the annual average, the more storage capacities are needed. Thus, the base load supply can only be fully covered by renewable energies if sufficient storage solutions are available, depending on the natural resources and the generation mix of a region. With the increase in renewable generation capacities, a constant oversupply or undersupply dominates the energy system from a certain level onwards. This development also poses challenges to the efficiency of the energy market and in some cases keeps the need for subsidies at a high level despite the cost efficiency.

[4] Aquila Capital Research based on data from ENTSO-E (2021)
[5] Aquila Capital Research based on data from ENTSO-E (2021)

Figure 7: Wind and solar production and corresponding hourly prices on the electricity exchange in Germany in MWh[6]

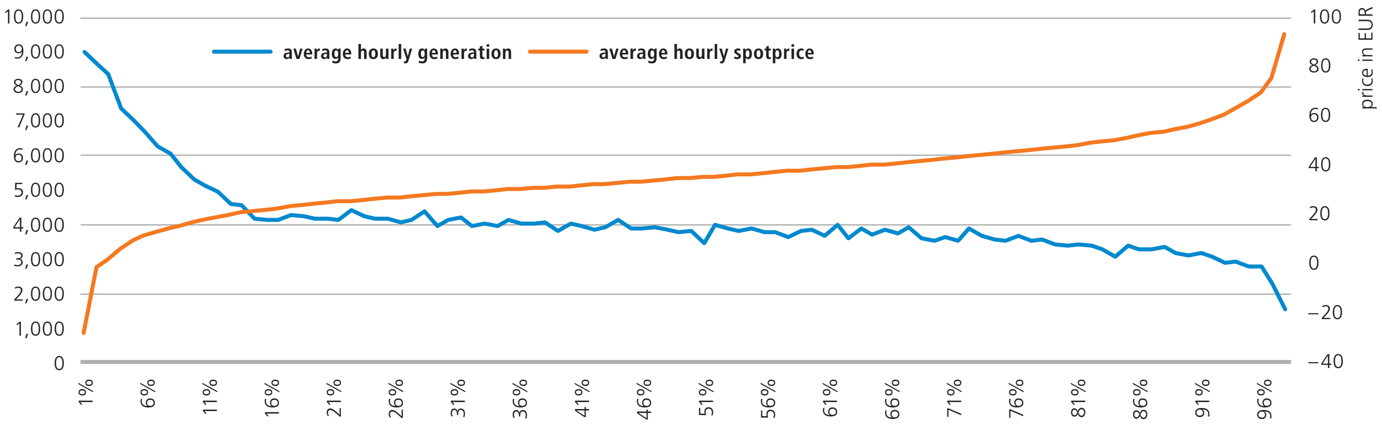
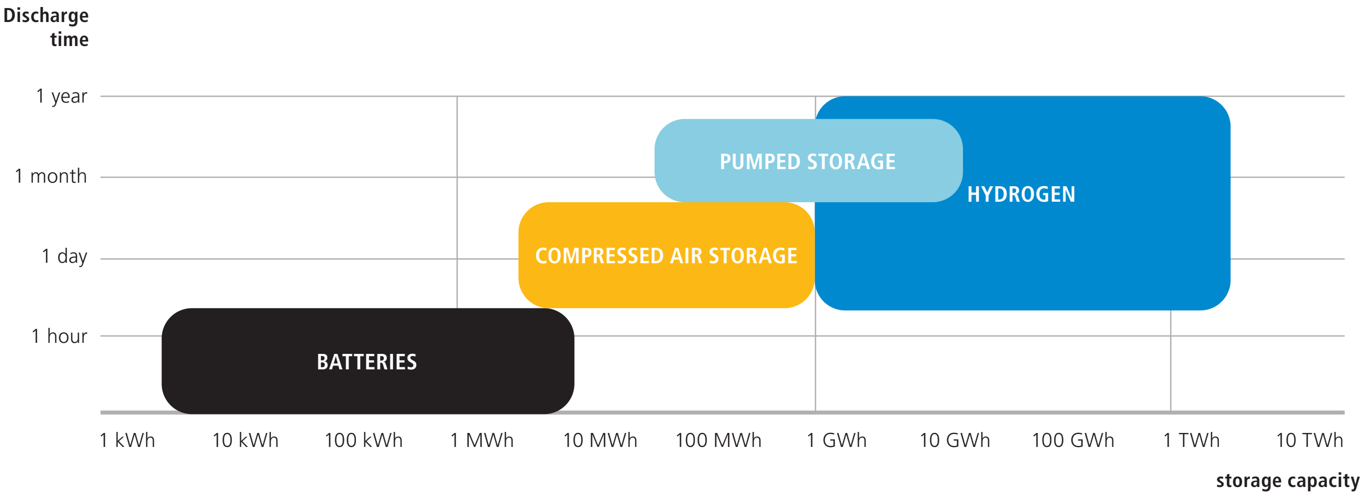


Figure 7 illustrates the relationship between supply and demand. Due to the change between oversupply and undersupply, the volatility of electricity prices increases with the expansion of renewable energies. This correlation illustrates the imperative need for storage solutions, but also offers potential, as will be shown in the following (from Chapter 4). Price forecasts by Bloomberg New Energy Finance for the United Kingdom, for example, show that electricity prices will fall as a result of the massive expansion of offshore capacities and will only pick up again with the growth of hydrogen production, thus supporting the expansion.

In terms of storage solutions, too, it will not be one technology alone; rather, a mix of technologies will produce the most efficient alternative in this area. Hydrogen offers particular advantages in this context.

Storage technologies by capacity and discharge period[7]



Whilst batteries provide short-term power to stabilise the grids, there is an increasing need for long-term options that can compensate for longer, e.g. seasonal fluctuations. Pumped storage power plants are an efficient option, but their expansion possibilities are strictly limited depending on the natural conditions. The energy carrier hydrogen, on the other hand, is a long-term option that has enormous advantages, especially with regard to the amount of land required.

[6] *ENTSO-E (2021)*
[7] *Wood Mackenzie (2021)*

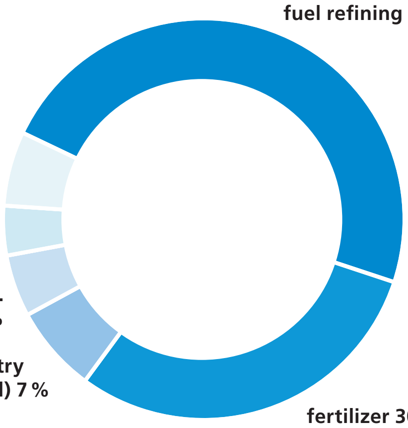
The downside is the high energy demand for production in electrolysis processes. In concrete terms, this means that the production of one kg of hydrogen (33.3 kWh/kg) requires around 51.3 kWh of electrical energy. Conversely, this means that the conversion of electrical energy into hydrogen leads to a loss of about 35 % (33.3/51.3-1) of the energy produced. Re-electrification of green hydrogen via fuel cells or gas power plants would further reduce efficiency significantly. In this context, the storage and recovery of renewable energy using hydrogen will not be the primary application for reasons of economic efficiency. The focus at present should rather be on replacing existing hydrogen production which is based on fossil processes. Otherwise unused energy, i.e. energy that is curtailed, could be used to expand sector coupling through the production of green hydrogen and help renewable generated energy gain a larger share of the market. In contrast, a parallel development of production structures and the expansion of the hydrogen economy accompanied by technological progress and economies of scale could set the course.

3. Technological readiness of hydrogen production

Hydrogen is already an important raw material that is widely used in industry. The focus here is on material applications, not energy applications.

As shown in the figure below, hydrogen is now mainly used as a feedstock and for processes in refineries (hydro-cracking and desulphurisation) and the chemical industry (fertiliser and methanol production). In total, Europe had a hydrogen demand of around 340 TWh in 2019, which corresponds to around 8.6 million tonnes.[8] The hydrogen market is dominated by grey hydrogen from fossil fuel-based steam reformation. Hydrogen from steam reformation is available on the market as a raw material, it is produced cheaply in large plants and correlates with the gas price. As an established standard for industrial production, hydrogen from steam reformation covers around 91 % of current EU demand. A share of only 2 % is accounted for by blue hydrogen using CCS[10] technologies. Around 7 % of the total hydrogen is produced as a by-product mainly in chlor-alkali electrolysers.

Figure 9: EU hydrogen demand per sector 2020[9]



BOX 1

Types of hydrogen production

- grey H_2: Steam reforming based on fossil sources (gas, coal, oil)
- blue H_2: Analogue to grey expanded to capture and store CO_2 emissions
- green H_2: Water electrolysis with renewable energy

Water electrolysis contributes only a marginal share to total European hydrogen production. Green hydrogen from water electrolysis based on renewable electricity has so far had a vanishingly small share of just 0.1 % of total production.[11] Since steam reforming emits around 10 t of CO2 per tonne of hydrogen produced by splitting the natural gas CH4, the establishment of green hydrogen must be sustainably strengthened in the course of climate policy adaptation.

[8] *Based on HHV (Higher Heating Value) 141,8 MJ/kg oder 39,4 kWh/kg*
[9] *Prognos – Kosten und Transformationspfade für strombasierte Energieträger (2020)*
[10] *Carbon Capture and Storage*
[11] *Hydrogen Europe: Clean Hydrogen Monitor (2020)*

Green hydrogen can be produced by using renewable generated electricity via water electrolysis. Electrolysis has been a common process technology for the production of gases for decades. In water electrolysis, water (H_2O) is split into its two components, hydrogen (H_2) and oxygen (O).

Currently, two technological solutions dominate the market for water electrolysis; alkaline electrolysis and the so-called PEM electrolysis („Protone Exchange Membrane"). Since PEM electrolysis is significantly more flexible and thus better suited to fluctuating production cycles of renewable energies, it is considered in the following exclusively as the basis for further calculations.

BOX 2

PEM electrolysis

PEM electrolysis ("proton exchange membrane") does not use a conductive reaction solution. The reaction takes place by means of a proton-permeable membrane whose two surfaces are coated with metals (usually platinum) and act as anode and cathode.

The systems are usually operated under pressure and are much more compact than atmospheric alkaline electrolysers. The proton-permeable membrane eliminates the need for filling with alkali. Nevertheless, the production and coating of the membrane is technically demanding and so far there is little experience regarding the service life and degradation (efficiency losses) in the field. One advantage of PEM electrolysis is the fast response behaviour, which makes exact tracking of wind profiles possible, but can also be used for primary control power.

In order to determine the economic viability of green hydrogen under these conditions, concrete models are calculated below based on our expertise in the field of renewable energies. The aim of the analysis is to assess the competitiveness, also taking into account positive interactions with the energy sector.

4. Green hydrogen – utopia or the future a scenario analysis

4.1 Baseline scenario

Based on the electricity prices on the German market, from which the necessity of storage technologies was already derived in chapter 2, the total costs of hydrogen production are calculated in a baseline scenario. In order to avoid incorrect estimates due to the special effects of the pandemic, we base our calculations on prices from 2019. In addition, the positive effects for the integration of renewable energies are to be examined in particular. For this reason, we subdivide the electricity prices that arose in reality into hours according to the respective price level.

Figure 10: Weighted exchange prices for electricity in Germany sorted by hourly prices in ascending order in EUR/MWh[12]

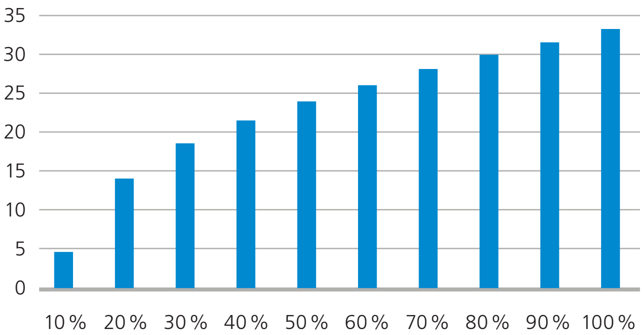
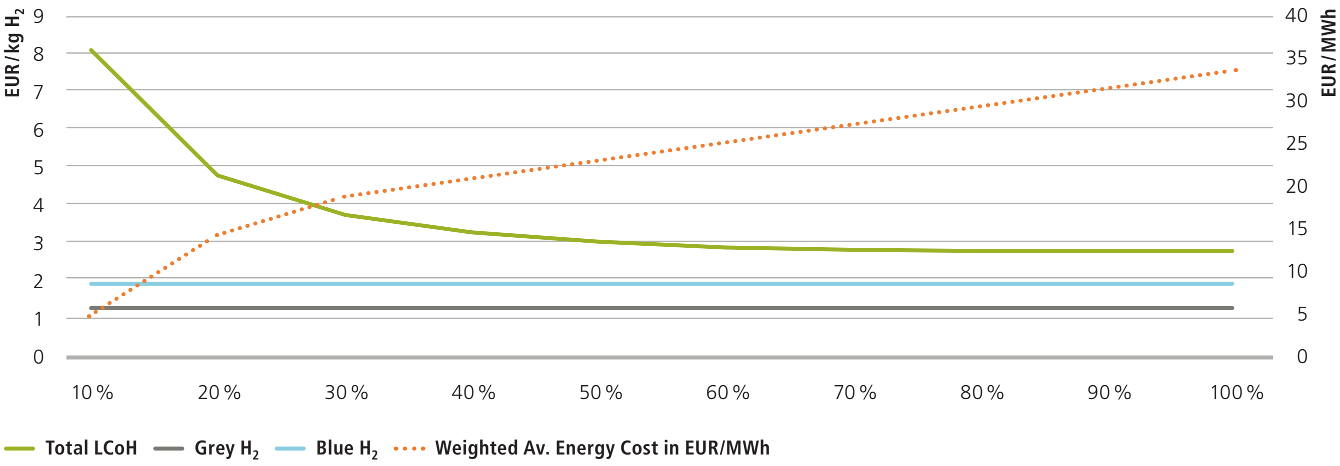


Figure 10 illustrates the volatility of market prices. Based on the correlations in the electricity market, which consequently reacts to an oversupply with very low, sometimes even negative prices, it will be examined how this oversupply can be channelled into the production of green hydrogen. The weighted average prices of the respective deciles are shown. The respective prices, e.g. bar one 10 % of the cheapest hours, result from the correlation with the supply. Thus, using the cheapest hours for hydrogen production would lead to two positive effects. On the one hand, the oversupply on the electricity market would be reduced and subsequently cause prices to stabilise. Secondly, the high energy demand of electrolysis would benefit from relatively low prices, whilst the sale of the hydrogen produced in this way would lead to further revenues.

Included in the analysis are all costs incurred for the construction and operation of an electrolyser with a capacity of 50 MW under real conditions. In addition, the total price per kg of hydrogen (LCoH – levelised cost of hydrogen) is calculated on the assumption of a 100 % equity-financed plant with a return on equity of 6 % without subsidies. The competitiveness compared to grey and blue hydrogen is examined in each case to enable a comparison without transport and storage costs, which are incurred regardless of the production type.

[12] *Aquila Capital Research based on data from ENTSO-E (2021)*

Figure 11: Total costs of hydrogen production as a function of electricity price.[13]



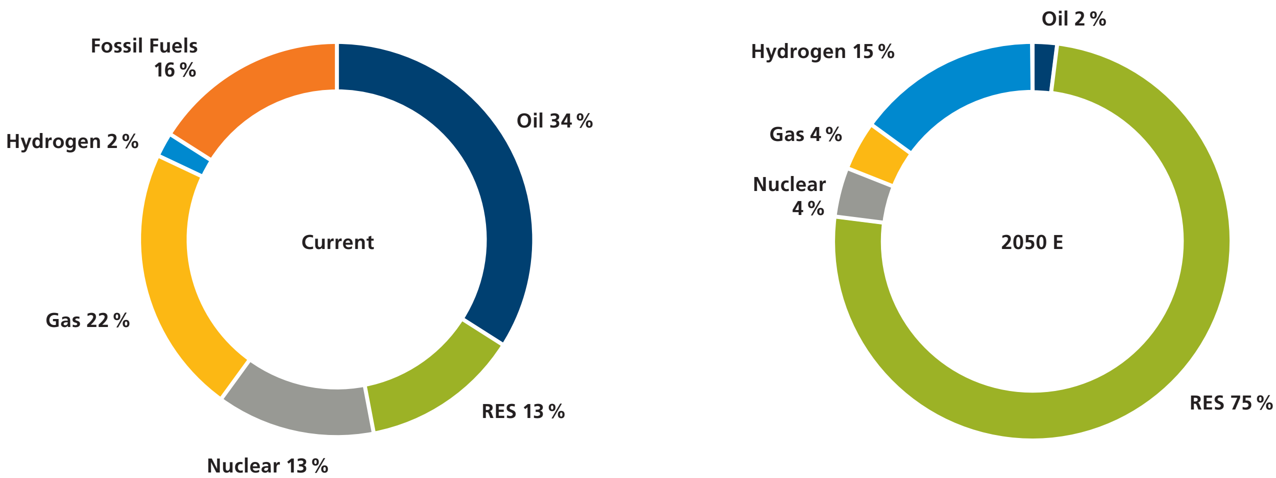
The graph shows that the production costs for green hydrogen decrease with increasing utilisation of the plant. Despite the electricity costs, which increase with higher utilisation of the plant due to sorting, this effect dominates. The distribution of the currently included CAPEX over increasing utilisation leads to the dominance of the fixed cost degression over the electricity price effects. As a result, the most favourable price to be achieved for green hydrogen under current conditions is 2.74 EUR/kg at 100 % utilisation of the electrolyser. This makes green hydrogen about 50 % more expensive than the alternative of blue hydrogen, whilst the price compared to grey hydrogen is more than double. Moreover, no positive effect on the fluctuations in the electricity market can be expected if the plant is running at 100 % capacity.

So are the ambitions of the EU and other member states to establish a hydrogen economy just wishful thinking or will appropriate measures change the conditions?

4.2 Changing framework conditions

Currently, hydrogen accounts for less than 2 % of primary energy consumption. By 2050, however, the share should be up to 15 % on the way to net zero.

EU hydrogen ambitions[14]



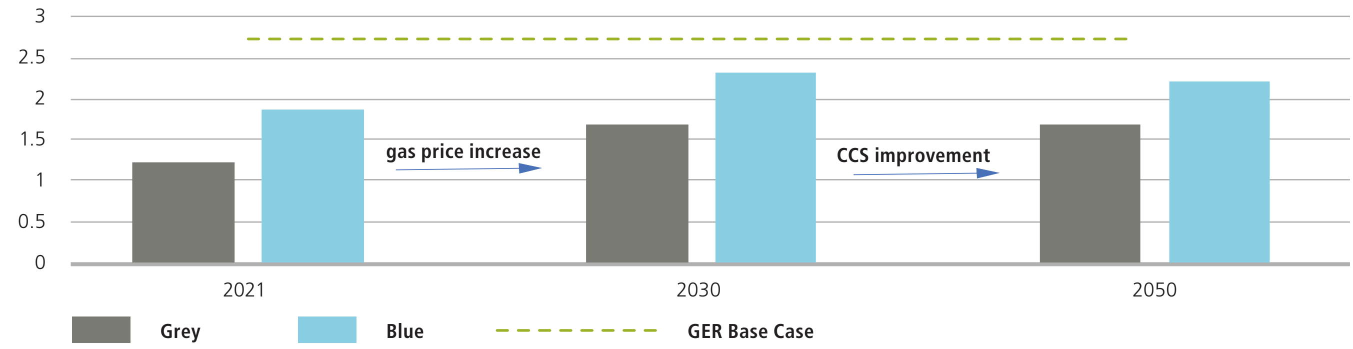
[13] *Aquila Capital Research (2021)*
[14] *Goldman Sachs (2021)*

To achieve this goal, massive investments will have to be made, which only the private sector can provide. But in this context, the competitiveness of green hydrogen must improve significantly.

Several effects will significantly determine future development.

Effect 1: Fossil alternatives become more expensive

Figure 13: Development of costs for grey and blue hydrogen (based on gas)[15]

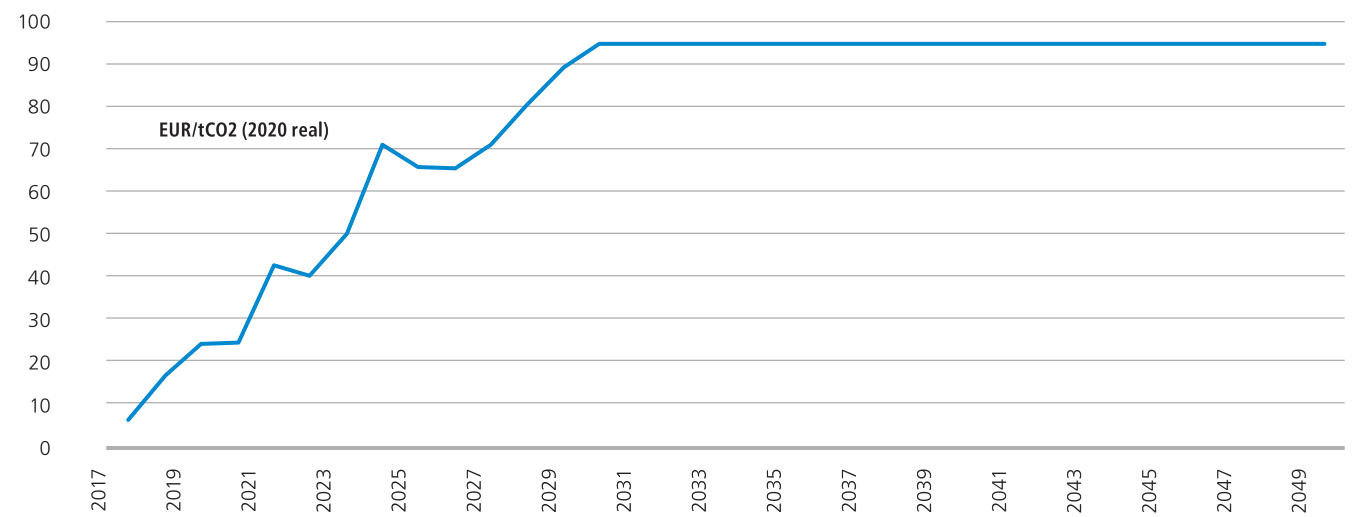


With an expected increase in gas prices, hydrogen production based on steam reforming is expected to become more expensive in the next decade. By 2050, on the other hand, it is expected that the production of blue hydrogen will fall again somewhat due to efficiency gains in CCS processes (CCS – carbon capture and storage), but will remain above the current level.

Effect 2: EU emissions trading

In the course of the EU's Green Deal, climate targets were significantly increased. To achieve these goals, the „Fit for 55" package was presented, which includes a comprehensive reform of emissions trading. Among other things, the supply of certificates is to be reduced linearly to the emissions target (–55 %) by 2030. This will have a significant impact on prices.

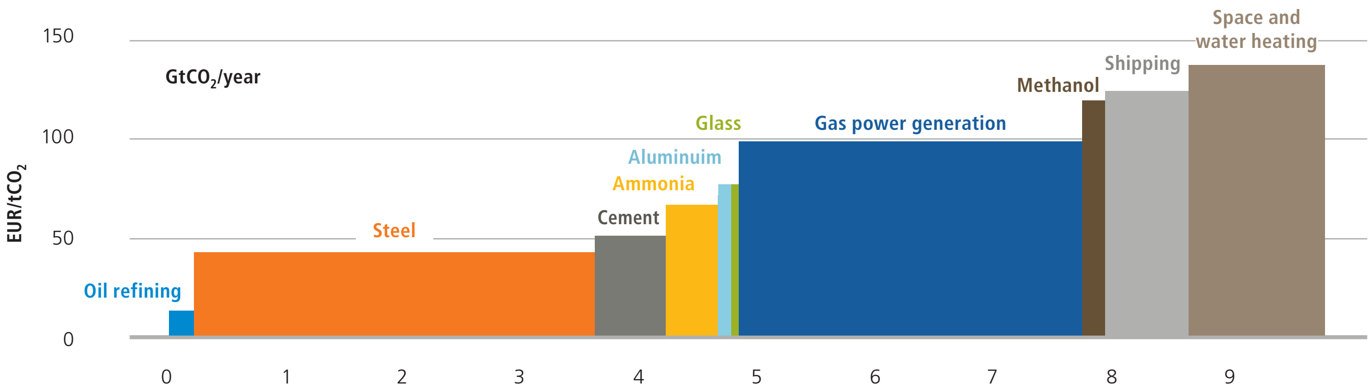
Figure 14: Forecast of the price development of EU emission allowances[16]



[15] *BNEF (2021)*
[16] *BNEF (2021)*

The already proven functionality of this instrument, which paved the way for renewable energies in the energy sector, will be extended to other sectors under the new regulations. In the course of this, competitive changes can be expected in the respective dependence of the price development.

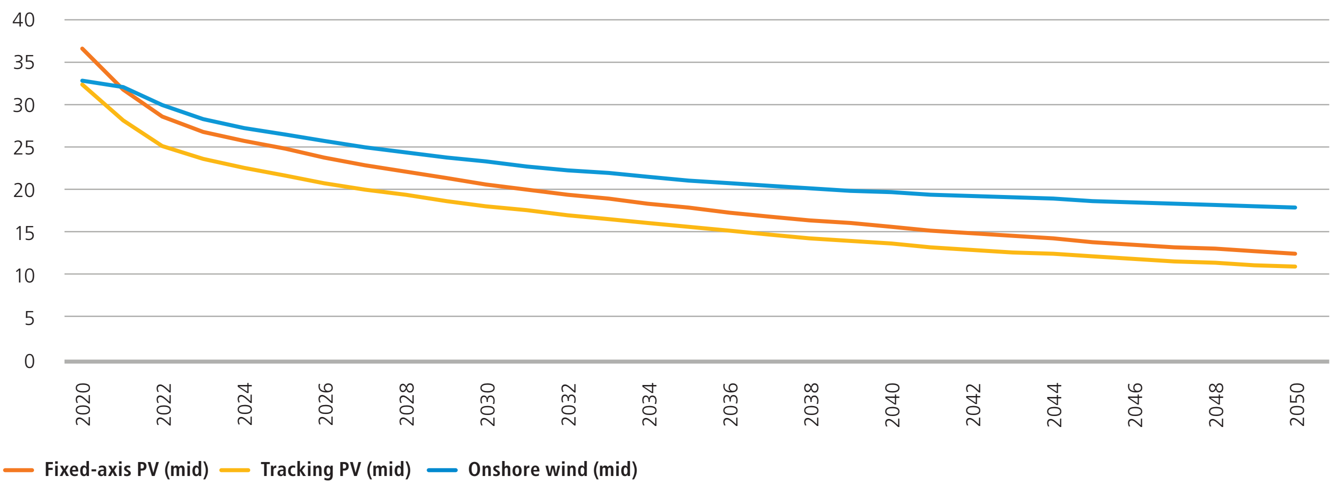
Figure 15: Economic viability of green hydrogen compared to conventional methods and associated fuels as a function of the carbon price[17]



In particular, oil refineries that use hydrogen to desulphurise fuels, but also the replacement of coal in steel production will be among the first applications in which the use of green hydrogen is economical, depending on the emission price.

Effect 3: Production costs of renewable energies continue to fall
After considerable price reductions in recent years, the increase in efficiency in the renewable energy sector continues.

Figure 16: Total costs (LCoEs) of renewable energies Spain[18]



[17] *BNEF (2021)*
[18] *BNEF (2021)*

In Spain, which has the lowest LCoEs in a European comparison due to extremely positive climatic conditions, prices are expected to fall by 66 % in the solar sector and 45 % in the wind sector by 2050. This development is particularly due to efficiency improvements, as the underlying return on equity for solar PV in Spain only marginally decreases.[19] In this context, however, it must be added that electricity prices do not necessarily follow the electricity production costs of solar. In Southern Europe in particular, electricity prices, as well as the average prices of long-term purchase contracts, are higher than today's LCOE because fossil-fuel power plants are the price-setters in the market.

Effect 4: Learning curve and economies of scale for electrolysers[20]
Effect 4 is – also with reference to the baseline scenario, which was dominated by the high CAPEX costs – the decisive one. Although the EU is currently the global leader in terms of electrolysis capacities, these are still at a very low level.

However, with the increase in global ambitions, the expansion will accelerate significantly. In this context, learning effects and economies of scale will have a massive impact and drastically change the initial situation.

Figure 17: Learning curve as a function of the predicted expansion[21]

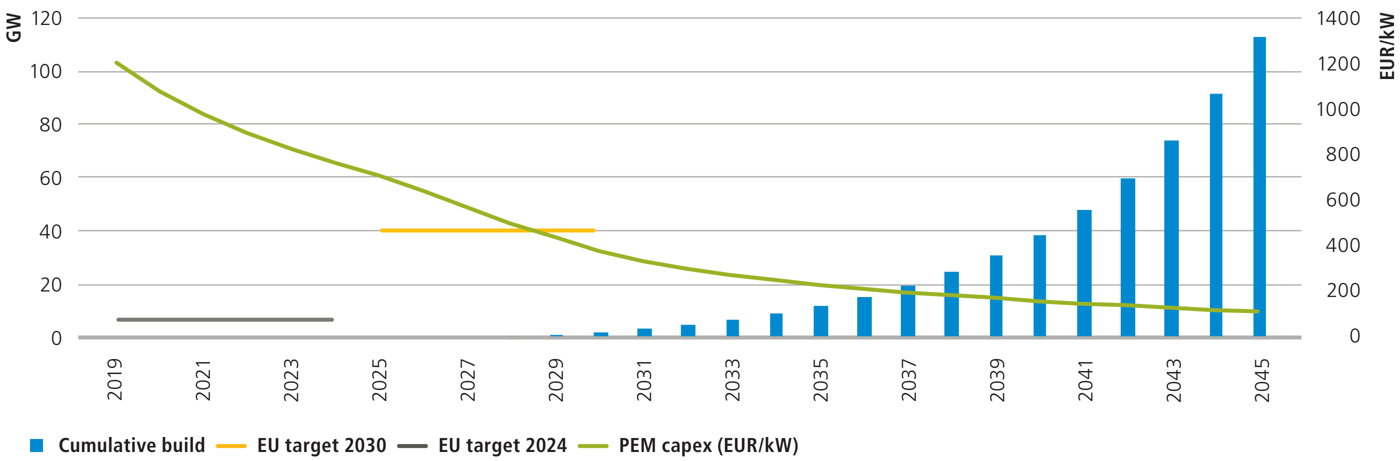


Figure 17 illustrates the potential of an increasing expansion of electrolysis capacities. Contrary to the forecast of Bloomberg New Energy Finance regarding the expansion, the announced ambitions of the EU are significantly higher. Should production capacities be expanded to this extent, even a faster cost degression can be expected. In addition to learning curves and expected economies of scale, technological innovations continue to offer high potential to increase efficiency and consequently reduce costs. One example of this development potential is this year's research achievement in the field of water electrolysis, which was awarded by Aquila Capital and an independent panel of experts.

BOX 3

Aquila Capital Transformation Award 2021
The second Aquila Capital Transformation Award in 2021 went to Dr Ning Yan, Assistant Professor at the Van't Hoff Institute for Molecular Sciences at the University of Amsterdam. A distinguished jury awarded the lead author for the research paper "A membrane-free flow electrolyser operating at high current density using earth abundant catalysts for water splitting". The annual prize supports research initiatives to mitigate climate change and is endowed with 20,000 euros.

The jury found that Ning Yan and his team demonstrate a promising and innovative way to produce green hydrogen, which will play an important role in our future energy system, more cost-efficiently and on an industrial scale. Central to the new innovative and energy-saving process of water electrolysis for the production of pure hydrogen is the combination of the advantages of

[19] *BNEF (2021)*
[20] *BNEF (2021)*
[21] *BNEF (2021); EU Commission (2021)*

different electrolyser concepts. In particular, the use of a membrane-free solution in a novel cyclic process offers potential to significantly improve economic efficiency.

Effect 5: The fluctuating production of renewable energies will lead to more grid-related curtailments in the course of the expansion

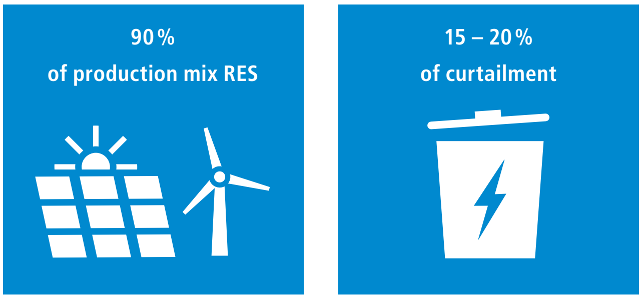
In order to keep the electricity grids stable, a balance between production and consumption is necessary. However, since renewable energies have a low scalability depending on the weather, they must be shut down, i.e. taken off the grid, in hours when high production does not match consumption to stabilise the grids. In Germany, a total of more than 6,400 GWh was shut down in 2019. This corresponds to a share of 2.8 % of all renewable electricity this year. Around €710 million was paid to operators as compensation for electricity that was never produced. With an increase in the share of renewable energies, these curtailments will increase as expected.

4.3 Outlook

a) Baseline scenario Germany 2030

Based on the baseline scenario for Germany, the effects described, i.e. reduced CAPEX (–69 %), emission prices (+0.95 EUR/kg for grey hydrogen) and the increase in the price of hydrogen alternatives are included in the calculation. All other parameters, i.e. electricity prices in 2019, 100 % equity and return on equity of 6 % – remain unchanged.

Forecast of the amount of regulated electricity with a 90 % share of renewable energies in the electricity mix[22]



Only storage solutions and sector coupling can dampen these effects. If this electricity were to be used at „zero cost" for the production of green hydrogen, on the one hand an emission-neutral alternative would be created for other sectors and, on top of that, the proceeds would directly reduce the compensation payments. From this dependency, government support for hydrogen production would represent an investment that shows a path to emissions neutrality whilst reducing the need for subsidies elsewhere. This case could mark a starting point from which a parallel expansion of renewable energies and the hydrogen economy can be designed in an economically sensible and climate-politically valuable way.

[22] *Goldman Sachs (2021)*

Figure 19: Baseline scenario in 2030 [23]

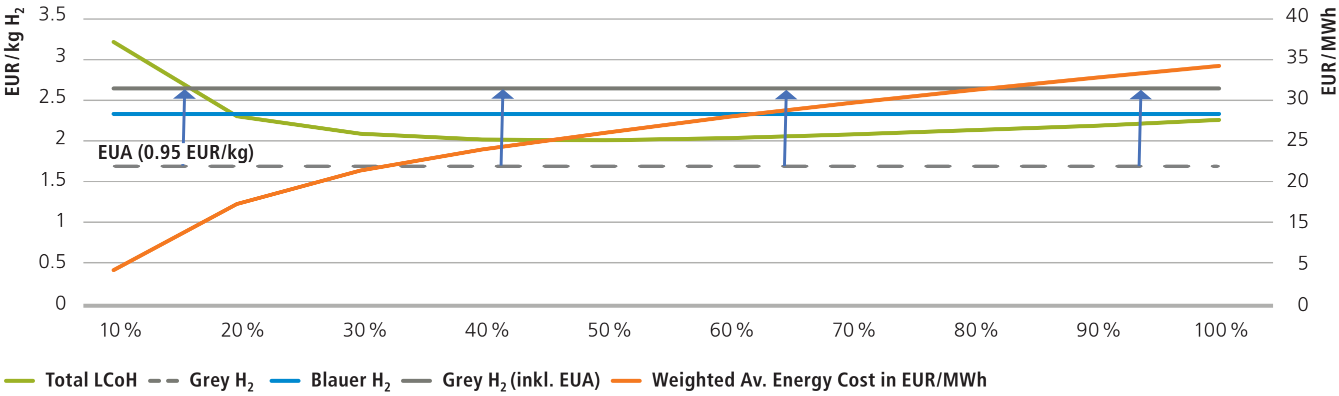
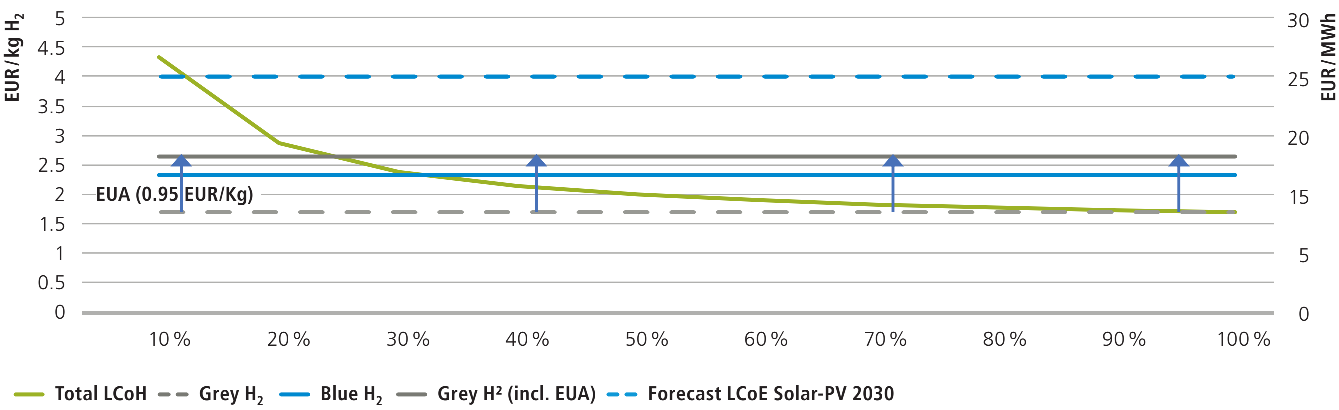


Figure 19 clearly illustrates how the effects work. Due to the reduced CAPEX, the prices for energy become much more important. The desired flexibilisation of the supply of renewable energy can thus be managed cost-efficiently even with lower utilisation of the electrolyser. Even at a capacity utilisation of 20 % – which can be roughly achieved with renewable energies – the comparative mark of blue hydrogen is undercut. Taking emissions trading into account, this also applies in competition with grey hydrogen. At a minimum cost utilisation of 50 %, the LCoHs correspond to almost 2 EUR/kg and are thus significantly below the alternative of grey hydrogen.

b) Hydrogen production Spain 2030

In this case – compared to scenario a (baseline scenario Germany 2030) – the electricity costs from 2019 are replaced by the projected LCoEs for solar PV plants in Spain. All other parameters remain at the same level as in scenario a) for Germany 2030.

Figure 20: Scenario Spain 2030 [24]



In contrast to scenario a), it becomes clear that competitiveness is only achieved from a utilisation rate of around 30 %. This follows from the fact that electricity costs are considered constant and the utilisation of favourable hours, as in the case of Germany, is not given. The favourable production costs in Spain, even if only theoretical, nevertheless give an indication of the potential in southern Europe. Here, too, the volatility of electricity prices will stand out in the future and significantly improve competitiveness.

Taking into account the effects described above and based on the forecasts of Bloomberg New Energy Finance, the competitiveness of green hydrogen compared to grey hydrogen will be achieved in Spain – under constant electricity prices – as early as 2026. It should be noted, however, that such an ideal-typical development from a hydrogen perspective does not correspond to reality. On the one hand, the actual electricity costs, especially in Spain, are already significantly higher than the electricity production costs for wind and

[23] *Aquila Capital Research (2021)*
[24] *Aquila Capital Research (2021); LCoE based on BNEF (2021)*

solar PV. On the other hand, in addition to other effects, the dynamically growing demand for electricity and the securing of the base load by gas-fired power plants will give electricity prices a further boost.

It remains to be said that the competitive production of green hydrogen is limited in the medium term by the high energy demand and the resulting costs. Political decision-makers are thus caught between the conflicting demands of supporting the development of electrolysers in order to benefit from economies of scale and limiting the burden of energy prices. Conflicts of interest arise from high electricity prices, which offer incentives to accelerate the expansion of renewable capacities, and the development of a hydrogen economy. Solutions can be found through subsidies in the hydrogen sector, which reduce demand elsewhere and provide stable framework conditions for producers of renewable electricity. Only the parallel development can make the efficiency and functionality of the energy supply systems a sustainable success.

5. Conclusion

From 2030 onwards, green hydrogen is expected to become competitive with the green and blue hydrogen alternatives based on fossil fuels. On the road to net zero, hydrogen can be the missing green molecule that enables the decarbonisation of non-electrifiable sectors and at the same time increases the integration of renewable energies and significantly improves the efficiency of the electricity market. But the energy demand requires a huge acceleration of renewable energy development, with the price of electricity becoming the key determinant on both sides.

Figure 21: Energy demand[25]

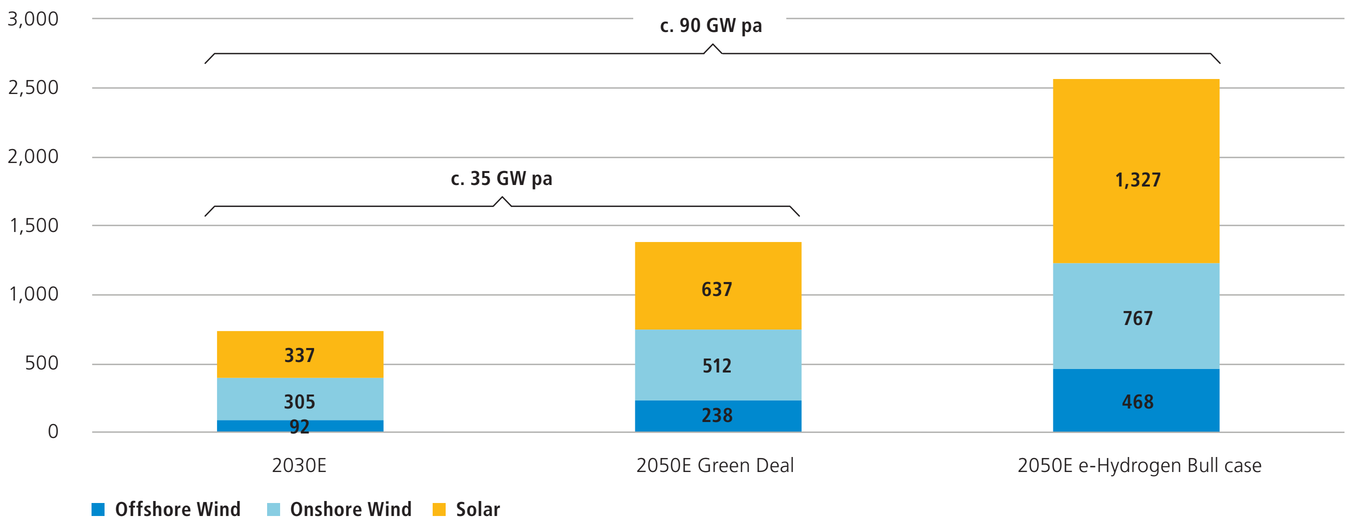
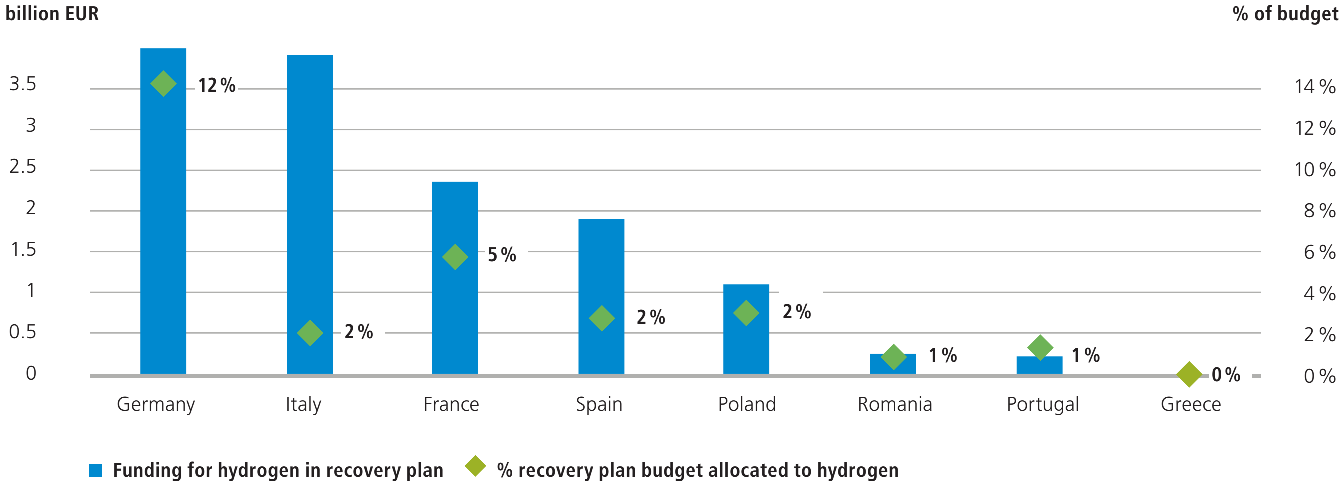


Figure 21 illustrates the enormous demand for generation capacity, which is largely shaped by the hydrogen demand of industry, for which hydrogen offers technological alternatives. For example, the German chemical industry estimates that an emissions-neutral reorganisation of the sector would require additional generation capacity to that currently available in Germany. The IEA further estimates that converting the Swedish steel sector to hydrogen would amount to about 45 % of current electricity consumption.

Analogous to renewable technologies, whose competitiveness was also based on initial elementary subsidies, there are opportunities to set appropriate incentives, which in turn result in synergies with the restructuring of energy systems.

[25] *Goldman Sachs (2021)*

Figure 22: Shares of the EU economic stimulus package directed at the hydrogen sector [26]



Within the EU, opportunities have been strengthened. Through the stimulus package and set „green quotas" for its use, there is financial scope in an increasing number of member states to support the development of a hydrogen economy.

In this context, competitive hydrogen could represent a tipping point in the energy transition. By reducing CAPEX through government subsidies but also through access to cheap debt capital, the required capacity utilisation can be reduced, as shown in the scenarios. As a result, a flexible reaction to existing supply prices would be possible. In this way, excess supply could be used economically and in this way stabilise the balance of the energy systems.

[26] *BNEF (2021)*

For more information please contact:

Aquila Capital
Valentinskamp 70
20355 Hamburg
Germany
Tel.: +49 (0)40 87 50 50 -100
E-mail: info@aquila-capital.com
Web: www.aquila-capital.com

Follow us on

Hamburg · Frankfurt · London · Luxembourg · Madrid · Lisbon · Oslo · Zurich · Invercargill · Singapore · Tokyo

A publication of Aquila Capital Investmentgesellschaft mbH. As of January 2022. Author: Peter Schnellhammer