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H2FUTURE
Green Hydrogen

Deliverable D9.5

Recommendations to regulatory bodies in line with the long term decarbonisation of the European industry

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Executive Summary

H2FUTURE is a European flagship project, funded by the Fuel Cell and Hydrogen Joint Undertaking (FCH-JU). The project aims to demonstrate a 6MW Polymer Electrolyte Membrane (PEM) electrolysis system at a steelworks in Linz, Austria and to supply this facility with green hydrogen from renewable electricity.

This report covers the EU policy and regulatory framework relevant to pivotal parts of the power-to-hydrogen (P2H) value chain represented in the H2FUTURE project, and in particular, EU legislation covering the promotion of renewable energy and the EU emissions trading scheme (EU-ETS). The policy and regulatory framework focusing on the promotion of green hydrogen has evolved significantly in the last four years, since the H2FUTURE started in early 2017.

The industrial transition from energy intensive processes towards a decarbonised industrial sector is complex. CO_2 intensive production routes will need to be abolished and massive investment into green (and low carbon) technologies and production routes, including via PEM-based electrolytic hydrogen with renewable electricity input, will be necessary. Such transformational processes are prone to high investment risks as well as opportunities for all players involved. The policy and regulatory framework can be decisive for the way new markets and new value chains are shaped.

With the European Green Deal, adopted in December 2019, the EU has set itself an ambitious goal to be the first continent to achieve carbon-neutrality by 2050. An important stepping stone towards this target is the recent decision by the European Council to increase EU's 2030 GHG emissions reduction target from 40% to 55%. Decarbonisation objectives are a key driver for the development of electrolytic hydrogen based on renewable electricity. Green hydrogen offers a decarbonisation pathway for the steelmaking industries, but also other industries, such as the fertiliser industry. A promising option for decarbonising the steel industry is the replacement of the BF/BOF process with the DR/EAF process coupled with green hydrogen. However, an appropriate regulatory framework is needed which allows for necessary cost reductions.

In view of already numerous studies and their accompanying policy recommendations following the increasing focus on the role of (green) hydrogen in the energy transition, the aim of this report is not to duplicate but rather to emphasise/complement existing policy recommendations. This is done on the basis of results and lessons learned from the PEM electrolyser demonstration and accompanying modelling analysis in the H2FUTURE project.

This report presents both commonly agreed recommendations within the H2FUTURE consortium, but also differing recommendations. Concerning the latter, it should be mentioned that the H2FUTURE project partners have different roles in the upcoming energy and industrial transition. For example, whilst VERBUND as a renewable energy producer aims to expand its value chain in order to become a producer of renewable hydrogen in the upcoming years, voestalpine is an important part of a possible hydrogen value chain as an industrial consumer of green hydrogen. Given these different roles, it is evident that – besides many shared views on policy and regulatory recommendations – diverging interests in relation to the market ramp up of green hydrogen persist throughout the transformation phase. These diverging view-points are rooted in the nature of the current and future market roles.

The recommendations with respect to regulatory framework to further promote green hydrogen are presented in Section 56. These are presented under four headings, notably:

- Ensuring sufficient renewable electricity for the production of green hydrogen;
- Facilitating the roll-out of electrolysers;
- Enabling the decarbonisation of the steel industry; and
- Cross-cutting issues related to the creation of a market for green hydrogen.

Our recommendations are based on the premise that both dedicated demand-pull and supply-push incentives are needed to kick-start a market for green hydrogen as well as for green steel, and a strengthening and adjustment of measures and incentives are needed to help bring down the cost of green hydrogen.

EU's energy sector is undergoing structural change. Under the Green Deal, relevant authorities (e.g. The European Union Agency for the Cooperation of Energy Regulators (ACER), The Council of European Energy Regulators (CEER), national regulatory authorities (NRAs), transmission system operators (TSOs) and distribution system operators (DSOs)) will all be responsible for contributing to reaching the European decarbonisation objectives. EU and Member States have to provide a regulatory framework that governs and facilitates the scaling up of green hydrogen, which also includes putting in place numerous aspects, such as standards, infrastructure, network plans, certification scheme, support schemes, just to mention a few. The recommendations presented in Section 5 of this report highlights also the entities who should be responsible for following up each recommendation.

Table of Contents

List of Figures

List of Tables

1 Setting the scene

The need for an energy transition is widely understood and shared; however, from the perspective of the contribution of hydrogen, the implications and challenges that must be resolved call for a concerted effort (Hydrogen Council, 2017). A key effort needed is the demonstration and scaling up of electrolysers for the production of green hydrogen from renewable electricity. Renewable energy, electrification, and energy storage have been identified as key components to realise an energy transition. But, even with a rapid deployment of renewable energies, such as wind and solar, it is broadly acknowledged that certain parts of the economy will be difficult to electrify. This includes, among others, processes in the steelmaking industry. Hydrogen is a versatile energy carrier, and a key component in promising and innovative power-to-gas (P2G) solutions. As such, hydrogen has the potential to be a powerful enabler of the ongoing energy transition, as it can bring low-carbon energy from where it is generated to where it is needed. Hydrogen, particularly when it is produced from renewable electricity via electrolysis, offers a sustainable and flexible option for overcoming multiple hurdles that stand in the way of a resilient and low-carbon economy. Hydrogen also offers an additional pathway, besides electricity, to utilize solar and wind energy.

In Europe, hydrogen is currently mainly produced via steam methane reforming (SMR), a well-known fossil-fuel process, which contributes directly to carbon emissions into the atmosphere. Green hydrogen, when produced through electrolysis using renewable electricity, is CO_2-free and can substitute fossil hydrogen, thus contributing to the decarbonisation of ‘hard-to-abate’ industrial sectors that need hydrogen as a reagent or today use carbon as a reducing agent. A huge potential for green hydrogen lies with the need to decarbonise industries, such as the steel, fertiliser, and refinery industries. In addition, the rapidly adjustable load of electrolysers offers a great source of flexibility that can contribute to solving stability problems in the electricity system due to the increasing variable supply of electricity from renewable sources. But, despite the promising benefits of electrolyser plants and its ability to produce green hydrogen from renewable electricity, this favourable technology still faces higher costs than established routes and other (regulatory) deployment barriers. It requires a regulatory framework and investment conditions that enable a timely move from demonstration to commercialization and upscaling.

1.1 Aim of the H2FUTURE project

H2FUTURE is a European flagship project, funded by the Fuel Cell and Hydrogen Joint Undertaking (FCH JU). The project aims to demonstrate a 6MW Polymer Electrolyte Membrane (PEM) electrolysis system at a steelworks in Linz, Austria, and to supply this facility with green hydrogen from renewable electricity. Providing green hydrogen to the steelworks in Austria is the primary goal of the PEM electrolyser being demonstrated in H2FUTURE (see picture to the right). Worldwide, the steel industry is an important CO_2 emitter and is therefore being called on to play a major role in mitigating climate change, among others, by reducing the CO_2 emissions from its production processes (OECD, 2015). An additional objective of the PEM electrolyser demo plant in H2FUTURE is to explore timely power price opportunities to provide grid services (i.e. ancillary services), as a means to attract additional revenues for the electrolyser plant. Figure 1.1 below depicts the scope of the H2FUTURE project.

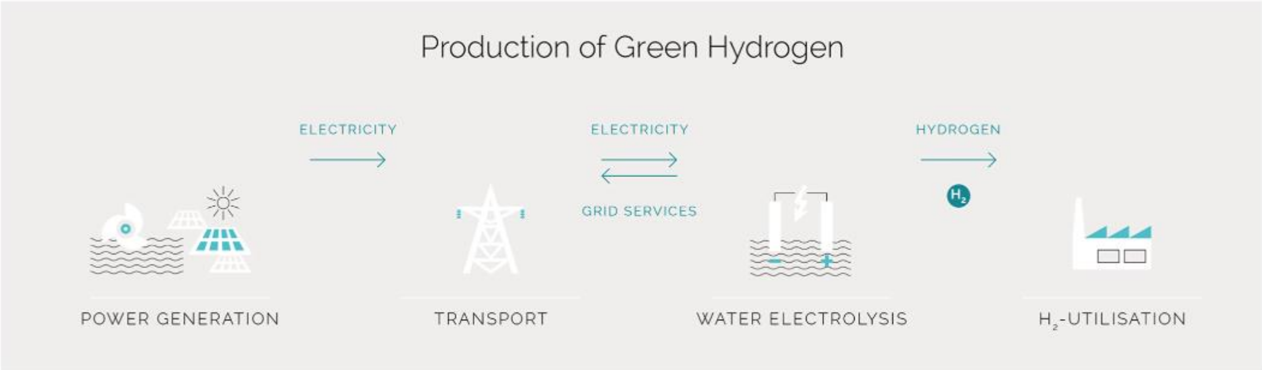

Figure 1.1: Schematic overview of scope of the H2FUTURE project

1.2 Why this report?

Work Package 9 (WP9) of the H2FUTURE project has the objective to explore and assess the technical, economic, environmental and grid-related performance of the 6 MW PEM electrolysis-based demo-plant for hydrogen production from renewable energy. The aim is also to identify scaling scenarios for, and the replication potential of the technology, taking into account its performance characteristics, and looking in particular at the steel and fertilizer industry in EU Member States. In order to accelerate the deployment of the demonstrated solution in the steel industry, in particular, the proposal of recommendations for regulatory changes are as well among the goals of WP9.

Demonstrating and scaling-up of green hydrogen production via electrolysis will require robust business cases. (IRENA, 2019) points out that electrolysis technologies still face critical challenges that primarily include the need for reaching higher durability and efficiency, for dynamic operation with robust and stable performance, and for reducing capital expenditures (CAPEX) and operational expenditures (OPEX). The bankability of a PEM electrolyser for the production of green hydrogen is contingent on a number of factors, in particular, a favourable regulatory framework.

1.3 Objective of this report

Against this background, this report provides recommendations that aim to improve the business case for further demonstration (in the short term) as well as upscaling and industrial implementation (in the medium to longer term). In view of already numerous studies and their accompanying policy recommendations following the increasing focus on the role of hydrogen in the energy transition, the aim of this report is not to duplicate but rather to emphasise/complement existing policy recommendations. This is done on the basis of results and lessons learned from the PEM electrolyser demonstration and accompanying modelling analysis in the H2FUTURE project.

This report covers the EU regulatory and governance framework relevant to pivotal parts of the power-to-hydrogen (P2H) value chain represented in the H2FUTURE project, and in particular EU legislation covering the promotion of renewable energy and the EU emissions trading scheme (EU-ETS). Where applicable, specific examples of national legislation or top-up measures for promoting hydrogen/electrolysis in some Member States are included, in particular for Austria, Germany and the Netherlands. R&D funding is also covered as it plays a pivotal role in supporting the piloting, demonstration, and upscaling of electrolysis-based hydrogen production. Additionally, this report gives a brief overview of the roles and responsibilities of relevant actors in the energy system, as defined in the EU legislative and regulatory framework.

1.4 How to read this report

This report reads as follows:

- Section 2 provides a description of the role of hydrogen in the energy transition.
- Section 3 elaborates the business case for PEM electrolysers and green hydrogen use in the steel sector with results from the project.
- Section 4 provides a brief overview of the EU's policy and legislative framework relevant to electrolytic green hydrogen production. It also includes a short update on EUs research and funding framework, with a focus on electrolytic hydrogen, as well as roles and responsibilities of relevant actors in the sector.
- Section 5 presents recommendations based on project results, as well as entities who should be responsible for following up the recommendation; these recommendations are presented as common recommendation (agreed by all project partners) and partner specific recommendations.
- Section 6 concludes.

H2FUTURE PEM Silyzer 300 electrolyser (source: © voestalpine)

2 Role of hydrogen in the energy transition

Today, the largest hydrogen consumption is in refining, in ammonia and methanol production and in the steel industry. Apart from consumption in many smaller industrial applications, there is a small but slowly increasing use as fuel in the transport sector (fuel-cell vehicles). The demand for hydrogen has more than doubled since the 1980s (see Figure 2.1).

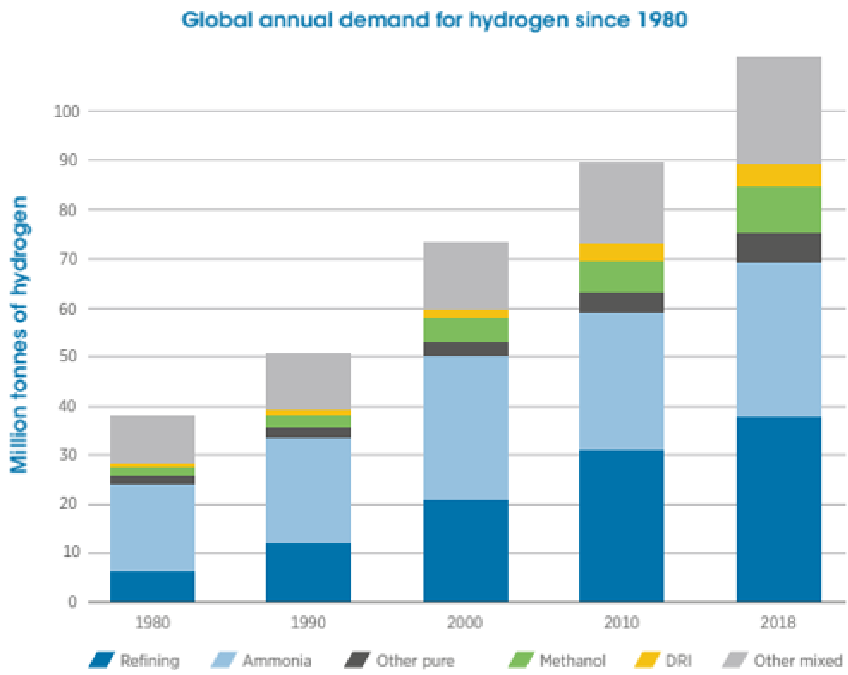

Figure 2.1: Global trends in hydrogen demand. Source: IRENA, 2019

Currently, hydrogen is almost exclusively produced from fossil fuels and is responsible for 830 Mton CO_2 emissions per year (IEA, 2019). To achieve the long-term target of the Paris Agreement, deep reductions of the emissions from the production of hydrogen need to be realised. There are three alternative routes for the production of hydrogen with low emissions: from fossil fuels with carbon capture and storage (CCS); from biomass; and from electrolysis with low-carbon, preferably zero-emission electricity of renewables and potentially also of nuclear. The production of hydrogen from electrolysis with renewable electricity (i.e. green hydrogen) can fulfil various roles in a sustainable energy system. The following sections highlight the role of (green) hydrogen in a sustainable energy supply and in steelmaking.

2.1 Role of H_2 in in a sustainable energy supply

Hydrogen is a versatile energy carrier which can fulfill multiple roles in a sustainable energy supply. It can be used to replace gaseous and liquid fossil fuels used for high-grade heat in industry, low-temperature heat in the built environment, and as transport fuel (especially for heavy duty vehicles such as trucks, shipping, etc.). Green hydrogen can also be used to replace fossil fuel-based feedstocks in industry (e.g. natural gas used for ammonia production). It can also be used as raw material for synthetic fuel production (e.g. synthetic kerosene for aviation). In this fashion, green hydrogen offers an alternative pathway to utilize renewable energy hydro, wind and solar for applications that are hard to electrify. Renewable energy resources are not distributed equally geographically and green hydrogen can be used to transport renewable energy via pipelines and ships from regions with an abundance of renewable energy to regions with limited availability.

As a long-term (seasonal) storage solution for variable renewable energy, such as wind and solar, green hydrogen supports the integration of (increased amounts of) renewable electricity in the energy market. Green hydrogen can additionally be used in power plants (large scale CCGTs or at smaller scale fuel-cell based) to provide clean, controllable and flexible power generation. The potential to reuse existing natural gas pipeline infrastructure for hydrogen supply may offer the opportunity for cost optimization in a sustainable energy system.

The roles and functions that hydrogen could fulfil are schematically presented in Figure 2.2 below.

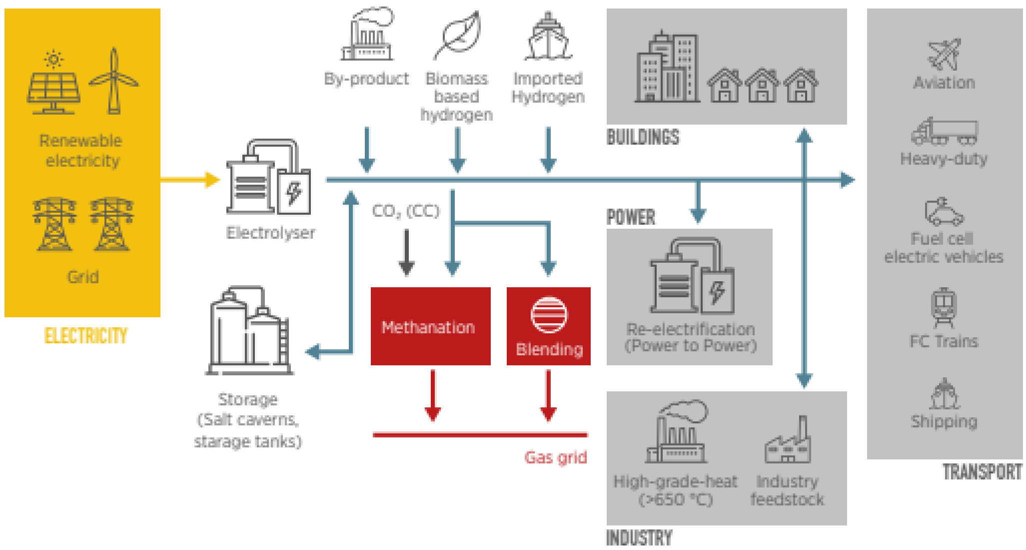

Figure 2.2: Hydrogen in the energy system. Source: IRENA, 2018

An important aspect of electrolysers as large and flexible consumers of renewable electricity, is the capability to offer grid services to power markets. Demand-side flexibility offered by electrolysis can reduce (both in frequency and severity) the instances of extremely low or negative electricity prices at times when large amount of renewable electricity is simultaneously supplied to the market. Flexible offtake of renewable electricity can thereby have a stabilizing impact on electricity prices and decrease risks for investors in renewables, making higher amounts of renewables attractive for exploitation. Altogether the production of green hydrogen makes it possible for larger amounts of renewable energy to be harvested.

2.2 Role of H_2 for the steel industry

Today, hydrogen in mixed form (with other gases such as carbon monoxide) is already used as reducing agent for steel production in both blast-furnace basic oxygen furnace (BF-BOF) and direct reduction (DR) steelmaking. Whereas the BF-BOF process accounts for the 71,6% of the worldwide crude steel produced, 27,9% is being produced via scrap-Electric Arc Furnace (EAF) and the remaining share (0,5%) correspond to other production processes (Worldsteel, 2020). Among those processes is the direct reduction of iron ores, with a direct reduced iron production of 111,3 Mt DRI/y (Worldsteel, 2021). In BF-BOF steelmaking hydrogen arises as a by-product of coal use and is part of a mix of “work-arising gases” (WAG) also including carbon monoxide and others. WAG is used for various onsite processes, but can also be used as fuel in power plants, for example, as fuel for the steel mill power plants. Approximately 9 Mton of hydrogen per year is used for BF-BOF steelmaking, accounting for 20% of the global use of hydrogen in mixed form (i.e. not pure hydrogen) (IEA, 2019). The direct reduction (DR) process, an alternative way of producing steel, uses a mixture of hydrogen and carbon monoxide as reducing agent. Contrary to BF-BOF, the hydrogen used in the DR-process is not a by-product but is produced from natural gas or coal in dedicated facilities. Approximately 4 Mt of hydrogen per year is used for DR, about 10% of global use of hydrogen in mixed form (IEA, 2019).

There are two main pathways for the reduction of CO_2 emissions from primary steel production: Carbon Direct Avoidance, which involves replacement of carbon by renewable electricity and/or fossil-free reductants, and Smart Carbon Usage, which involves process integrated measures and utilization of CO_2 as raw material (CCU), optionally combined with CCS [EUROFER, 2019]). For DR it is technically possible to almost entirely substitute natural gas with green hydrogen. The future demand for green hydrogen in steelmaking depends on the ratio of primary to secondary steelmaking, the share of direct reduced iron in primary steelmaking and the level of substitution of natural gas. IEA (2019) estimates that in a pathway compatible with the Paris Agreement 4.5 Mt H_2/year from renewable electricity could be required by 2030, with a remaining 4.5-6.5 Mt H_2/year sourced from natural gas. Using the DR(H_2) route to largely eliminate CO_2 emissions from primary steelmaking, in line with the long-term Paris Agreement goals, could see the demand for green hydrogen increase to 47-67 MtH_2/year by 2050 (IEA, 2019).

3 Business case for PEM electrolysers and green hydrogen use in the steel sector

3.1 Business case for PEM electrolysers

The business case for PEM electrolysers is driven by the investment and operational costs for the electrolyser, on the one hand, and the revenues that can be generated, on the other hand. In the H2FUTURE project the capital costs of the atmospheric PEM electrolyser system have been estimated at 700-950 €/kW in 2020. The estimates drop to 600-830 €/kW in 2030 and 450-660 €/kW in 2050. The values should however be read with caution. The values represent the cost of technology available in the indicated year once it has reached a certain stage of maturity after deployment of a significant capacity of the technology in multiple projects. These are not the cost of new types of systems that are built for the first time.

Other project costs add an estimated 80% of the equipment cost (ISPT, 2020)(Northern Gas Networks, Equinor, Cadent, 2018), giving total project investment costs of 1260-1710 €/kW in 2020, 1080-1490 €/kW in 2030 and 810-1190 €/kW in 2050. Fixed operational costs for a PEM electrolyser are estimated at 30 €/kW/year in 2020, dropping to 21 €/kW/year in 2050. The main operational costs for electrolysis are the costs of electricity, which is determined by the wholesale price of electricity and taxes, fees and levies, such as CO_2 price components. The electricity price varies per Member State and its exact influence on the business case is therefore dependent on the location. Figure 3.1 shows the impact of electricity costs on the hydrogen production costs is relatively large compared to the impact of investment costs. At lower utilization rates (full load hours per year), for instance due to limited availability of renewable electricity, the relative share of fixed (investment) costs and O&M costs in the cost of hydrogen increases (IEA, 2019).

A large portion of the electricity costs consist of taxes, fees and levies, such as CO_2 price components. On average in the EU in 2019, taxes on electricity accounted for 30% of electricity costs for large industries and network costs accounted for 15% of electricity costs (European Commission, 2020b). In absolute terms, large industries pay less for electricity (76 €/MWh in 2019) than small industries (109 €/MWh) and household consumers (214 €/MWh) (European Commission, 2020b). In absolute terms, therefore, large industries pay lower taxes per MWh of electricity than small industries and household consumers.

The main source of revenues for a PEM electrolyser is the sale of hydrogen. The amount of revenues that can be generated is related to the market price of hydrogen. Market prices are in part determined by various elements outside the control of the owner of the PEM electrolyser, like the demand for hydrogen and the costs of alternative hydrogen production methods (such as steam methane reforming – the costs of which depend on, amongst other things, gas prices, CO_2 prices and whether or not CCS is applied). The costs of hydrogen from steam methane reforming are around €1.5 per kg H_2 without CCS, and €2 per kg with CCS, not taking into account the sharp increase in CO_2- and natural gas prices in 2021 (European Commission, 2020b). The revenues for a PEM electrolyser can be higher if there is a premium paid for hydrogen produced from renewable electricity through electrolysis. Demonstration of renewable properties and compliance with sustainability criteria, through for example sustainability certificates or Guarantees of Origin (see Section 4.2), will likely be a requirement for receiving premiums for renewable hydrogen.

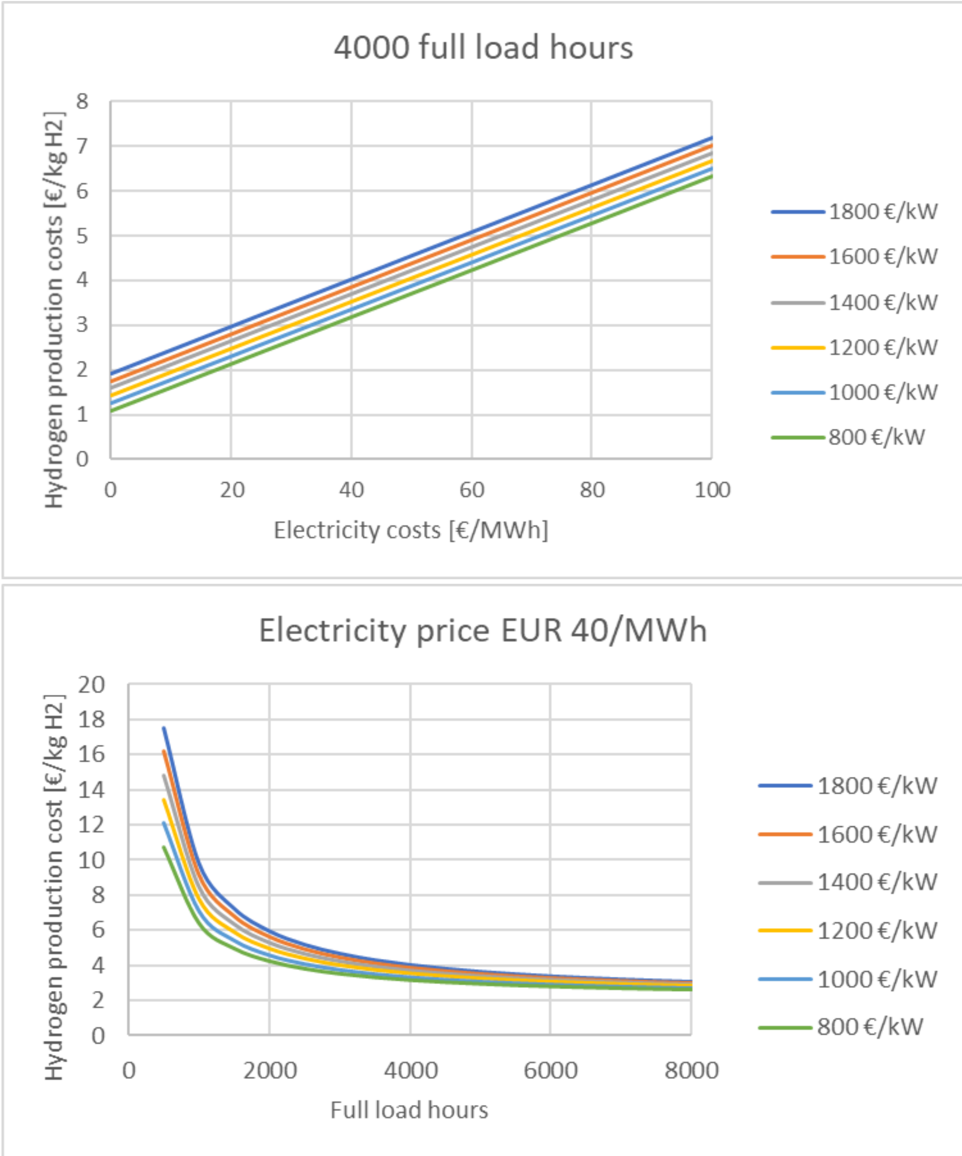

Figure 3.1: The impact of investment costs, electricity costs and full load hours on the production costs of hydrogen. Assumed are O&M costs of 30 €/kW/year, 30 year lifetime and an efficiency of 52.5 $kWh_e/kg\ H_2$.

An additional source of income for PEM electrolysers is providing grid (balancing) services, scaling production up or down as required by electricity market operators. Kopp, et al. (2017) studied the economics of a 4 MW_{el} nominal capacity PEM electrolyser with an additional 2 MW peak power (overload) capability operating as a secondary control reserve with 4 MW_{el} in Mainz, Germany. They found that the unit can generate revenues of the order of €188,000 per year. The system can produce 89.8 kg H_2 per hour, which adds up to a maximum of 786,648 kg H_2 per year. Even at hydrogen prices of €1-3 per kg, the revenues from grid services are relatively modest compared to revenues from the sale of hydrogen. The impact offering grid services can have on the business case for the PEM electrolyser depends on the member state where the system is located, the compensation received for supplying grid services, and the loss of revenues from hydrogen sales due to the operation on the grid balancing market.

3.2 Business case for green hydrogen in steelmaking

The H2FUTURE project has explored the business case for the use of green hydrogen in steelmaking, measured by the impact on the cost of crude steel (see project deliverable 9.1). Three cases were compared: blast furnace/basic oxygen furnace steel making (reference case), direct iron reduction (DRI) with methane (CH4) and an electric arc furnace (EAF) (first transition step), and direct iron reduction with hydrogen and an EAF (carbon-lean steelmaking). The main assumptions for the analysis are presented in Table 3.1. Figure 3.2 shows the current costs of steelmaking with blast furnaces and basic oxygen furnaces largely depend on the fixed costs, with additional costs from CO_2 pricing. Fixed costs are slightly lower for the direct reduction processes, but when using hydrogen as reducing agent the costs increase due to the operational costs of the electrolyser and the cost of electricity. In both direct reduction cases electricity is also required for the EAF. A viable business case for steel industry will also depend on the economic availability of green hydrogen and the corresponding support (e.g. carbon contracts for difference).

Table 3.1: Overview cost assumptions for steelmaking business case analysis.

Cost element	Units	2020	2030	2050
Electricity	€/MWh	54.6	0-100	0-100
Natural gas	€/MWh	18.5	21.7	22.5
CO_2	€/t	25	75	160
Electrolyser CAPEX	€/kW	825	715	555
Electrolyser OPEX	€/kW	30	27	21
Operating hours electrolyser	Hours/year	8000	8000	8000

Figure 3.3 compares the impact of electricity prices on the business case of DR steelmaking with electrolytic hydrogen to the costs of steelmaking with the alternative options. The comparison is made for 2020 and 2050, in which the main differences are the costs of natural gas, the electrolyser, and the CO_2 price (see Table 3.1). The costs of BF/BOF steelmaking in 2050 is significantly higher than in 2020 due to the high CO_2-price. The costs of DRI/EAF with natural gas also increase in 2050 due to higher natural gas costs and a higher CO_2-price. The electricity used in the EAF also lead to an increase in steel costs at higher electricity costs. The influence of electricity costs is more significant with the DR(H_2)/EAF process due to the electricity consumption of the electrolyser. Figure 3.3 shows that in 2050, with a CO_2 price of approximately 160 €/ton, DR(H_2)/EAF is competitive with BF/BOF steelmaking at an electricity price below 74 €/MWh. However, for the conditions used for 2020 calculations and focusing on the DR(H_2)/EAF, electricity prices have to fall below 10 €/MWh in order to be competitive against the BF/BOF route.

Meanwhile, circumstances are changing rapidly. The analysis was carried out in 2019-2020, but at the time of the completion of this report, the CO_2 price is already 70-80 EUR/t and the natural gas price is reaching record highs with prices of 100 EUR/MWh and more. Whether this has also made the DR(H_2)/EAF option more attractive remains to be seen, as electricity prices have also risen considerably. The higher CO_2 price is expected to be structural, but it is not yet clear how energy prices will develop. In any case, if the current high volatility in energy prices continues, it will not become easier to make major investment decisions for production facilities based on new technology.

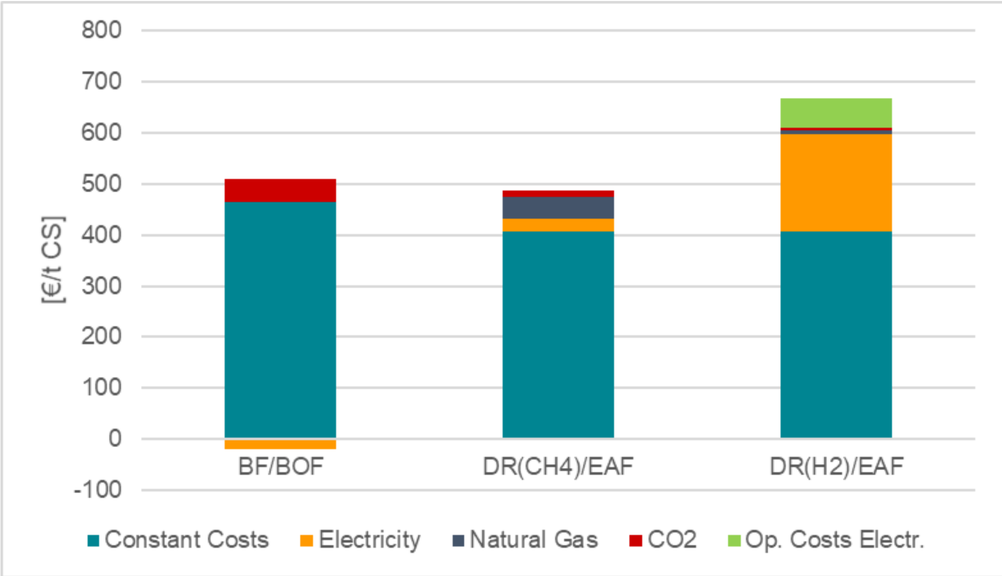

Figure 3.2: Comparison of the costs of crude steel production in 2019 with blast furnace/basic oxygen furnaces and direct reduction using methane and hydrogen (Source: H2FUTURE deliverable D9.1 Report on exploitation of the results for the steel industry in EU28).

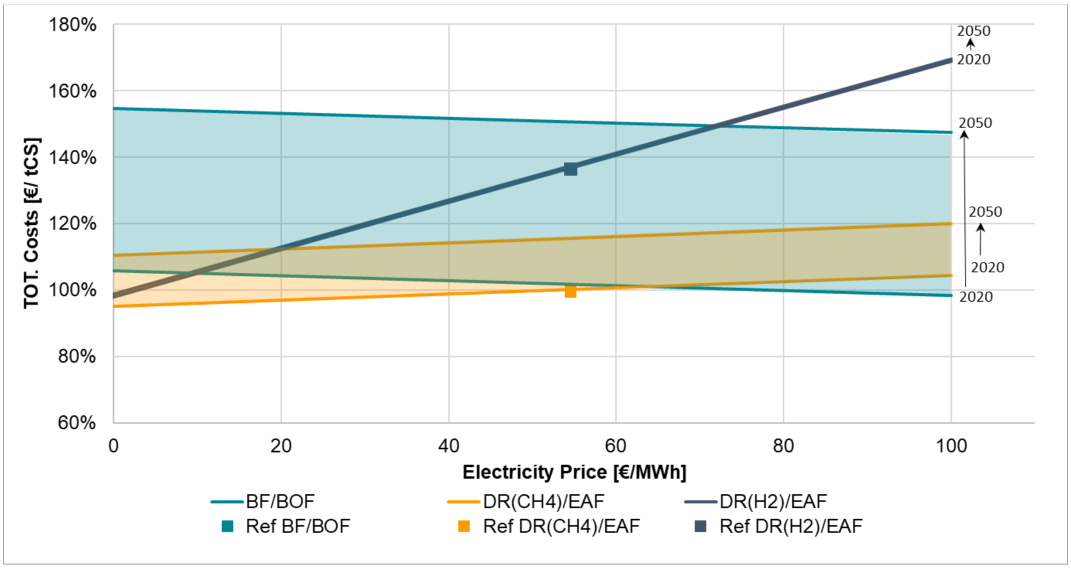

Figure 3.3: Impact of electricity prices on the business case for DR/EAF steelmaking with electrolytic hydrogen, compared to the costs of steelmaking with BF/OF and DR/EAF with natural gas under various cost assumptions in 2020 and 2050.

4 EU's policy and regulatory framework

Since the start of the H2FUTURE project in 2017, EU's energy and climate policy & regulatory framework has evolved significantly. Leading up to today's increased focus on green (and low carbon) hydrogen, it is timely to present a short summary of key policy developments and their implications for the promotion of green hydrogen, starting with EUs response to the 2015 Paris Agreement. Figure 4.1 gives a snapshot of important policy and legislative initiatives that have taken place since the start of the H2FUTURE project, including the COP21 (which took place shortly before start of the H2FTURE project. Highlights from these policy and legislative initiatives will be covered in the following sections.

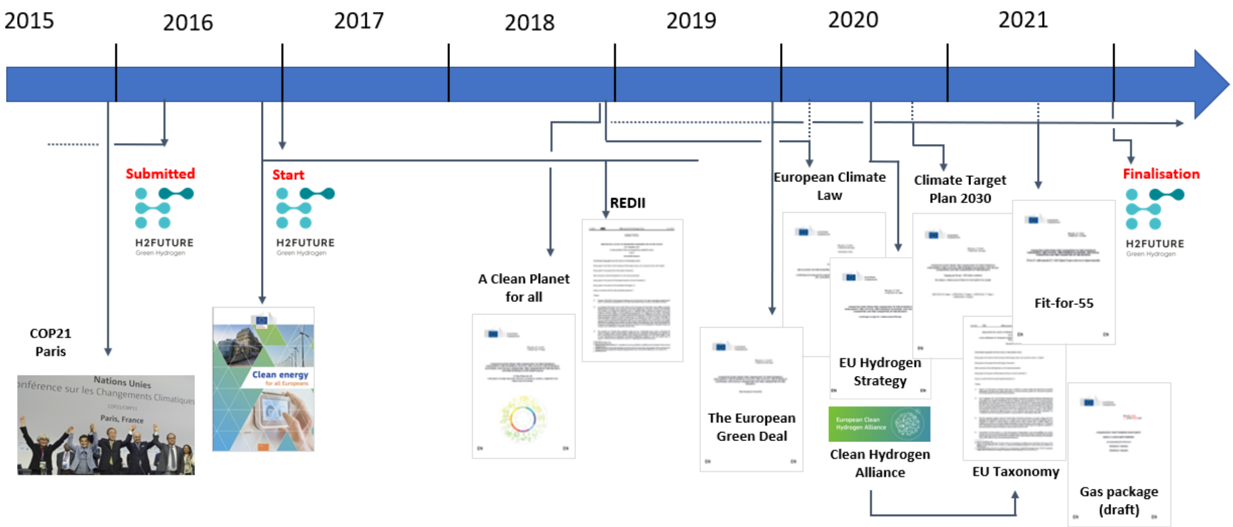

Figure 4.1: Snapshot of key policy developments at global and EU level since the start of the H2FUTURE project. (Source: TNO, 2021).

4.1 EU's long term decarbonisation objective

As a response to EUs commitment to the 2015 Paris Agreement[1] and to EU's aim of continued global energy transition leadership, the European Commission proposed in 2016 a set of ambitious legislations under the "Clean Energy for all Europeans" (CE4All) package. These included, among others, the recast Renewable Energy Directive (European Commission, 2018b) (hereafter REDII), which was finally adopted and entered into force in December 2018.

The Commission's vision for a climate-neutral EU was initially presented in the 2018 communication 'Clean Planet for All' (European Commission, 2018a), which explores several pathways for the energy transition. Notably, the communication includes hydrogen's possible contributions to reaching the longer term decarbonisation target. It acknowledges that hydrogen can gradually take the role of an energy vector beyond its potential role as a chemical storage of electricity, and can replace natural gas, coal or other fossil source as an energy fuel per se and as feedstock for industrial applications, including steelmaking. The in-depth analysis supporting the 'Clean Planet for All'

[1] The Paris Agreement aims to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C. See: https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement

communication highlights: *"In the decarbonised future, hydrogen obtained from electrolysis using decarbonised electricity is the preferable option, including "green" hydrogen obtained from renewables."* (European Commission, 2018a).

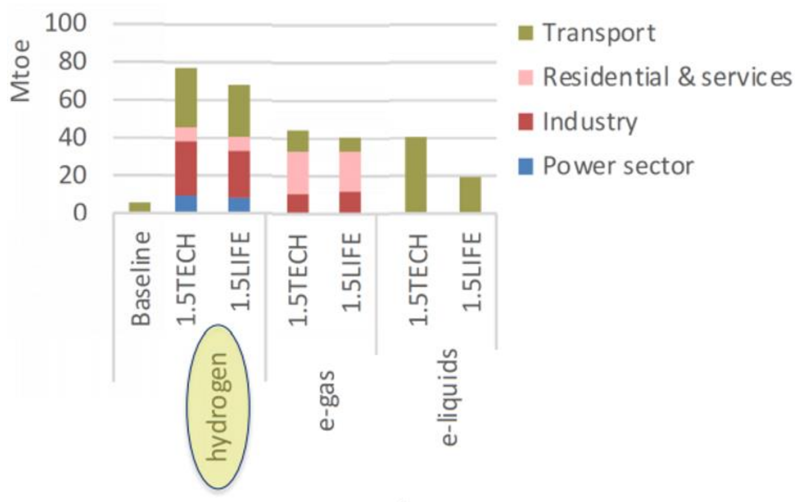

Figure 4.2 shows the possible contribution of hydrogen for the industry sector in two of the pathways (1.5TECH and 1.5LIFE), both presented in the in-depth analysis supporting the 'Clean Planet for All' communication.

In December 2019, the European Commission published the "European Green Deal' (European Commission, 2019), initiating a set of policy measures aimed at making Europe climate neutral by 2050. As a part of the European Green Deal, the Commission also announced a possible increase of EUs 2030 GHG emissions reduction target from 40% to 50-55%, compared to 1990 levels. In December 2020, the European Heads of State agreed to a 55% reduction target by 2030.

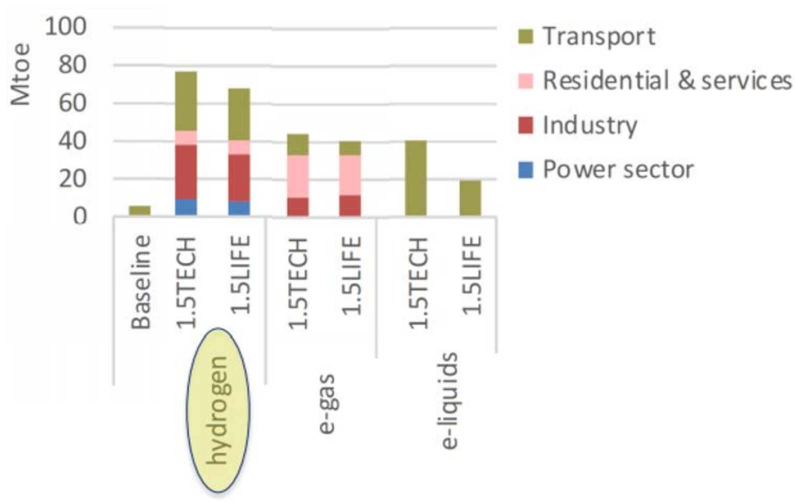

Figure 4.2: Scenarios from the 'Clean Planet for All' showing consumption of new fuels, including hydrogen, by sector in 2050. (Source: DG CLIMA)

Several important policy and legislative initiatives have been presented following the European Green Deal. Firstly, the Commission's proposal for a European Climate Law, adopted in March 2020, which aims to make the net-zero emissions target by 2050 legally binding. Secondly, in July 2020, the Commission presented two important strategies, namely the EU Hydrogen Strategy (European Commission, 2020c) and the EU Energy System Integration Strategy (European Commission, 2020a). Together, these two strategies identify important actions and steps needed to mainstream hydrogen in the transition and decarbonisation of the European energy system (details presented in Annex II). EU's Hydrogen Strategy sets green hydrogen as a top priority in EUs energy and climate policy, considering also blue hydrogen as an intermediary solution. By 2024 and 2030, the EU is committed to achieving set targets of 6 GW and 40 GW target for electrolysers (European Commission, 2020c), respectively. Several Member States have published national hydrogen strategies, e.g. Germany, France, Netherlands and Spain.

In order to implement the 2030 energy and climate targets set out in the EU climate law, the European Commission proposed the "Fit for 55" legislative package in July 2021. The package consists of 12 legislative proposals and several other non-legislative communications, many of them relevant for the deployment of green hydrogen production, including proposed amendments to REDII (see below.)

On 15 December 2021, the European Commission put forward its long-awaited Hydrogen and Decarbonised Gas Market Package, with proposals for revisions of the existing Gas Directive and Regulation. Among other things, the directive proposal on common rules for the internal markets in renewable and natural gases and in hydrogen (European Commission, 2021c) includes a specific provision on the certification of renewable and low carbon fuels, applicable to both domestic and imported production, to ensure a level playing field and avoid carbon leakage.

4.2 EU's evolving legislative and regulatory framework

At present, there is no dedicated legislation governing hydrogen at EU level. Despite this fact, the growing interest in the role of green hydrogen has, among others, led to the inclusion of hydrogen in EU directives, notably the REDII. Additional legislation is in the pipeline which is expected to improve the framework for green (as well as low carbon) hydrogen.

2018 recast Renewable Energy Directive (REDII)

REDII includes renewable fuels of non-biological origin (RFNBO), which covers green hydrogen. Furthermore, it creates the opportunity for RFNBO, including green hydrogen, to contribute towards the renewable energy share in the transport sector. However, at the same time the REDII establishes strict sustainability requirements. These include, on the one hand, a GHG emission intensity reduction of 70% compared to a fossil benchmark, and on the other hand, restrictions with regard to the eligibility of the renewable electricity input (i.e. additionality, temporal and geographical correlation of energy demand and supply). Concerning the latter, an interpretation of the REDII provisions entails three options for electrolytic hydrogen based on renewable electricity:

- Renewable electricity supplied via a direct connection to the hydrogen production facility, e.g. electrolyser, whereby the electricity input will be counted as 100% renewable;
- Grid-transmitted electricity which may count as 100% renewable if it meets the sustainability requirements (including temporal and geographical correlation of supply and demand) in accordance with forthcoming Delegated Acts ; and
- Grid-transmitted electricity whereby the renewable share of electricity in the relevant national grid as a whole will be used to determine the renewable share of input to the hydrogen production facility.

A Delegated Act detailing the rules for the production of hydrogen from electricity has not yet been published at the time of writing this report.

Whilst the existing REDII criteria apply to the transport sector, it is worth noting that in connection with the revision of the REDII, these criteria are also considered for a wider use of green hydrogen in other sectors, and in particular, the industrial sector (see below).

Additionally, REDII requires EU member states to extend existing Guarantees of Origin (GO) schemes to include renewable gases, including ‘green’ hydrogen. According to the REDII, the GO has the sole purpose of proving to a final customer that a given share of energy has been produced from renewable sources. This is relevant for the promotion of green hydrogen. Not only could a GO help to distinguish green hydrogen from grey hydrogen, it could also potentially create an additional revenue stream by putting a value on green hydrogen produced from renewable electricity as compared to grey hydrogen produced form natural gas.

European Commission’s “Fit-for-55” legislative package

In July 2021, the European Commission released a package of regulatory proposals as part of its “Fit for 55” legislative package that aims to achieve the European Green Deal’s target of 55% net reduction in GHG emissions by 2030. The package includes proposed revisions to the REDII (European Commission, 2021a). Revisions of particular importance to the steel industry include:

- Targets for “green” hydrogen in hydrogen-consuming industries, incl. steel and ammonia. More specifically, Member States are to ensure that industry uses RFNBOs for final energy and non-energy purposes equivalent to 50% of the hydrogen used for final energy and non-energy purposes in industry by 2030;
- REDII restrictions on how and when renewable electricity supply for green hydrogen production would satisfy the sustainability criteria for production of RFNBOs, still to be defined in the delegated act under REDII, will also apply in relation to the targets for hydrogen use in industry

Whilst the proposed amendment (first bullet) could help to create a demand for green hydrogen, the latter proposed amendment (second bullet) could create a significant hurdle to the development (or implementation) of electrolytic hydrogen from renewable electricity. The proposed REDII amendments also include an extension of the Union database for tracing RFNBOs and recycled carbon fuels to include all end-use sectors in which these fuels are used (and not only transport). The aim of the Union database extension is to monitor the production and consumption of those fuels *“to avoid any risk of double claims on the same renewable gas, a guarantee of origin issued for any consignment of renewable gas registered in the database should be cancelled”* (European Commission, 2019). The proposed amendments mentions also that the certification of low-carbon fuels will be addressed in a separate legislative proposal, such as the Hydrogen and Decarbonised Gas Market Package. The recently directive proposal on common rules for the internal markets in renewable and natural gases and in hydrogen (European Commission, 2021c) includes a specific provision on the certification of renewable and low carbon fuels (mentioned in Section 4.1 above). Given the sustainability criteria and additionality issues related to green and low-carbon hydrogen, “traditional” GO schemes as defined by REDII may not be sufficient to meet the necessary tracking requirements. On the other hand two dual systems for tracking production and consumption of green hydrogen, i.e. book & claim based Guarantee of Origin scheme, and a certification scheme based on mass balance approach, together with the Union database for monitoring the production and consumption of these fuels will cause additional efforts and, likely, uncertainty.

The “Fit-for’55” initiative also includes a proposal for a Carbon Border Adjustment Mechanism (CBAM) which is closely linked to revisions to the EU Emission Trading System (EU ETS). The

ETS applies among others to the EU steel industry as well as the production of other industrial products relevant to the production of green steel in the EU (e.g. hydrogen and electricity). The EU Commission's proposal for revisions to the EU ETS (European Commission, 2021b), include among others, the following aspects which are of interest to EU steel producers:

- Reduction of the total ETS allowances in circulation;
- Revision of the benchmark values for free allowances;
- Phase out period of free allocations of ETS allowances to installations operating in a sector that is also covered by CBAM, as steel will be.
- A transitional phasing-out period that will apply between 2026 and 2035 (with the free allocation being reduced by 10% each year).

In general, the revisions to the ETS are designed to gradually drive up the price of ETS allowances, which have already reached levels above 80 EUR/ton by the end of 2021, increasing the costs of ETS compliance for EU steel producers. The revisions to the ETS also propose an expansion of the Innovation Fund Section, which will provide increased funding from the auctioning of allowances (see also Section 4.3). Decisions on the “Fit-for-55” package are still pending.

The “Fit-for-55” legislative proposals have yet to go through EU’s co-legislative procedure. In addition, in November 2021 the EU has announced an agreement with the United States on “green steel” and “green aluminium”, addressing the same issues of CBAM and to be developed until 2023. Against the background of a global level playing field, such bilateral agreements have to be considered as well.

4.3 EU’s research and innovation funding

Scale and learning effects are pivotal in bringing down the cost of electrolysers and the cost of green hydrogen supply. The European Commission has acknowledged that the 2020 EU Hydrogen Strategy’s electrolyser deployment goals for 2024 and 2030, i.e. 6GW and 40GW respectively, will require a strong investment agenda, whilst also exploiting synergies and ensuring coherence of public support across the different EU funds and EIB financing. The EU has initiated a number of new and revised funding schemes of relevance for the further demonstration and upscaling of renewable-based electrolytic hydrogen, such as:

- **EU Innovation Fund**: Focuses on innovative technologies and big flagship projects within the EU focused on significant emission reductions. Assessment of the projects to be funded is done according to GHG emission avoidance, innovation, maturity level, scalability and cost efficiency criteria.
- **Horizon Europe (HEU)**: EU’s key funding programme for research and innovation, running from 2021-2027. HEU’s Cluster 5 “Climate, energy and mobility” of is of particular relevance for hydrogen activities, along with its dedicated Clean Hydrogen Partnership. The Clean Hydrogen Partnership (starting in 2022) will focus on production, distribution and storage of clean hydrogen to supply hard-to decarbonize-sectors, such as the steel industry. Key objectives include: develop technology to enable clean hydrogen production at ~€1.5-3/kg by 2030, with efficiency improvement and lowering CAPEX costs. This also assumes the availability of renewable electricity at favorable prices, as well as allowing penetration into mass markets, and reducing distribution costs to less than €1/kg of hydrogen at scale. €1 billion has been proposed as budget under the Clean Hydrogen Partnership.

- **Important Projects of Common European Interest (IPCEI)**: In December 2020, 22 EU countries and Norway signed a manifesto paving the way for a cleaner hydrogen value chain and committing to launch IPCEIs in the hydrogen sector. The signatories committed to jointly design, and eventually launch, IPCEIs and agreed that projects should cover the full value chain — from renewable and low-carbon hydrogen production to hydrogen storage, transmission and distribution, and hydrogen application notably in industrial sectors[2]. At present, the signatory countries are busy pre-selecting projects that may receive state aid, which in turn need to be approved by the European Commission.

The European Commission has established a 'Hydrogen Public Funding Compass'[3], which is an online guide for stakeholders to identify public funding sources for hydrogen projects, designed as a single entry point for stakeholders to access information on the most important public funding programmes and funds, available at both EU level as well as at EU Member State level, for renewable and low carbon hydrogen.

With regard to the Hydrogen Public Funding Compass, the European Commission highlights, among others, that "*The large number of EU funding instruments that can support hydrogen projects means that EU financing is available for a wide variety of hydrogen activities, ranging from the production of renewable and low-carbon hydrogen to its transmission and distribution, and application in industry and for mobility purposes, among others. Individual projects can obtain funding from several EU funding instruments in combination, provided that there is no double funding of the same costs."*

Against this background, the development of new renewable-based electrolytic hydrogen projects in the EU seems promising given the Commission's upcoming legislative proposals coupled with the multiple sources of EU (and Member State) programmes and funding sources.

[2] See: IPCEIs on hydrogen (europa.eu)
[3] See: Funding guide (europa.eu)

5 Recommendations to support green H_2 and its contribution towards decarbonisation of the steel industries

This chapter presents policy and regulatory recommendations aimed at supporting green hydrogen and its contribution towards decarbonising the steel industry in the EU. The recommendations are based on lessons learned in the H2Future project. Whilst the steel industry has been the focus of the H2FUTURE project, some analysis covering the ammonia/fertiliser industry has also been conducted within the project. As there are no project partners representing the ammonia/fertiliser industry in the project, this section does not include specific recommendations for this sector. Most recommendations presented here are also applicable to the ammonia/fertiliser industry.

The industrial transition from energy intensive processes towards a decarbonised industrial sector is complex. CO_2 intensive production routes will need to be abolished and massive investment into low carbon technologies and production routes will be necessary. Such transformational processes are prone to high investment risks as well as opportunities for all players involved. The policy and regulatory framework can be decisive for the way new markets and new value chains are shaped.

VERBUND and voestalpine have different roles in this upcoming industrial transition. While VERBUND as a renewable energy producer aims to expand its value chain in order to become a producer of renewable hydrogen in the upcoming years, voestalpine is an important part of a possible new hydrogen value chain as an industrial consumer of green hydrogen. Given these different roles, it is evident that – besides many shared views on policy and regulatory recommendations – diverging interests in relation to the market ramp up of green hydrogen persist throughout the transformation phase. These diverging view-points are rooted in the nature of the current and future market roles.

Hence, this chapter presents commonly agreed recommendations in Section 5.1 and recommendations specific to individual H2FUTURE partners in Section 5.2.

5.1 Common recommendations

5.1.1 Ensuring sufficient renewable electricity for the production of green hydrogen

The expansion of renewable electricity assets and associated grid expansion stands out as a major bottleneck for green hydrogen growth. Whilst installing the necessary electrolysers and infrastructure to supply green hydrogen (and to transport it to where it is needed) is in itself a huge and expensive challenge, the supply of green hydrogen is not feasible without the availability of and access to cost-competitive renewable electricity, and thus, eventually, competitive business models for producers and consumers as well.

New renewable electricity generation assets and associated infrastructure will be needed in order to supply green hydrogen at large scale. REDII aims to addresses this by adopting rules for renewable electricity expansion and related support schemes. In order to reflect the need for new renewable electricity given the increased demand for green hydrogen, REDII furthermore introduced the concept of “additionality” for electricity sourcing for renewable hydrogen if counted towards the renewable energy transport obligations, (ref. Art. 25, REDII). Other criteria include renewability; and temporal and geographical correlation.

The ‘additionality’ requirement stems from the notion that green hydrogen should be produced only from additional renewable energy capacity in order to avoid increasing CO_2 intensities in the remaining grid mix due to compensation of the renewable electricity used for hydrogen by fossil-based electricity to cover conventional demand. Failing to ambitiously expand renewable electricity generation capacity would slow down electrification of economic activities with electricity from renewable energy sources that *“is critical for a successful energy transition, and actually cause more fossil fuels to be brought into the power mix.”* (IRENA, 2020).

The REDII criteria also aim to ensure that a given threshold of GHG emission savings are achieved through RFNBO as well ensuring a timely correlation between the renewable electricity production and when it is used in the electrolyser, and that the production of green hydrogen will not be hampered by bottlenecks in the electricity grid. Whilst the above-mentioned restrictions of the REDII are currently aimed at the use of green hydrogen in the transport sectors, the proposed revisions of the REDII suggest an extension of these strict criteria to hydrogen consumed in the industry sector.

While the underlying objective of the “additionality concept”, namely to ensure sufficient new renewable electricity for green hydrogen production without undesired effects on the GHG intensity of the existing grid mix, is commendable especially in an overall, longer term perspective, these strict criteria are a concern for the scale up of electrolytic hydrogen from renewable energy sources. For example, the trade association Hydrogen Europe points out that *“The requirement to prove ‘additionality’, placed solely on the responsibility of RFNBO producers, is the single highest regulatory barrier holding back renewable hydrogen deployment in Europe,”* and calls for any additionality requirements to be deferred until 2025.

With the current REDII binding EU target of 32% renewable energy by 2030 (potentially increasing to 40% according to the proposed revision of REDII), increases in renewable electricity should be scheduled in the Member States’ National Energy and Climate Action Plans (NECPs). However, taking into account also national ambitions for electrolysers and green hydrogen production, it is necessary that Member States revisit and update their NECPs to ensure that sufficient renewable electricity deployment is planned on a transparent, holistic and reliable basis to meet these new ambitions.

H2FUTURE Recommendations

Ensuring sufficient renewable electricity for the production of green hydrogen	THE EUROPEAN COMMISSION should avoid strict criteria for renewable H_2 in terms of eligible electricity supply (e.g. additionality, and temporal & geographical correlation) to allow for the development of green H_2 projects, at least during a transitional period. Since these criteria will also apply to imports of green hydrogen (if counted to the potential industry quota), these criteria need to be feasible in order to allow for industrial decarbonisation. Especially, any restrictive requirements on renewable energy generation for further transformation, such as production of RFNBOs, needs to be avoided in order to minimize the risk of additional hurdles, complexities or uncertainties. Given the fact that the regulatory framework for green hydrogen production is under constant development, first-mover installations such as the H2Future electrolyser face uncertainty on whether they can comply with future criteria. In order to avoid sunk costs, these assets should be protected from retroactive changes in the regulatory framework.

	THE EUROPEAN COMMISSION should take measures to ensure an ambitious expansion of renewable electricity capacities, such as requesting EU Member States to address transparently, holistically and reliably the need for new renewable electricity generating assets to meet their national ambitions for renewable energies, including electrolysers and green hydrogen production, in their NECPs and infrastructure planning. This includes also the expansion of the electricity grid infrastructure in order to ensure system stability.

5.1.2 Facilitating the roll-out of electrolysers

Electricity costs represent a large portion of the cost of running an electrolyser, and taxes and grid fees represent a significant share of the electricity costs (see Chapter 3.1). Partial or full exemption of taxes and grid fees for electrolysers can be used to strengthen the business case for electrolysers and reduce the cost of electrolytic hydrogen. The recast IEM-D allows the European Commission to adopt specific guidelines for network tariffs for energy storage. Kreeft (2017) argues that this would allow for a specific tariff regime that recognizes the contribution of energy storage and power-to-gas to decarbonization and security of supply. In some Member States, such as Austria, tariff exemptions are in place already.

Another significant barrier for the large-scale roll-out of electrolysers are the administrative hurdles to the realization of electrolyser projects, such as permitting processes. These hurdles can cause delays or the cancellation of electrolyser projects that hamper the scaling up of electrolyser technology on the short term.

H2FUTURE Recommendations:

Facilitating the roll-out of electrolysers	THE EUROPEAN COMMISSION AND EU MEMBER STATES should allow for exempting electrolysers from taxes and fees as a first move to reduce the cost of electrolytic hydrogen from renewable electricity.
	THE EUROPEAN COMMISSION AND EU MEMBER STATES should introduce further measures to reduce administrative hurdles for electrolyser projects (e.g. permitting process, timeline for large scale projects).

5.1.3 Enabling decarbonisation of the steel industry

Green hydrogen-based direct reduction DR(H_2)/EAF steel production is a key technology for the decarbonization of the steel industry. As illustrated in Chapter 3 the costs of green hydrogen-based steel depend strongly on electricity costs. The business case of green hydrogen-based steel improves relative to BF-BOF steelmaking with increasing carbon dioxide prices. The success of green hydrogen-based steel is therefore dependent on the continuing political momentum for measures such as carbon dioxide pricing and the proposed carbon border tax. Furthermore this also depends on the economic availability of green hydrogen and the corresponding support (e.g. carbon contracts for difference). On the other hand, the introduction of a carbon border tax adjustment measure (CBAM) creates uncertainty for sectors prone to carbon leakage, such as the iron and steel industry, that currently receive free allocation of ETS allowances.

The shift to green steel production will also require significant investments from the steel sector to replace and upgrade existing steelmaking facilities. The income from CO_2-pricing mechanisms can be used to facilitate the technological switch by enabling access to funding for the required investments and decarbonisation projects in the iron and steel industry.

H2FUTURE Recommendations:

Enabling decarbonisation of the steel industry	In contrast to the current situation where EU MEMBER STATES are asked to spend at least half of the returns from the ETS to support GHG emissions abatement, the EUROPEAN COMMISSION should ensure that all of the revenues from allowance auctions support decarbonization projects including projects in the iron and steel industry.
	EU MEMBER STATES should earmark funds from CO_2 pricing instruments for investments in carbon-leakage exposed sectors and decarbonization projects (e.g. national innovation and transition funds), especially in energy intensive industrial sectors, with a great potential for CO_2 savings, and for provision against non-competitive operating costs e.g. by implementing carbon contracts for difference.

5.1.4 Cross-cutting issues related to the creation of a market for green hydrogen

General framework conditions

As mentioned, dynamic policy and legislative developments are taking place in view of the European Green Deal's net-zero ambitions. However, a stable regulatory framework for hydrogen in the EU is required to attract necessary investments, whereby incentives to reduce the cost of electrolysers are one of the most important issues for the future of green hydrogen. Without a stable policy and regulatory framework, preferably with clear targets and supporting instruments, private sector will not be willing to leverage investments.

Green Public Procurement

There are ample opportunities for energy and infrastructure companies to grow their business by focusing on 'green' hydrogen, however, risks and uncertainties are still high. Also, the green hydrogen and green steel markets remain in their infancy. To help stimulate these markets, and in particular, the demand for green hydrogen, additional measures are needed to complement existing or proposed measures (e.g. fuel mandates, targets on share of consumption). One example is the use of public procurement requirements and standards. Green public procurement (GPP) is an important policy tool that is gaining a lot of traction. With GPP, public authorities can use their purchasing power to procure goods and services with reduced carbon footprint. GPP policies can take many forms, for example preferential buying obligations, e.g. "green" steel for public infrastructure projects. It is also possible to consider procurement alliances between countries to catalyse large-scale demand and/or procure 'green' steel for large cross-border infrastructure and/or IPCEI projects. Green fertilizer is another important lead market for green hydrogen. GPP could also cover obligations to purchase "green" fertilizer in public agricultural projects.

Accelerating the demand for green hydrogen is, besides the availability of green hydrogen at internationally competitive conditions, essential for the creation of a green hydrogen market. Without demand, there will be no incentives to generate supply. To stimulate markets, industrial policies at the EU and Member State level could incorporate, among others, GPP policies to help stimulate the creation of lead markets for green hydrogen and associated value chains, such as green steel in mobility, infrastructure and buildings, green fertilizer, fuel cell trucking, green hydrogen in refineries and petrochemicals, and green shipping.

H2FUTURE Recommendations:

General framework	THE EUROPEAN COMMISSION AND EU MEMBER STATES need to ensure stable framework conditions and investment and planning security for the scale-up of a H2 economy (Avoidance of constant changes in the regulatory framework).
	THE EUROPEAN COMMISSION AND EU MEMBER STATES should make use of public procurement and implementation of procurement standards to help stimulate uptake of green H2, e.g. for “green” steel in public infrastructure projects and “green” fertilizer in public agricultural projects.
	THE EUROPEAN COMMISSION AND EU MEMBER STATES should broaden industrial policies to include the creation of lead markets for green hydrogen and associated value chains including green steel.

Certification/Guarantees of Origins

It is necessary to be able to document the sustainability characteristic of green hydrogen. As mentioned above, the debate on sustainability criteria (additionality, etc.) is still ongoing at the time of writing. While it is to be expected that an EU wide definition for sustainability criteria will be adopted either by the REDII Delegated Act or by adopted amendments to REDII, the criteria in question and their scope (transport sector or entire industry) are still heavily disputed. Currently, certification and GOs can provide proof that renewable electricity has been used to produce green hydrogen, which in turn provides consumers with confidence in the renewable nature of the hydrogen.

Putting in place a robust and comprehensive EU-wide guarantees of origin (GO) or a similar single scheme, in contrast to a rigid “certification scheme” bound to physical transfers, could help to promote demand for green hydrogen. Such a scheme can enable correct markets signals related to the willingness to pay for green hydrogen. A GO scheme based on ‘book & claim’ approach has several advantages compared to a ‘mass balance – chain of custody’ approach, such as increased liquidity and tradability, easier to implement than mass balancing, and compatibility with electricity market. Despite the REDII’s provision to include renewable gases (including hydrogen) in the Member States’ GO schemes, only few Member States have taken any real action to do so. For example, in Austria, a labelling ordinance for gas suppliers is already in place. There are several voluntary schemes in place (e.g. CertifHy). A few voluntary European certification schemes for green hydrogen have been established; such as CertifHy, Low Carbon Fuel Standard, TÜV SÜD Standard. Certification bodies have started a discussion on how to upgrade their certificates to comply with new regulatory requirements. However, a key challenge will be to avoid multiple systems working in parallel as this could potentially confuse all stakeholders, including end-users, hamper cross-border trade and increase risk of double-counting.

An important prerequisite for certification and GO schemes is a clear set of definitions for different types of hydrogen. Definitions presented in the EU Hydrogen Strategy in July 2020 are an important starting point (see Annex II), however, these definitions do not sufficiently distinguish between the different 'shades' of hydrogen. Currently, there are no internationally recognised ways of differentiating green from grey hydrogen (IRENA, 2020). There is also a need for consistency between green electricity, hydrogen and biomethane standards due to the potential bidirectional flows between the different energy carriers. This is particularly relevant when dealing with renewable electricity GOs or biomethane GOs to validate the production of green hydrogen (Velazquez, 2020).

As regards existing regulations on GOs, REDII contains rules about the expansion of the GO scheme for renewable electricity to cover renewable gas, including hydrogen. Once in place, a GO scheme for green hydrogen could create an extra revenue stream for the electrolyser plant. Despite REDII setting rules for GOs, these rules are not complete and linked to other parts of the REDII, such as the role of RFNBO and how these will be treated in relation to the transport targets mentioned in the directive. The GO schemes to be implemented in Member States for green hydrogen may be linked to certification schemes that could be used to prove the renewability of RFNBOs. The European Commission has yet to present two Delegated Acts (due end of 2021) further specifying the treatment of RFNBOs, i.e. establishing a methodology for treating synthesised fuels as fully renewable, and a methodology for assessing the greenhouse gas emission savings delivered by RFNBOs.

CertifHy[4], as the first voluntary EU-wide GO system for green and low-carbon hydrogen in Europe, could represent a starting point for setting up a (combined) GO and certification framework for green hydrogen in Member States. However, in order to be accepted by policy makers in Member States, the criteria and standards applied to the CertifHy GOs will need to be evaluated, and potentially modified to meet Member States' requirements as well as meeting the REDII requirements, e.g. 70% reduction in GHG intensity. Currently, the CertifHy scheme applies a 60% reduction in GHG intensity compared to hydrogen production from natural gas. To be acknowledged by the European Commission, the CertifHy GHG emissions reduction threshold would have to be aligned with the REDII (and any potential revisions to REDII).

H2FUTURE Recommendation:

Certification/GOs	THE EUROPEAN COMMISSION AND EU MEMBER STATES should enforce the implementation of a full certification and disclosure scheme for all energy carries on the basis of a book & claim system. The scheme should allow for transferring the green property from one energy carrier to another energy carrier and eventually attributing it to the final end product. This GO scheme should be harmonised at EU level, be fraud-resistant, avoid double counting and allow for the inclusion of H_2 imports in the long run. H_2 certification should include emissions from the energy value chain, including upstream emissions. Establish off-grid certificates for H_2 produced in off-grid installations (i.e. in industrial sectors) in order to incentivize a technology switch.

R&D/deployment funding schemes

[4] See: https://www.certifhy.eu/

To date, R&D support through the FCH-JU has been important for the advancement of electrolysis technology and reductions in investment costs to date. H2FUTURE has successfully benefitted FCH-JU funding, achieving also positive impacts to the development of green hydrogen towards the energy transition. To meet the European Green Deal ambitions, also in view of economic recovery from COVID-19, a series of new funding schemes at EU level have been implemented, which should include the promotion of green hydrogen. Naturally, continued R&D support is important for achieving further reductions in investment (CAPEX) and operational (OPEX) costs. In particular, reducing investment risk is an additional opportunity to increase deployment of electrolysers and achieve cost reductions. R&D support is also important to optimize/further improve current technology and to develop next generation technology that in time will lead to a further reduction of investment cost and/or operational cost.

However, a number of crucial aspects are necessary to consider in the further R&D funding of electrolytic hydrogen. These are linked to deployment funding, including market introduction and development, and upscaling of existing technology, previously developed with R&D funding. Examples include value chain issues, the need for harmonizing EU funding with Member State funding programmes, introduction of new instruments to support decarbonisation efforts, e.g. carbon contracts for difference (CCfD) and, last but not least, EU state aid guidelines and associated rules in general.

H2FUTURE Recommendations:

R&D/deployment funding schemes	THE EUREOPEAN COMMISSION currently revises EU State aid guidelines for - amongst others - environmental protection and energy to ensure/allow for an effective funding of investments (e.g. direct funding of breakthrough-technologies and pilot projects) and compensation of higher operating costs for industrial implementation of innovative low-carbon processes and utilization of renewable energies as well as green H_2. To allow for cost-efficient funding of operating costs, funding systems should be designed adequately, e.g. via competitive tendering or via Carbon Contracts for Difference (CCfD).
	Sufficient funds for the co-funding of EU subsidies must be guaranteed by MEMBER STATES, which are intended for the generation of renewable H2 as well as for the development of H_2 infrastructure, for its storage and - potentially in the long run - re-electrification. Any obstacles for combining EU and national funds should be removed.
	To overcome the valley of death from R&D to mass deployment, it is necessary that funding/co-financing follows a value-chain approach. Firstly, it is necessary to ensure secured access to funding programmes for various technology levels (development of technologies, upscaling, implementation and operation). Secondly, funding options should not be limited to single calls, but should be planned and set up for the entire value chain for a number of subsequent years (to ensure planning reliability especially for large scale innovative projects).
	THE EUROPEAN COMMISSION AND EU MEMBER STATES should ensure early and sufficient information on (upcoming) funding schemes to provide enough time for project development, especially for large scale demonstration projects. One stop shop funding support, streamlined guidelines on national

	and EU level (regarding combination of funding instruments, eligibility of costs, but also documentation, reporting and audit) should be established. Harmonised guidelines on eligibility of costs are particularly important, since policy instruments such as the IPCEI initiative might reinforce competition between green hydrogen projects. This is without prejudice to the importance of the IPCEI initiative as an important industrial policy tool for market development.
	THE EUROPEAN COMMISSION should promote cost reduction of electrolysers by scaling up instruments to help close investment & operational cost gaps, such as R&D funding, de-risking instruments (concessional loans, grants, etc).

Reliable rules including standards

The value chain of the green hydrogen consists of several elements; namely, electrolysis and reliable access to renewable electricity, transport and storage of green hydrogen, and its distribution to end users. New reliable rules are needed to ensure the commercialization of a green hydrogen value chain that contributes to EU and global decarbonisation goals. For example, new reliable rules are needed for the definition and characterization of green hydrogen. Concerning the latter, reliable rules are needed for GHG emission accounting and thresholds (see Section 4.2). Given the ambition, and necessity, of many countries to import/export green hydrogen (i.e. cross-border trade), reliable rules including standards for green hydrogen will need to be recognized across EU Member States as well as internationally. A multitude of standardization efforts are currently developed or in the process of being developed (Velazquez Bad, 2020), however, a harmonization effort will be required in order to facilitate cross-border trade.

H2FUTURE Recommendation:

Reliable rules including standards	Harmonization of reliable rules and standards for green H_2 plants, applications and production on international level, as well as harmonization of national and European safety and environmental as well as sustainability standards. This should, first and foremost, be ensured by THE EUROPEAN COMMISSION.

5.2 Sector specific recommendations

5.2.1 Recommendations from the perspective of the steel industry (voestalpine)

For a successful transformation towards climate neutrality, especially industry needs low-carbon energy and according input materials, including green hydrogen, in sufficient quantities at internationally competitive prices. Therefore, increasing costs for any input only hampers investments and progress by increasing OPEX than paving the way to decarbonisation. Rather on the contrary, green H_2 needs to be made available at internationally competitive conditions. This means that the pledge for the cancellation of the free allocation for e.g. grey hydrogen cannot be supported while no reliable provisions to secure urgently required green electricity and green hydrogen at internationally competitive conditions have been comprehensively implemented.

However, this could be achieved, besides innovation and developments, by removing levies and tariffs on renewable energies as wells as enabling long term demand for large volumes by supporting according uptake, contracts and investments.

Furthermore, it should be noted that the achievement of targets on the integration of renewable and low carbon energy in the European industrial sector requires inevitably the deployment of the required amount of renewable and low carbon electricity and hydrogen at large scale, making them available reliably at cost-competitive prices, and realising the required infrastructure (i.e., for all gases and electricity). Any measure should be set via holistic, transparent, reliable and realistic assessments of the demand, supply, and infrastructure needs, comprehensively including the targeted sectors. The international competitiveness of industrial energy users as well as their products and services needs to be taken fully and as explicit priority into account, in addition to other determining criteria.

Another essential activity for maintaining our global competitiveness concerns the discussion about the introduction of a CBAM. Therefore the European Commission should ensure the implementation of an effective carbon border adjustment mechanism (CBAMs) in order to ensure an equivalent level of protection for energy intensive industries and power generation inside and outside Europe. EC should ensure that measures are implemented to guarantee a comprehensive, detailed determination of the CO_2 emissions embedded in the imported goods from non-EU countries in order to ensure a fair competitiveness between importers outside of the EU and producers inside the EU subjected to the CBAM taxes. Given the level of legal and regulatory uncertainty, which such a new mechanism entails, care should be taken to ensure that the level of protection of sectors prone to carbon leakage is guaranteed also in the CBAM implementation phase, i.e. by continuing free allowances under the Carbon Leakage list until the effectiveness of the CBAM is proven. For this reason, the current practice of ETS allowances, especially the free allocation, for the steel industry needs to be continued at least at the level for which the effectiveness of the CBAM cannot be proven in order to enable an international level playing field in terms of climate change related costs.

In conclusion, it should be noted that the ambition for promoting the consumption of renewable energies and renewable fuels of non-biological origin (RFNBOs) in industry should be assessed and further developed on the overall ambition of climate neutrality together with other relevant legal acts, such as the EU ETS, the Renewable Energies Directive RED, the Energy Efficiency Directive EED or the EU Gas Framework since the legal framework for a hydrogen market, its value chains and the adequate infrastructure needs yet to be defined. Such a holistic approach to impact assessments, planning and implementation should also apply to all the other relevant legal provisions and be performed by continuous integration, taking EU-wide und international competitiveness fully into account.

5.2.2 Recommendations from the perspective of the energy utility (VERBUND)

Conventional hydrogen as a carbon leakage sector

The production of conventional (grey) hydrogen is currently classified as a carbon leakage sector. This means that steam methane reformers which produce grey hydrogen receive free allowances for their emissions and will continue to do so until 2030. Even a rising CO_2 price can thus not deliver a steering effect towards a clean technology option such as renewable hydrogen, as the CO_2 price has no effect on the production of grey hydrogen.

For the production of renewable hydrogen, however, this remains a serious problem, as the relative competitiveness of renewable hydrogen compared to grey hydrogen is weakened. Renewable hydrogen has to compete with a fossil product which receives a counter-productive subsidy, namely free allocations of CO_2 allowances. VERBUND is of the opinion, that conventional hydrogen needs to be removed from the Carbon Leakage list in order to create a level playing field for renewable hydrogen.

The ‘Fit for 55’ legislative package has identified the free allocations for SMRs as a field for action and has proposed a mitigation measure in the proposal for a revision of the EU ETS, i.e. to allocate free allowances also to large electrolysers producing renewable hydrogen. While such a measures would potentially mitigate the competitive disadvantage for green hydrogen, VERBUND believes that on a systemic level, the allocation of free allowances for non-emitting technologies is a step away from achieving true costing.

Renewable hydrogen quota for industry

VERBUND welcomes the introduction of the 50% quota for renewable hydrogen end use by 2030 in the proposal for the REDIII. This is an important lever for a market ramp up and can contribute significantly to achieving the objectives of the EU hydrogen strategy. Demand-side measures are indispensable for a market ramp up. In order to address availability concerns by hydrogen end users, it is important to note that the strict production criteria (sustainability criteria) for renewable hydrogen (additionality, regional and temporal correlation etc.) need to be designed in such a way that production can actually be achieved in adequate quantities and at reasonable costs. This is of particular importance, as the production criteria will also be applied to the imports of renewable hydrogen.

6 Conclusions

With the European Green Deal, the EU has set itself an ambitious goal to be the first continent to achieve carbon-neutrality by 2050. In addition, it should be mentioned that Austria would like to take a more ambitious path and be carbon-neutrality by 2040. An important stepping stone towards this target is the recent decision by the European Council to increase EU's 2030 GHG emissions reduction target from 40% to 55%. Decarbonisation objectives are a key driver for the development of electrolytic hydrogen based on renewable electricity.

Green hydrogen offers a decarbonisation pathway for the steelmaking industries. An option for decarbonising the steel industry is the replacement of the BF/BOF process with the DR/EAF process coupled with green hydrogen.

For green hydrogen to play a significant role in the energy market, the policy framework needs to ensure sufficient generation of renewable electricity for the production of green hydrogen. In fact, a scaling up of green hydrogen would require increasing the availability of renewable electricity in the overall EU electricity grid mix, as well as sufficient renewable electricity assets to feed renewable electricity to electrolysers. Overcoming the barriers and transitioning green hydrogen from a niche player to a widespread energy carrier will also require dedicated policies in each of the stages of technology readiness, market penetration and market growth (IRENA, 2020). PEM electrolysiers, such as the one used in the H2FUTURE project, is already a proven technology. Despite successful demonstration projects, such as in the H2FUTURE project, electrolysers still faces high investment costs.

The cost of green hydrogen is mainly determined by the electrolyser investment costs and the cost of electricity. The costs of hydrogen decrease at higher operating hours, as the impact of investment costs on the total cost decreases. Ensuring sufficient operational hours, in addition to the availability of renewable electricity, is therefore important. At higher operational hours the share of electricity costs in total hydrogen costs increases; making it more relevant to look at lowering the costs of electricity for electrolyser plants. The business case for hydrogen use in steelmaking and fertilizer industry improves by lowering electrolyser costs, electricity costs as well as costs for according inputs and/or increasing the international CO_2 price. PEM electrolysers also have the possibility to operate on the balancing market, creating possible additional revenue streams. Additional instruments, such as certificates and GOs which document the source and sustainability of the green hydrogen, can also open and create additional markets and revenue for electrolyser operators.

Today's regulatory frameworks offers many measures to improve the uptake of electrolysers for green hydrogen production. In December 2020, the European Council adopted conclusions[5] on steps to be taken towards creating a hydrogen market for Europe and the aim *"to build an integrated energy system fit for climate neutrality and outlining a hydrogen roadmap for the EU with objectives for, among others, electrolyser upscaling and deployment, improving cost-competitiveness of hydrogen in particular produced by electrolysis, a corresponding investment agenda, proposals for boosting supply and demand and elements for a market and infrastructure framework, all embedded in a holistic view of the potentials of stronger synergies between the energy carriers and end-use sectors."*

In its conclusions, the Council asks the Commission to further elaborate and operationalise the EU Hydrogen Strategy, and in particular invites the Commission to outline a pathway towards the objectives of installing at least 6 GW of renewable hydrogen electrolysers in the EU by 2024 and 40 GW by 2030. As input to the Commission's follow-up, we present here a set of recommendations for improving the policy framework, based on the results from the demonstration of the 6MW electrolyser of the H2FUTURE project. Our recommendations are based on the premise that both dedicated demand-pull and supply-push incentives are needed to kick-start a market for green hydrogen as well as for green steel, and a strengthening and adjustment of measures and incentives are needed to help bring down the cost of green hydrogen.

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8 ANNEX I: Highlights and definitions of hydrogen presented in the EU Hydrogen strategy for a climate-neutral Europe (COM(2020) 301 final)

Important highlights from the EU Hydrogen Strategy:

- Proposes ambitious targets for targets for 6GW and 40GW installed electrolyser capacity by 2024 and 2030 respectively.
- Presents a set of definitions for hydrogen, comprising ‘electricity based hydrogen’, ‘renewable hydrogen’, ‘fossil based hydrogen’, ‘low carbon hydrogen’, and ‘hydrogen-derived synthetic fuels’.
- Identifies two main lead markets for boosting a hydrogen demand; firstly, industry where priority uses of hydrogen will be close to the point of production in existing carbon-intensive industrial applications, where electrification will be difficult, and secondly, transport applications where electrification is expected to be difficult, i.e. heavy duty vehicles, aviation and maritime transport.
- Additional government support is needed for investments in scaling up renewable and low carbon hydrogen demand and supply.
- Acknowledges the potential role of low-carbon hydrogen from fossil fuels, at least for a transition period on the journey to the ultimate target of renewable hydrogen.

Important highlights from the EU Energy System Integration Strategy:

- Mimics the EU Hydrogen strategy’s clear message that EU’s priority is to develop hydrogen production from RES-E. However, acknowledges that in a transitional phase, other forms of low-carbon hydrogen are also needed to replace existing hydrogen and kick-start an economy of scale.
- Introduce a comprehensive terminology and a European certification system covering all renewable and low carbon fuels. Such a system, based notably on full life cycle GHG emissions savings, will allow for more informed choices when deciding on policy options at the EU or national level.
- Commission plans to develop certification proposals, which would include European-wide criteria for the certification of renewable and low carbon hydrogen, by June 2021.
- Proposes to develop a regulatory framework for the certification of carbon removals based on robust and transparent carbon accounting to monitor and verify the authenticity of carbon removals (by 2023)
- Proposes demonstration and scaling-up the capture of carbon for its use in the production of synthetic fuels, possibly through the Innovation Fund (from 2021)
- Promote the financing of flagship projects of integrated, carbon-neutral industrial clusters producing and consuming renewable and low-carbon fuels, through different EU-funding programmes, such as ETS Innovation Fund, Horizon Europe, InvestEU and LIFE programmes and the European Regional Development Fund (from 2021)
- Consider additional measures to support renewable and low-carbon fuels, possibly through minimum shares or quotas in specific end-use sectors (incl. aviation and maritime), through the revision of REDII and building on its sectoral targets (June 2021), complemented, where appropriate, by additional measures assessed under the REFUEL Aviation and FUEL Maritime initiatives (2020).

Definitions presented in the 2020 EU Hydrogen Strategy:

'Electricity-based hydrogen' refers to hydrogen produced through the electrolysis of water (in an electrolyser, powered by electricity), regardless of the electricity source. The full life-cycle greenhouse gas emissions of the production of electricity-based hydrogen depends on how the electricity is produced.

'Renewable hydrogen' is hydrogen produced through the electrolysis of water (in an electrolyser, powered by electricity), and with the electricity stemming from renewable sources. The full life-cycle greenhouse gas emissions of the production of renewable hydrogen are close to zero. Renewable hydrogen may also be produced through the reforming of biogas (instead of natural gas) or biochemical conversion of biomass, if in compliance with sustainability requirements.

'Clean hydrogen' 'refers to renewable hydrogen.

'Fossil-based hydrogen' refers to hydrogen produced through a variety of processes using fossil fuels as feedstock, mainly the reforming of natural gas or the gasification of coal. This represents the bulk of hydrogen produced today. The life-cycle greenhouse gas emissions of the production of fossil-based hydrogen are high.

'Fossil-based hydrogen with carbon capture' is a subpart of fossil-based hydrogen, but where greenhouse gases emitted as part of the hydrogen production process are captured. The greenhouse gas emissions of the production of fossil-based hydrogen with carbon capture or pyrolysis are lower than for fossil-fuel based hydrogen, but the variable effectiveness of greenhouse gas capture (maximum 90%) needs to be taken into account.

'Low-carbon hydrogen' encompasses fossil-based hydrogen with carbon capture and electricity-based hydrogen, with significantly reduced full life-cycle greenhouse gas emissions compared to existing hydrogen production.

'Hydrogen-derived synthetic fuels' refer to a variety of gaseous and liquid fuels on the basis of hydrogen and carbon. For synthetic fuels to be considered renewable, the hydrogen part of the syngas should be renewable. Synthetic fuels include for instance synthetic kerosene in aviation, synthetic diesel for cars, and various molecules used in the production of chemicals and fertilisers. Synthetic fuels can be associated with very different levels of greenhouse gas emissions depending on the feedstock and process used. In terms of air pollution, burning synthetic fuels produces similar levels of air pollutant emissions than fossil fuels.