EUROPEAN
COMMISSION

Brussels, XXX
[...](2020) XXX draft

SENSITIVE*

COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS

Building a hydrogen economy for a climate-neutral Europe. A strategic roadmap.

1. INTRODUCTION – WHY WE NEED A STRATEGIC ROAD MAP FOR HYDROGEN

Hydrogen is enjoying a renewed and rapidly growing attention in Europe and around the world. Hydrogen can be used as a feedstock, a fuel or an energy carrier and storage, and has many possible applications across industry, transport, power and buildings sectors. Most importantly, it does not emit CO2 when used. It thus offers a solution to decarbonise industrial processes and economic sectors where reducing carbon emissions is both urgent and hard to achieve. This makes hydrogen essential for the global effort to reach climate neutrality and implement the Paris Agreement.

Yet, today, hydrogen represents a modest fraction of the global and EU energy mix, and is still largely produced from fossil fuels[1],· notably from natural gas or from coal, and the resulting carbon dioxide - 70 to 100 million tonnes annually - is released into the atmosphere. For hydrogen to contribute to climate neutrality, it needs to achieve a far larger scale and its production must become fully decarbonised.

In the past, hydrogen knew already peaks of interest, but it did not take off. Today, the rapid cost decline of renewable energy, technology developments and the urgency to drastically reduce greenhouse emissions, are opening up new possibilities for renewable and low-carbon hydrogen.

Every day new investments are announced, often on a GW scale. Between November 2019 and March 2020, market analysts increased the list of planned global investments from 3,2 GW to 8,2 GW of electrolysers by 2030 (of which 57% in Europe). Japan, has announced that the next Olympic Games will be "hydrogen Olympics". The number of countries joining the International Hydrogen Council has grown from 13 in 2017 to 60 today. Many indicators signal that we are close to a tipping point

There are many reasons why hydrogen is a key priority to achieve the European Green Deal and Europe's clean energy transition. Renewable electricity is expected to decarbonise a large share of the EU energy consumption by 2050, but not all of it. Hydrogen has a strong potential to bridge some of this gap also as a vector for renewable energy storage and transport, ensuring back up for seasonal variations and connecting production locations to more distant demand centres. In the European Commission's Long Term Decarbonisation Strategy[2], the share of hydrogen in Europe's energy mix is projected to grow from the current less than 2%[3] to 13-14% by 2050.

Furthermore, hydrogen can replace fossil fuels in in some carbon intensive industrial processes, such as in the steel or chemical sectors, lowering greenhouse gas emissions and boosting global competitiveness for those industries. It can offer solutions for hard to abate parts of the transport system, beyond what can be achieved through biofuels. A progressive uptake of hydrogen solutions can also lead to repurposing or re-using of existing natural gas infrastructure avoiding stranded assets. Cumulative investments in renewable hydrogen in Europe could be up to EUR 180 billion by 2050[4], and in the range of EUR 3-18 billion for low-carbon fossil-based hydrogen. Combined with EU's leadership in renewables technologies, the emergence of a hydrogen value chain serving a multitude of industrial sectors and other end uses could employ up to 1 million people, directly or indirectly.

In the integrated energy system of the future hydrogen will be one of the elements, alongside renewable electrification and a more efficient and circular use of resources. Yet, large-scale deployment of clean hydrogen at a fast pace is key for the EU to achieve a higher climate ambition, reducing greenhouse gas emissions by minimum 50% and towards 55% by 2030, in a cost effective fashion.

Moreover, Europe is highly competitive in clean hydrogen technologies manufacturing and is well positioned to benefit from a global development of clean hydrogen as an energy carrier. Analysts[5] estimate that clean hydrogen could meet 24% of energy world demand by 2050, with annual sales in the range between EUR 200 billion to EUR 700 billion. However, today clean hydrogen is not yet cost competitive and substantially more expensive than fossil-based hydrogen

To harness all the opportunities associated with hydrogen economy, the European Union needs a strategic approach. The EU industry is rising to the challenge and has developed an ambitious plan to reach 2x40 GW of electrolysers by 2030[6]. Almost all Member States have included plans for clean hydrogen in their National Energy and Climate Plans and 26 of them signed up to the "Hydrogen Initiative[7]". Some have already adopted national strategies or are in the process of adopting one. But developing a clean hydrogen economy in Europe faces important challenges that neither the private sector nor Member States can address alone. Driving hydrogen development past the tipping point needs an investment critical mass to ensure market scale, an enabling regulatory framework, sustained research and innovation bringing solutions to the market, an infrastructure network that only the EU Single Market can offer and cooperation with our third country partners. All actors, public and private, at European national and regional level, must work together, across the entire value chain, to build a dynamic hydrogen ecosystem in Europe.

In order to implement the climate ambition of the European Green Deal[8] and building on the Commission's *New Industrial Strategy for Europe*[9] and its Next Generation EU recovery plan[10], this Communication sets out a vision of how the EU can turn clean hydrogen into a viable solution to decarbonise different sectors over time, producing [1] million tonnes of renewable hydrogen in the EU by 2024 (with 4 GW[11] of renewable hydrogen electrolysers installed by then) and [10] million tonnes by 2030 (with 40 GW[12] of renewable hydrogen

[4] IRENA estimates that to achieve the Paris agreement around 8% of global energy consumption will be provided by hydrogen (IRENA, Global Renewables Outlook, 2020).
[5] Source needed
[6] 40 GW in Europe and 40 GW in Europe's neighbourhood with export to the EU
[7] Linz declaration, 17-18 September 2018. https://www.eu2018.at/calendar-events/political-events/BMNT-2018-09-17-Informal-TTE.html
[8] COM(2019) 640 final
[9] COM(2020) 102
[10] 'Europe's moment: Repair and Prepare for the Next Generation', COM(2020) 456 final.
[11] [or 0,5 million tonnes of renewable hydrogen]
[12] [or 5 million tonnes of renewable hydrogen]

electrolysers installed by then). This Communication identifies the challenges to overcome, lays out the levers that the EU can mobilise and presents a roadmap of actions for the coming years.

As investment cycles in the clean energy sector run for about 25 years, the time to act is now. This Strategic roadmap provides the policy frame within which the **Clean Hydrogen Alliance**, a collaboration between public authorities, industry and civil society, launched at the same time, will develop an investment agenda and a pipeline of concrete projects. It complements the **Strategy for Energy System Integration**[13], which describes how the ongoing work streams of EU energy policy, including hydrogen development, will bring a climate neutral energy system with renewable electricity, circularity and renewable and low-carbon fuels at its core.

2. ADVANCING TOWARDS A HYDROGEN ECONOMY IN EUROPE: A ROADMAP TO 2050

The different ways to produce hydrogen, their greenhouse gas emissions and their relative competitiveness

Hydrogen may be produced through a variety of processes. These production pathways are associated with a wide range of greenhouse gas emissions, depending on the technology and energy source used and have different costs implications and material requirements. In this Communication:

- **'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 greenhouse gas emissions of the production of electricity-based hydrogen can be high and low[14], depending on the greenhouse gas contents of the electricity used.
- **'Renewable hydrogen'** refers to hydrogen produced through the electrolysis of water (in an electrolyser, powered by electricity), and with the electricity stemming from renewable sources. The full life greenhouse gas emissions of the production of renewable hydrogen are close to zero[15].
- **'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 full life greenhouse gas emissions of the production of fossil-based hydrogen are high[16].
- **'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 CCS or pyrolysis are lower than for fossil-fuel based hydrogen, but the variable effectiveness of full life greenhouse gas capture (maximum 90%) needs to be taken into account[17].
- **'Clean hydrogen'** refers to renewable hydrogen.

13

14 The well-to-gate greenhouse gas emissions for the EU energy mix are 8.9 kgCO2eq/kgH2.

15 (Specify GHG emissions for this production pathway)

16 The well-to-gate greenhouse gas emissions of steam reforming of natural gas are 10-11 kgCO2eq/kgH2

17 The well-to-gate greenhouse gas emissions of steam reforming of natural gas with CCS with 90% capture are 3 kgCO2eq/kgH2.

- **'Low-carbon hydrogen'** encompasses fossil-based hydrogen with carbon capture and electricity-based hydrogen.

Renewable hydrogen, in particular from wind and solar, is the most compatible option with the EU's climate neutrality goal in the long term and is the priority focus of this EU Strategic Roadmap. The choice for renewable hydrogen builds on European industrial strength in electrolyser production, will create new jobs and economic growth within the EU and support a cost-effective integrated energy system. **In the short and medium term, however, low-carbon fossil-based hydrogen will also play a role**, primarily to rapidly reduce emissions from existing hydrogen production and support the parallel and future uptake of renewable hydrogen.

Today, neither renewable hydrogen nor low-carbon fossil-based hydrogen are cost-competitive against fossil-based hydrogen. Estimated costs today for fossil-based hydrogen with CCS are around [2.5] €/kg; renewable hydrogen [2.5-5] €/kg versus 1.5-1.7 €/kg for fossil-based hydrogen[18]. Carbon prices in the range of EUR€55-90 per tonne of CO_2 would be needed to make low-carbon fossil-based hydrogen competitive with fossil-based hydrogen today. Costs for renewable hydrogen are going down quickly, and are expected to become competitive with fossil-based hydrogen by 2030[19]. Electrolyser costs have already been reduced by 60% in the last ten years, and are expected to halve in 2030 compared to today with economies of scale.[20] In areas where renewable electricity is cheap, electrolysers are expected to be able to compete with fossil-based hydrogen in 2030. These elements will be key drivers of the progressive development of hydrogen across the economy.

Building a hydrogen economy: a roadmap for the EU

A clean hydrogen economy is **likely to develop through a gradual trajectory**, at different speed across sectors and possibly across regions within the EU and requiring different policy solutions.

In the first phase, from 2020 up to 2024, the EU strategic objective is to promote the production of **[1] million tonne of renewable hydrogen, with at least 4 GW of renewable hydrogen electrolysers installed by then,** to decarbonise existing hydrogen production, e.g. in the chemical sector and facilitating take up of hydrogen consumption in new end-use applications such as other industrial processes and heavy-duty transport. This will reduce greenhouse gas emissions in the short term in view of the increased 2030 climate ambition and prepare end-use sectors for future demand.

In this phase, existing hydrogen production plants should be decarbonised by retrofitting them with carbon capture and storage technologies and manufacturing of electrolysers, including

18 ADD source

19 Assuming current electricity and gas prices, low-carbon fossil-based hydrogen is projected to cost in 2030 between €2.2-2.5/kg in the EU, and renewable hydrogen are projected to cost between €1.1-2.4/kg (IEA, IRENA, BNEF).

20 Based on cost assessments of IEA, IRENA and BNEF. Electrolyser costs to decline from EUR 900/kW to EUR 450/KW or less in the period after 2030, and EUR 180/kW after 2040. Costs of CCS increases the costs of natural gas reforming from EUR 810/kWh2 to EUR 1512/kWh2. For 2050, the costs are estimated to be EUR 1152/kWh2.

large ones (up to 100 MW), needs to be scaled up, with the necessary public support. These electrolysers could be installed next to existing demand centres in larger refineries, steel plants, and chemical complexes. They would preferably be powered directly from local renewable electricity sources. In addition, first applications in heavy-duty transport, such as buses and trucks, will be incentivised. Electrolysers will thus also be needed to locally supply an increasing number of hydrogen refuelling stations.

Infrastructure needs will remain limited as demand will be met initially by production close or on site and in certain areas blending with natural gas might occur, but planning of medium range and backbone transmission infrastructure should begin.

The policy focus will be on laying down the regulatory framework for a liquid and well-functioning hydrogen market and on incentivising both supply and demand in lead markets, including through bridging the cost gap between conventional solutions and renewable and low-carbon hydrogen and through appropriate State aid rules. Enabling framework conditions will push concrete plans for large wind and solar plants dedicated to gigawatt-scale renewable hydrogen production before 2030.

The Clean Hydrogen Alliance will help build up a robust pipeline of investments. Funding instruments of the Commission's Next Generation EU recovery plan, including the Strategic Investment Facility under InvestEU, will enhance the funding support and help bridge the investment gap generated by the COVID 19 crisis.

In a **second phase, from 2025 to 2030**, hydrogen needs to become an intrinsic part of **an integrated energy system** with a strategic objective to produce **[10] million tonnes of renewable hydrogen in the EU by 2030 and at least 40 GW of renewable hydrogen electrolysers installed by then.** This would lead to an estimated 173 TWh of renewable hydrogen produced by electrolysers by 2030. Additionally, around 50% of existing fossil-based hydrogen production could be retrofitted to produce low-carbon fossil-based hydrogen[21].

In this phase, renewable hydrogen will gradually become cost competitive with other forms of hydrogen production and industrial demand should gradually include new applications, including **steel-making** and in the transport sector beyond trucks to **shipping** applications. It will start playing a crucial role in balancing a **renewables-based electricity system** by transforming electricity into hydrogen when renewable electricity is abundant and cheap and by providing flexibility. Hydrogen will also be used for daily or seasonal storage, as a backup and provide buffering functions[22], enhancing security of supply in the medium term.

Local hydrogen clusters or regional ecosystems – so-called "Hydrogen Valleys" will develop, relying on local production of hydrogen based on decentralised renewable energy production and local demand, transported over short distances. In such cases, a dedicated hydrogen infrastructure can use hydrogen not only for industrial and transport applications, and

[21] The optimal role for gas in a net-zero emissions energy system', Navigant, March 2019.

[22] Energy buffering realized through renewable hydrogen is a function very much beyond the renewable electricity storage. Buffering indeed makes available amounts of energy across space via H2 transportation also reaching H2 stocking facilities out, it may interlink different end-use sectors other than electricity and it could allow to re-price energy in specific H2 markets

electricity balancing, but also for the provision of heat for residential and commercial buildings[23].

In this phase, the need for an EU-wide logistical infrastructure will emerge, and steps will be taken to transport hydrogen from areas with large renewable potential to demand centres located possibly in other Member States. The back-bone of a pan-European grid will need to be planned and a network of hydrogen refuelling stations to be established. The existing gas grid could be partially repurposed for the transport of renewable hydrogen over longer distances and the development of larger-scale hydrogen storage facilities becomes necessary. Driven by cost factors and progressive technological and investment developments outside the EU, international trade can also develop, in particular with the EU's neighbouring countries in Eastern Europe and in the Southern Mediterranean.

In terms of policy focus, such a sustained scaling up over a relatively short period will require gearing up the EU's support to building a fully-fledged hydrogen industrial ecosystem. By 2030 the EU will aim at completing an open and competitive EU hydrogen market, with unhindered cross-border trade and efficient allocation of hydrogen supply among sectors.

In a third phase, from 2030 onwards and towards 2050, renewable hydrogen technologies should reach maturity and be deployed at large scale to reach all hard-to-decarbonise sectors where other alternatives might not be feasible or have higher costs.

In this phase, renewable electricity production needs to massively increase as about [one third[24]] of electricity might be used for renewable hydrogen production by 2050.

Towards 2050, hydrogen could penetrate more largely across a wider range of sectors of the economy, from aviation to hard-to-decarbonise buildings. Biogas may also have a role in replacing natural gas in hydrogen production facilities with carbon capture and storage and create negative emissions but only in line with the biodiversity objectives and the principles stated in the EU2030 Biodiversity Strategy[25].

3. AN INVESTMENT AGENDA FOR THE EU

Achieving the deployment goals outlined in this strategic roadmap by 2024 and 2030 requires a strong investment agenda.

From now to 2030, investments in electrolysers could range between €13 and €15 billion by 2030. In addition, over the same period, €50-150 billion would be required to scale up solar and wind energy production capacity to 50-75 GW, to provide the necessary electricity. Investments in the production of low-carbon fossil-based hydrogen by retrofitting existing plants with carbon capture and storage are estimated between €1-6 billion. In addition, investments of €120-130 billion will be needed for hydrogen transport, distribution and storage, and hydrogen refuelling stations.

From now to 2050, investments in production capacities would amount to €50-200 billion,

---

[23] Pilot projects are ongoing to analyse the potential to replace natural gas boilers with hydrogen boilers.
[24] ADD source
[25] reference

depending in particular on the scale of renewable hydrogen production that would be achieved domestically in the EU.

Finally, adapting end-use sectors to hydrogen consumption will also require significant investments. For instance, it takes some €300-600 million to convert a typical EU steel installation coming to end-of-life to hydrogen. In the transport sector, rolling out 400 small-scale hydrogen refuelling stations could require investments of €450-540 million.

To support these investments and the emergence of a whole hydrogen eco-system the Commission kick-starts today the **Clean Hydrogen Alliance** – announced in the Commission's New Industrial Strategy – bringing together the industry, national, regional and local public authorities and the civil society. The Alliance will play a crucial role in facilitating and implementing the actions of this Strategy and in particular its investment agenda. It is strongly anchored in the hydrogen industrial value chain, covering renewable and low-carbon hydrogen from production via transmission to mobility, industry, energy, and heating applications. Through interlinked, sector-based CEO round tables and a policy-makers' platform, the Alliance should support scaling up production and demand for renewable and low-carbon hydrogen, coordinate action, and provide a broad forum to engage civil society.

To support this Strategic roadmap, the EU will mobilise its funding levers in a coordinated and targeted way, providing public support where appropriate and crowding in private investment. **Building up a clear pipeline of projects will be essential** to give visibility to these projects and allow them to find appropriate support where necessary. **The Clean Hydrogen Alliance** will serve to identify such a pipeline of projects. It will facilitate coordinated investments and policies along the hydrogen value chain, and building cooperation across private and public stakeholders across EU. At this point, already 1.5-2.3 GW of new renewable hydrogen production projects are under construction or announced, and an additional 22 GW of electrolyser projects[26] are envisaged and would require further elaboration and confirmation.

Moreover, the Commission will promote well-coordinated or joint investments and actions across several Member States aimed at supporting a hydrogen supply chain by following up to the recommendations identified in a report by the **Strategic Forum for Important Projects of Common European Interest (IPCEI)**[27]. The cooperation that has been initiated within the hydrogen ecosystem in the **Strategic Forum**[28] will contribute to a swift uptake of activity in the Clean Hydrogen Alliance. The Clean Hydrogen Alliance will simultaneously facilitate cooperation in a range of large investment projects, including **IPCEI projects**, along the hydrogen value chain. The specific IPCEI instrument enables State aid for projects where, for example, hydrogen is significantly and factually contributing to EU's climate goals.

Investment in renewable and low carbon hydrogen will foster sustainable growth and jobs, which will be critical in the context of recovery from the COVID-19 crisis. The Commission's recovery plan[29] highlights the need to unlock investment in key clean technologies and value chains, to foster sustainable growth and jobs. It stresses in particular

---

26 Source

27 [citation of the report itself]

28 The Strategic Forum for Important Projects of Common European Interest (IPCEI).

29 'Europe's moment: Repair and Prepare for the Next Generation', COM(2020) 456 final.

clean hydrogen as one of the essential areas to address in the context of the energy transition, and mentions a number of possible avenues to support it.

In particular, as part of the **new recovery instrument Next Generation EU, InvestEU** will see its capacities more than doubled. It will continue to support the deployment of clean hydrogen, in particular by incentivising private investment, with a strong leverage effect, through its new Strategic Investment Facility. In addition, **the Innovation Fund of the EU's Emission Trading System**, which will pool together around €10 billion to support low-carbon technologies over the period 2020-2030, has the potential to facilitate first-of-a-kind demonstration of innovative hydrogen-based technologies. The Fund can substantially reduce the risks of large and complex projects, and therefore offers a unique opportunity to prepare such technologies for a wide-scale roll out. A first call for proposals under the Fund is planned for mid-2020.

The EU sustainable finance taxonomy[30] also includes hydrogen in relation to private investments across key economic sectors of the economy by promoting economic activities and projects that will provide a substantial contribution to de-carbonisation.

A number of Member States have identified renewable and low-carbon hydrogen as a strategic element of their National Climate and Energy Plans. They will need to build, among others, on these plans, and on the priorities identified in the context of the European Semester, when designing their national recovery plans in the context of the new Recovery and Resilience Facility, which will aim to support Member States' investment and reforms that are essential for a sustainable recovery.

The Commission will also exchange with Member States through the HyNet network on the inclusion of hydrogen-related investments in their national recovery plans.

Furthermore, the **European Regional Development Fund and the Cohesion Funds**, which will benefit from a top-up in the context of the **new initiative REACT-EU**, will continue to be available to support the green transition. The Commission will work with Member States and the industry so that these funds contribute to support innovative solutions in the field of clean hydrogen, with technology transfer, public-private partnerships, as well as pilot lines to test new solutions or perform early product validation. [It will also explore how to support interregional innovation investments in the context of the European Regional Development Fund.] The possibilities offered to carbon intensive regions under the **Just Transition Mechanism** should also be fully explored. Finally, the Connecting European Facility Energy will intervene to fund dedicated infrastructure for hydrogen, repurposing of gas networks and carbon and capture projects, and, in synergy with the Transport part, a network of fuelling stations.

4. BOOSTING DEMAND FOR AND SCALING UP PRODUCTION OF RENEWABLE AND LOW-CARBON HYDROGEN

Building up a hydrogen economy in Europe requires a full supply chain approach. The production of hydrogen from renewable or low-carbon sources, the development of infrastructure to supply hydrogen to the end-consumers, and the creation of market demand

[30] Regulation on establishment of a framework to facilitate sustainable investment

need to go in parallel, activating a virtuous circle of **increased supply and demand for hydrogen.** It also requires **reduced supply costs** – through declining costs for clean production technologies and affordable costs of renewable energy input, ensuring cost competitiveness with fossil fuels. In addition, it will require a large amount of raw materials, and especially those materials on the EU's critical raw materials list used in fuel cells and electrolysers (such as the platinum group metals) or in the various renewable energy sectors generating electricity for hydrogen. Securing the raw materials needed to develop resilient hydrogen systems and their infrastructure should, therefore, be also looked at in the Critical Raw Materials Action Plan and implementation of the Circular Economy Action Plan.

Boosting demand in end-use sectors

The creation of new lead markets goes hand in hand with the scaling up of the production of clean hydrogen. Two main lead markets**, industrial applications and mobility,** can be gradually developed to use the potential of hydrogen for a climate-neutral economy cost-effectively.

An immediate application in **industry**, is to reduce and replace the use of carbon-intensive **hydrogen in refineries, the production of ammonia, and in methanol production**. In a second phase, hydrogen can also replace fossil fuels as a feedstock for **steel production.**

In transport, hydrogen is also a promising option where electrification is more difficult. In a first phase, **early adoption of hydrogen** is likely to occur in captive uses, such as **local city buses or specific train lines,** where hydrogen refuelling stations can easily be supplied by regional or local electrolysers. Besides ensuring the availability of hydrogen vehicles and the charging infrastructure, it will also be important to develop a standardised approach for the form of supply of hydrogen from the filling station to the vehicle (e.g. high –pressure gaseous, liquid, chemical compounds like ammonia, etc.) and to agree on standards and deployment roadmaps.

For road transport in particular, hydrogen should already in the short term be encouraged **in heavy-duty road vehicles**, including buses, coaches, special purpose vehicles and long-haul road freight given their high C02 emissions and the lack of alternatives. The regulation on **CO2 emissions for trucks** is an important driver to create a lead market for hydrogen solutions, once fuel cell technology is sufficiently mature and cost-effective. Projects of the Horizon 2020 Hydrogen and Fuel Cell Joint Undertaking (HFC-JU) are aiming to accelerate Europe's technological lead.

Hydrogen fuel-cell trains, which already operate as a technological proven concept on one regional line from one single train supplier, could be extended to viable train commercial routes that are difficult or not cost-effective to electrify. This represents a significant part of the transportation field: 20 % of the rail traffic and about 40 % of the mainline network is still being served by diesel technology today. Certain fuel-cell hydrogen train applications (e.g. Multiple Units) can already be cost competitive with diesel today in scenarios where the energy to produce hydrogen is cheap.

For **inland waterways and short-sea shipping**, hydrogen can become an alternative low emission fuel. For example, the FLAGSHIP project is developing two commercial vessels in France and in Norway, with hydrogen produced on-site with 1 MW electrolysers powered by renewable electricity. Hydrogen is also a key stepping-stone in the production of ammonia or electro-fuels with higher energy density, which are required for longer-distance and deep-sea shipping.

Hydrogen will likely be one of few options to decarbonise the **aviation sector**, through the production of liquid synthetic kerosene, alongside advanced biofuels. These are "drop-in" fuels that can be used with existing aircraft technology. Hydrogen-powered fuel cells, requiring adapted aircraft design, or hydrogen-based jet engines may also constitute an option for the aviation, but will require considerable long-term research and innovation efforts.

The Commission will further examine how to facilitate the use of hydrogen in the transport sector in the upcoming **Sustainable and Smart Mobility Strategy**, and in related initiatives, including by encouraging more favourable taxation of hydrogen and corresponding vehicles.

The key limiting factor for the use of clean and low-carbon hydrogen in industrial applications and transport is often the higher costs, including additional investments into hydrogen-based equipment. Furthermore, the potential impact of supply chain risks and market uncertainty are amplified by the tight margins for final industrial products due to international competition.

Demand side support policies are therefore needed and could take the form **of quotas of renewable hydrogen in specific end-use sectors**[31] (for instance certain industries as the chemical sector, or transport applications) or **minimum shares**[32], allowing demand to be driven in a targeted way and giving the choice of when and how to deploy hydrogen to those best placed to make an informed decision.

Scaling up production for building up a sustainable industrial ecosystem

Whilst around 280 companies[33] are active in the production and supply chain of electrolysers and more than 1 GW of electrolyser projects are in the pipeline, the total European production capacity for electrolysers is currently below 1 GW per year. To reach the strategic objective of 40 GW electrolyser capacity by 2030, a coordinated effort with the Clean Hydrogen Alliance, Member States and front-runner regions is needed as well as support schemes before hydrogen becomes cost-competitive. The technologies for scaling up decarbonised hydrogen production such as solar and wind energy as well as carbon capture and storage continue to get increasingly competitive as we are building up the supply chain.

To kick-start clean and low-carbon hydrogen development, European industry needs clarity and investors need certainty in the transition, notably a clear understanding across the Union on (i) the hydrogen production technologies that need to be developed in Europe, as well as (ii) what can be considered as low-carbon or renewable hydrogen. The end goal is clear: climate-neutral energy system integration with renewable hydrogen and renewable electricity at is core. As this will be a challenge taking a long period of time, the EU will need to plan

[31] he Renewable Energy Directive already provides support for renewable hydrogen and includes it explicitly as a means of meeting the sectorial target for renewables in the transport sector.

[32] The concept of virtual blending could be further explored to accelerate the deployment of hydrogen in a transitional phase

[33] 60% of EU companies active are small- and medium-size enterprises.

this transition carefully, taking into account today's starting points and infrastructure that may differ across Member States. In this transition, a dual approach is appropriate.

First, for the general purpose of kick-starting a hydrogen economy, the Commission will propose a **common low-carbon threshold/standard for the promotion of hydrogen production installations based on their direct greenhouse gas performance**. In order to have a straightforward threshold for the direct greenhouse gas emissions of the installation that produces the hydrogen, it can be defined [in the revision of the ETS Directive or the RED] **relative to the existing ETS benchmark**[34] for hydrogen production. This should be considered a minimum threshold that can be used to define production technologies on which industrial policy and research and innovation efforts should focus e.g. for Member States actions, and industrial policies (such as IPCEI's and State aid).

As regards electricity-based hydrogen, the growing share of renewables in power generation together with the ETS cap on the CO2 emissions of electricity for the EU as a whole will naturally lead to lower CO2 emissions upstream while replacing fossil fuels downstream in end-use sectors. In the case of low-carbon fossil-based hydrogen, the Commission will address upstream methane emissions occurring during the production and transport of natural gas. Mitigating measures will be proposed as part of the upcoming EU Strategy on Methane.

Secondly, in order to **define renewable hydrogen,** notably for the purpose of **consumer information** and **for targeted production support**, the Commission will propose **a comprehensive terminology** and **European-wide criteria for the certification of renewable hydrogen**. This framework could be based on the *life cycle* greenhouse gas emissions of hydrogen consumed and rooted within the wider terminology and certification framework of other renewable fuels[35], taking into account also already existing industry initiatives to set up hydrogen guarantees of origin for renewable and low-carbon hydrogen[36] The development of such a comprehensive certification framework could build on the provisions set out in the Renewable Energy Directive, and on the specific, complementary functions that Guarantees of Origin (GOs) and sustainability certificates already play under this Directive. In addition to greenhouse gas emissions, the framework should include sustainability criteria where biomass is used in the process. Consistency should also be ensured in various financing sources where climate impact is a criteria.

A supportive policy framework for scaling up hydrogen

An incentivising, supportive policy framework needs to enable clean and low-carbon hydrogen to contribute to decarbonisation at the lowest possible cost, whilst considering other important aspects, such as industrial competitiveness and its value chain implications for the energy system. The EU already has the basis for a supportive policy-framework, notably with the Renewable Energy Directive, the Emission Trading System (ETS) and with the NextGenerationEU providing the instruments and financial resources to accelerate our efforts towards a sustainable recovery.

---

[34] Only refers to steam methane reforming

[35] See Energy System Integration Strategy COM (2020) XXX final

[36] E.g. CertifHy

The ETS, as a market based instrument, already provides a technology neutral, EU-wide incentive towards cost-effective decarbonisation in all its covered sectors through carbon pricing. A strengthened ETS, with potential expansion in scope as announced as part of the Green Deal, will gradually reinforce that role, also for the production of clean hydrogen and use in different sectors. Almost all existing fossil based hydrogen production is covered by the ETS, but the sectors concerned[37] are deemed to be at a significant risk of carbon leakage and therefore receive free allocation at 100% of benchmark levels. As foreseen in the ETS Directive[38], the benchmark used for free allocation will be updated for phase 4. In the coming **revision of the ETS**, the Commission will consider how the production of clean hydrogen could be further incentivised, while taking due account of the risk for carbon leakage for sectors exposed to carbon leakage. Should differences in climate ambition levels around the world persist, the Commission will propose a Carbon Border Adjustment Mechanism in 2021 to reduce the risk of carbon leakage, in full compatibility with WTO rules and will also look at the implications for hydrogen.

With the need to scale-up renewable and low-carbon hydrogen before it is cost-competitive, **support schemes are likely to be required** for some time. Hence, a possible supply-side policy instrument is to create tendering systems for **carbon contracts for difference** ('CCfD'). Such a long term contract with a public counterpart would cover the difference between the CO2 strike price and the actual CO2 price in the ETS in an explicit way, bridging the gap[39] in costs between conventional and clean technologies. It is expected that the competitive nature of tenders will lead to price discovery and reduce costs. One area where a pilot scheme for carbon contracts for difference can be applied is to accelerate the replacement of existing hydrogen production in the **low carbon and circular steel and basic chemicals**, and to support the deployment in the maritime sector of hydrogen and derived fuels such as **ammonia**. It can be implemented at EU, or national level, including with the support of the Innovation Fund. A **State aid framework** could be implemented in the revision of the State aid guidelines for energy and environmental protection, foreseen in 2020.

Furthermore, **direct and transparent, market-based support schemes providing investment or operating aid** for renewable hydrogen, allocated through competitive tenders, could be envisaged. Market-compatible support should be coordinated within a transparent, efficient and competitive hydrogen market providing price signals that reward electrolysers for the flexibility and other services they provide to the energy system (e.g. flexibility services, augmenting renewable production levels, reducing burden from renewable incentives).

5. DESIGNING A FRAMEWORK FOR HYDROGEN INFRASTRUCTURE AND MARKET RULES

The role of infrastructure

A condition for a widespread use of hydrogen as an energy carrier in the European Union is the availability of energy infrastructure for connecting supply and demand. Hydrogen can be

[37] Notably for refineries and fertiliser production

[38] Reference

[39] The contract would cover the difference between the CO_2 strike price and the actual CO_2 price in the ETS in an explicit way,

transported via pipelines, but also via non-network based transport options, e.g. trucks or ships docking at adapted LNG terminals[40]. Transport can happen as pure gaseous or liquid hydrogen, or bound in bigger molecules that are easier to transport (e.g. ammonia). Hydrogen can also provide cyclical or seasonal storage, e.g. in salt caverns[41], to produce electricity to cover peak demand, secure hydrogen supply, and allow electrolysers to operate flexibly.

The infrastructure needs for hydrogen will ultimately depend on the pattern of hydrogen production and demand and transportation costs and are linked to the different phases of the development of hydrogen production, increasing significantly after 2024. Following the stepwise approach outlined in this strategy, demand for hydrogen may initially be met by production on-site (from local renewables sources or natural gas) in industrial clusters and coastal areas through existing "point-to-point" connections between production and demand. The existing rules for so-called closed distribution systems, direct lines or exemptions in the gas and electricity markets may provide guidance on how to address this[42].

In the second phase, local hydrogen network would emerge to cater for additional industrial demand. With increasing demand, the optimisation of the production, use and transport of hydrogen will have to be secured and is likely to require longer-range transportation to ensure that the entire system is efficient through the revision of the **Trans-European Networks for Energy (TEN-E)**. To ensure interoperability of markets for pure hydrogen, common quality standards (e.g. for purity and thresholds for contaminants) or cross-border operational rules may be necessary.

This process should be combined with a strategy to reach transport demand through a network of refuelling stations for heavy-duty long haul vehicles and shipping, linked to the review of the **Alternative Fuels Infrastructure Directive** and the revision of the **Trans-European Transport Network (TEN-T)**.

With the imminent phase-out of low calorific gas and with the demand for natural gas expected to decline after 2030, elements of the existing pan-European gas infrastructure could be repurposed to provide the necessary infrastructure for large-scale transport of hydrogen including across borders[43]. **Repurposing can provide an opportunity for a cost-effective energy transition in combination with (relatively limited) new build hydrogen dedicated infrastructure[44].**

---

[40] As pressure requirements, and hence energy use, are larger for hydrogen than for natural gas, pipeline transport for hydrogen becomes inefficient at distances around 1500km (compared to 3500km for natural gas).

[41] In the UK, at Teesside in Yorkshire, a British company stores 1 million m3 of pure hydrogen (95% H_2 and 3–4% CO_2) in three salt caverns at a depth about 400 m at 50 bar. Europe's technical potential to store hydrogen in salt caverns is around 85 PWh (Caglayan et al. 2020).

[42] See Articles 28 and 38 of Directive 2009/73/EC (OJ 211/94 of 14.08.2009) and Articles 7 and 38 of Directive (EU) 2019/944 (OJ 158/125 of 14.06.2019).

[43] A first repurposing project in Germany strives for completion by 2023. Plans exist to realise by 2030 1200 km of hydrogen network in Germany. Main elements of a future hydrogen network in the Netherlands can be realised by 2026 whilst work can start soon after 2020. See for instance Tennet (2019) Infrastructure Outlook 2050; Gasunie and Tennet (2019) Pathwas to 2050; GetH2 initiative, and FNBgas (2020) netzentwicklungplan Gas 2020-2030

[44] E.g. it is expected that a hydrogen network in Germany and the Netherlands may consist of up to 90% of the of repurposed natural gas infrastructure. Repurposed pipelines are often already to a large extent depreciated.

However, existing natural gas pipelines are owned by network operators that are often not allowed to own, operate and finance hydrogen pipelines. To enable repurposing of existing assets, the review of the regulatory framework for competitive decarbonised gas markets should allow such financing and operation with an overall energy system perspective in mind. Sound infrastructure planning, such as on the basis of ten year network development plans ('TYNDP'), is needed on the basis of which decisions to invest can be taken. Such planning should also inform and be the basis for incentivising investments by private investors in electrolysers at the best locations. The Commission will thus ensure the full integration of hydrogen infrastructure in the infrastructure planning, including through the revision of the Trans-European Networks for Energy and the work on Ten-Year Network Development Plans (TYNDPs), taking into account also the planning of a network of fuelling stations.

The blending of hydrogen in the natural gas network at limited rations may enable decentralised hydrogen production in local networks in a transitional phase by providing a reliable evacuation route and, if combined with support schemes, guaranteed revenues to kick-start production[45]. However, blending is less efficient and diminishes the value of hydrogen. Blending also changes the quality of the gas consumed in Europe and may affect the design of gas infrastructure, end-user applications, and cross-border system interoperability. Blending thus risks fragmenting the internal market if neighbouring Member States accept different levels of blending and cross-border flows are hindered. To mitigate such a situation, the technical feasibility of adjusting the quality and cost of handling the differences in gas quality need to be assessed. Current gas quality standards – national and CEN – would need to be updated. Moreover, reinforcement of instruments may be needed to secure cross-border coordination and system interoperability for an unhindered flow of gases across Member States. In this context, the concept of **virtual blending** could be explored. These options require careful consideration in terms of its contribution to the decarbonisation of the energy system as well as economic and technical implications.

Fostering liquid markets and competition

As EU Member States have different potential for the production of renewable hydrogen, an open and competitive EU market with unhindered cross-border trade has important benefits for competition, affordability, and security of supply.

Moving **towards a liquid market** with commodity-based hydrogen trading would facilitate entry of new producers and would be beneficial for deeper integration with other energy carriers (where commodity-based trading is the norm). It would create viable price signals for investments and operational decisions. Whilst recognising the inherent differences, existing rules that enable efficient commercial operations developed for the electricity and gas markets, such as access to trading points and standard product definitions, could be considered for a hydrogen market under the review of the gas legislation for competitive decarbonised gas markets.

To facilitate the deployment of hydrogen and develop a market where also new producers have access to customers, **hydrogen infrastructure should be accessible to all** on a non-discriminatory basis. In order not to distort the level playing field for market-based activities,

[45] Particularly for electrolysers located at optimal production sites, rather than in proximity to demand, a lack of sufficient dedicated hydrogen infrastructure may imply increased investments in on-site storage and/or curtailment of production

network operators should remain neutral. Third-party access rules, clear rules on connecting electrolysers to the grid and streamlining of permitting and administrative hurdles will need to be developed to reduce undue burden to market access. Providing clarity now will avoid sunk investments and the costs of ex-post interventions later.

An open and competitive market with prices that reflect energy carriers' production costs, carbon costs, and societal costs and benefits would efficiently provide clean hydrogen to end users and ensure, in line with the energy efficiency first principle. To ensure that relative prices of different energy carriers are not distorted, equal treatment of hydrogen with other carriers must be ensured. For instance, energy losses from hydrogen production or conversion should not be socialised if it generates undue advantage compared to other carriers and CO2 prices should be reflected.

5. PROMOTING RESEARCH AND INNOVATION IN HYDROGEN TECHNOLOGIES

The EU has supported research and innovation on hydrogen for many years, through traditional collaborative projects[46], as well as with the Fuel Cell and Hydrogen Joint Undertaking (FCH JU)[47]. These efforts have enabled several technologies to come close to maturity[48], alongside the development of high-profile projects in promising applications[49], and to achieve EU global leadership for future technologies, notably on electrolysers, hydrogen refuelling stations and MW-scale fuel cells. EU funded projects also allowed to improve the understanding of the applicable regulation for boosting the production and utilisation of hydrogen in the EU.

To ensure a full hydrogen supply chain to serve the European economy, further research and innovation efforts are required, spanning a variety of technologies and maturity levels as well as pre-conditions for boosting a sustainable, affordable and safe hydrogen economy.

First, on the **generation** side, this will entail upscaling to **larger size electrolysers in the range of the GWs** that, together with mass manufacturing capabilities and new materials, to supply hydrogen to large consumers. As a first step, a call for proposals for a 100 MW electrolyser will be launched this year. **Solutions at lower technology readiness level** need also to be incentivized and developed such as, for example, hydrogen production from marine algae, from direct solar water splitting, or from pyrolysis processes with solid carbon as side product, while paying due attention to sustainability requirements

Second, infrastructure needs further development to **distribute, store and dispense hydrogen at large volumes** and possibly over long distances. The **repurposing use of existing gas infrastructure** for transporting hydrogen needs also further research, development and innovation activities.

---

46 First examples are the hydrogen bus demonstration through the CUTE projects (started in 2003) and its successor HyFLEET: CUTE, which made major advances in proving fuel cell and hydrogen propulsion technologies.

47 FCH JU is a public private partnership aligning European research and industry to a common research agenda. Over the last decade, the EU contributed around EUR 900 million to FCH JU.

48 eg buses, passenger cars, vans, material-handling vehicles, and refuelling stations

49 eg e-fuels for aviation, hydrogen in rail, and the maritime sector

Third, **large scale end-use applications** need to be further developed, notably in **industry** (e.g. using hydrogen to replace coking coal in steel-making or upscaling renewable hydrogen in chemical and petrochemical industry) and in **transport** (e.g. heavy duty road transport, rail, waterborne and aviation). Pre-normative research, including the safety dimension, should be tailored to assist deployment plans and enable improved, harmonised standards.

Finally, further research is needed to support policy making on a number of cross-cutting areas, in particular to enable **improved and harmonized (safety) standards** and monitoring. Reliable methodologies have to be developed for **assessing the environmental impacts of hydrogen technologies** and their associated value chains, including their full life-cycle greenhouse gas emissions and sustainability. Importantly, securing the supply of **critical raw materials in parallel to material reduction**, substitution and recycling needs a thorough assessment in the light of their future expected increasing deployment, with due account being paid to ensuring security of supply and high levels of sustainability in Europe.

Coordinated EU research and innovation support is also needed for **large-scale high-impact projects across the entire hydrogen value chain**, including large scale electrolysers (100s MW), connected to clean electricity production and supplying renewable hydrogen for example to industrial areas or mobility hubs (as proposed in the Green Deal Call), that are able to test technology in real life environment.

To address all these challenges the Commission will carry out a set of actions targeting research, innovation, and relevant international cooperation[50], supporting the energy and climate policy objectives.

Under the Research and Innovation framework Programme Horizon Europe, an institutionalized **Clean Hydrogen Partnership** was proposed with main focus on renewable hydrogen production, transmission, distribution and storage, alongside selected fuel cell end-use technologies[51]. While the Clean Hydrogen Partnership will support research, development and demonstration of technologies to bring them to market readiness, the Clean Hydrogen Alliance will pool resources to bring scale and impact to industrialization efforts, in order to achieve further cost reductions and competitiveness. The Commission also proposes to increase the support for research and innovation in the end-use of Hydrogen in key sectors through important partnerships under Horizon Europe, notably on transport[52] and on industry[53]. Close cooperation between these partnerships would support the development of supply chains for hydrogen and jointly scale-up investments.

Beyond the partnerships, the Commission will provide targeted support to build the necessary capacity for preparation of financially sound and viable hydrogen projects in Member States through dedicated instruments (e.g. InnovFin EDP, InvestEU) possibly in combination with advisory and technical assistance from the Cohesion Policy, from the European Investment Bank or under Horizon Europe.

---

[50] For international actions in Research and Innovation please refer to part 7

[51] As fuel cell and electrolyser technologies have many similarities

[52] For example on zero emission road transport and on clean aviation

[53] For example on clean steel, circular and climate neutral industries

The cooperation with research and innovation efforts of Member States in the context of the Strategic Energy Technologies (SET) Plan priorities[54] will also be ensured. Synergies with other instruments such as the Innovation Fund or Structural Funds will be sought in order to bridge the valley-of-death through first-of-a-kind demonstration projects reflecting the diversity of opportunities for renewable and low-carbon fossil-based hydrogen across the EU.

7. The international dimension

For many years, research was the basis for international cooperation on hydrogen. The EU, together with the US and Japan, developed the most ambitious research programmes addressing different segments of the hydrogen value-chain, and the **International Partnership for a Hydrogen Economy (IPHE)** was established as a first vehicle in this respect.

The interest in clean hydrogen is now growing globally with several other countries developing ambitious research programmes along national hydrogen strategies[55]. The US and China are investing massively in hydrogen research and industrial development. Some of the EU's current gas suppliers (e.g. LNG exporters, and countries in the EU's Neighbourhood that are connected to the EU market through pipelines) but also countries with a strong potential for renewables are considering opportunities to export renewable electricity or clean hydrogen to the EU. For example North-Africa, due to its abundant solar potential and geographic proximity, could be a supplier of cost-competitive renewable hydrogen to the EU requiring that the deployment of renewable power generation strongly accelerates. In the coming years, an international trade market will likely develop.

The EU has therefore a strategic interest in placing hydrogen high on its external energy policy agenda, continuing to invest in international cooperation on research activities but also broadening its agenda to the areas below.

First, clean hydrogen may open new **opportunities for re-designing Europe energy partnership with neighbouring countries and regions, advancing** supply diversification and helping design stable and secure supply chains. Taking into account natural resources, physical interconnections and technological development, the Eastern Neighbourhood, in particular Ukraine, and the Southern shore of the Mediterranean should be priority partners. Cooperation should range from research and innovation to regulatory policy, direct investments and trade. According to industry's estimate 40 GW of electrolysers could be installed in the Eastern and Southern Neighbourhood by 2030, ensuring a sustained cross-border trade with the EU. Realising the ambition and supplying significant amounts of renewable hydrogen to the EU will be addressed in our cooperation with the countries concerned.

To support investments in clean hydrogen in the European Neighbourhood, the Commission will mobilise the available financing instruments including the Neighbourhood Investment Platform, which has financed for many years projects accompanying the clean energy transition of partner countries. The Commission would also be ready to support new

[54] In particular the SET Plan actions where hydrogen use is addressed, such as the actions on industry, on fuels and on CCSU.

[55] e.g. Australia, Canada, South Korea, and several EU Member States.

hydrogen-related project proposals by international financial institutions, for potential co-financing through this blending facility, in particular in the context of the Western Balkans Investment Framework[56].

The EU Stabilisation and Association Agreements with the Western Balkans, as well as the Association Agreements with **Neighbourhood countries**, provide the political framework for the participation of those countries in joint hydrogen research and development programmes with the EU. The **Energy Community and the Transport Community** will have a critical role to play for the promotion of clean hydrogen, including the deployment of new infrastructure, such as refuelling networks and the re-use, where relevant, of existing natural gas grids, as the regional sectorial international cooperation fora. Participation of the Western Balkans and Ukraine in the Clean Hydrogen Alliance will be encouraged.

In the **Southern Neighbourhood** the "*Observatoire Méditerranéen de l'Energie*" will be the privileged international cooperation forum to promote joint activities. The energy dialogues with partners in the region will help define and advance a common agenda and identify projects. The Commission will explore in the context of the **Africa-Europe Green Energy Initiative**[57] the opportunity to support awareness raising of clean hydrogen opportunities amongst public and private sectors. It will also consider promoting the involvement of the European Fund for Sustainable Development[58] in the development of potential projects.

More broadly hydrogen could be mainstreamed in the EU regional and bilateral energy diplomacy efforts, but also on climate, research, trade and international cooperation. The Partnership Instrument and the proposed Neighbourhood, Development and International Cooperation Instrument could support bilateral dialogues with concrete actions promoting EU regulations, standards and technologies.

Second, the EU should promote in **multilateral fora** the development of international standards and the setting up common definitions and methodologies for defining overall emissions from each unit of hydrogen produced and carried to final use as well as international sustainability criteria. The EU is already highly involved in IPHE, and co-leads the new clean hydrogen mission under Mission Innovation and the Clean Energy Ministerial Hydrogen initiative (CEM H2I). International collaboration could also be expanded through international standardisation bodies and global technical regulations of the United Nations (UN-ECE, IMO), including harmonisation of automotive regulation for hydrogen vehicles. Cooperation under G20, as well as with the International Energy Agency (IEA) and the International Renewable Energy Agency (IRENA), creates further opportunities for exchange of experiences and best practices.

Finally, to reduce the foreign exchange risks for EU market operators, both on imports and exports, it is important to facilitate the development of a structured international hydrogen

[56] Which is endowed with funds of the EU Instrument for Pre-accession Assistance, as well as with contributions from the International Financing Institutions belonging to its platform.

[57] The Africa Europe Green Energy Initiative was laid out in the Communication 'Towards a comprehensive Strategy with Africa' JOIN(2020) 4 final of 09.03.2020

[58] The European Fund for Sustainable Development (EFSD) supports investments in Africa and the EU's neighbouring countries to help achieve the sustainable development goals of the UN 2030 Agenda and the Paris Agreement on Climate Change and Sustainable Development Goals of the UN 2030 Agenda for Sustainable Development.

market in euro. Hydrogen being a nascent market, the Commission will develop a **benchmark for euro denominated transactions in hydrogen** thus contributing to consolidate the role of the euro in trade of sustainable energy.

8. CONCLUSIONS

Renewable and low-carbon hydrogen can contribute to reduce greenhouse gas emissions ahead of 2030, to the recovery of the EU economy, and to pave the way for a climate-neutral economy in 2050, by replacing fossil fuels in hard-to-decarbonise sectors. They also offers a unique opportunity for innovation, maintaining and expanding Europe's technological leadership, and creating jobs across the full value chain and across the Union.

This requires ambitious and well-coordinated policies at national and European levels. This strategy brings different strands of policy action together, covering the entire value chain, as well as the industrial, market and infrastructure angles together with the research and innovation perspective and the international dimension, in order to create an enabling environment to scale up hydrogen supply and demand for a climate-neutral economy. In collaboration with the Clean Hydrogen Alliance, the Commission intends to invite interested stakeholders to debate in a joint **large dedicated public event** at the end of this year and to launch **public consultations and impact assessments to inform the preparation of the proposals foreseen for 2021 and beyond**.

The Commission invites the Parliament, the Council, other EU institutions and all stakeholders to discuss how to leverage the potential of hydrogen to decarbonise our economy while making it more competitive, building on the following actions:

KEY ACTIONS

An investment agenda for the EU

- Take forward the **Clean Hydrogen Alliance** to develop an investment agenda to stimulate the roll out of production and use of hydrogen and build a concrete pipeline of projects.
- Support **strategic investments** in clean hydrogen in the context of the Commission's recovery plan, in particular through the **Strategic European Investment Window of InvestEU**.
- Launch the calls for proposals under the **ETS Innovation Fund**, pooling together around €10 billion, for supporting low-carbon technologies in the period 2020-2030.

Boosting demand for and scaling up production of renewable and low-carbon hydrogen

- Propose a viable **framework for hydrogen in the future EU strategy on Clean Steel**.
- Introduce contracts for difference schemes to incentivise the roll-out of dedicated **gigawatt- scale green hydrogen factories**.
- Remove potential **regulatory obstacles to new equipment and technologies** needed for hydrogen, including requirements and standards.
- Facilitate the use of hydrogen in the transport sector through the upcoming **Sustainable and Smart Mobility Strategy**, and in related initiatives, including by encouraging more favourable taxation of hydrogen and corresponding vehicles (2020).

- Set a GHG emissions threshold/standard for low-carbon hydrogen production facilities in the ETS (June 2021) in the context of the revision of the ETS Directive.
- **Propose a comprehensive terminology and a European framework for the certification** and accounting of all renewable hydrogen applications, including non-energy use (by June 2021). **Design additional support measures** for renewable hydrogen building on and revising existing provisions of Renewable Energy Directive (by June 2021).
- Develop a pilot scheme for a **Carbon Contracts for Difference programme**, in particular to support the production of low carbon and circular steel, and basic chemicals.

Designing an enabling and supportive framework: support schemes, market rules and infrastructure

- Design enabling **market rules to the deployment of hydrogen**, including the removal of barriers for efficient hydrogen infrastructure development (e.g. via repurposing) and ensure access to liquid markets for hydrogen producers and customers and the integrity of the internal gas market, through the upcoming legislative reviews (e.g. review of the gas legislation for competitive decarbonised gas markets (June 2021)).
- Ensuring **the full integration and interoperability of hydrogen infrastructure in the infrastructure planning**, including the Trans-European Networks for Energy and the Ten-Year Network Development Plans (TYNDPs) (2021) taking into account also the planning of a network of fuelling stations.
- Accelerate the **deployment of different hydrogen vehicles and vessels and resulting refuelling infrastructure** in the revision of the Alternative Fuels Infrastructure Directive and the revision of the Regulation on the Trans-European Transport Network (2021).

Promoting research and innovation in renewable and low-carbon hydrogen technologies and accelerate investment

- **Launch a 100 MW electrolyser call for proposals** as part of the European Green Deal call under Horizon 2020 (Q3 2020).
- Launch the **Clean Hydrogen Partnership** (2021), focusing on renewable hydrogen production, storage, transport, distribution and key components for priority end-uses of clean hydrogen at a competitive price.
- Steer the development of **key pilot projects that support Hydrogen value chains**, in coordination with the SET Plan (from 2020 onwards).

The international dimension

- **Strengthen EU leadership in international fora for technical standards, regulations and definitions** on hydrogen
- Develop cooperation with **South and East Mediterranean partners and Energy Community countries, notably Ukraine** on renewable electricity and hydrogen
- Set out a **cooperation process on renewable hydrogen with the African Union** by collaborating with the African Hydrogen Partnership Association.

- Develop **a benchmark for euro denominated transactions** by 2021.

ANNEX – DIFFERENT FORMS OF HYDROGEN PRODUCTION

Electricity-based hydrogen refers to hydrogen produced in electrolysers powered by electricity, through a chemical process (electrolysis) splitting water into hydrogen and oxygen. The full life cycle emissions of electricity-based hydrogen depend on the electricity source.

Renewable hydrogen is part of electricity-based hydrogen and usually refers to hydrogen produced in electrolysers powered by renewable electricity. Such hydrogen (often referred to as 'green hydrogen') has very limited emissions across its full life cycle. Renewable hydrogen may also refer to hydrogen produced through the reforming of biogas (instead of natural gas) or biochemical conversion of biomass which – combined with carbon capture – could create negative emissions, or through the pyrolysis of biomass.

Fossil-based hydrogen refers to hydrogen produced through a variety of processes using fossil fuels as feedstock, mainly the reforming of natural gas and the gasification of coal. It is often referred to as "grey" hydrogen.

Fossil-based hydrogen with carbon capture mainly refers to hydrogen produced from the reforming of natural gas, combined with the capture of up to 90% of the carbon dioxide emitted during the process. It is often referred to as 'blue hydrogen'. Pyrolysis of natural gas is another emerging pathway to decarbonise hydrogen from fossil fuels, through the thermal decomposition of methane in the absence of oxygen at high temperature. In addition, the variable effectiveness of CO_2 capture, as well as concerns about methane emissions associated with the production and transport of natural gas need to be taken into account.

Clean hydrogen refers to renewable hydrogen

Low-carbon hydrogen encompasses fossil-based hydrogen with carbon capture and electricity based hydrogen.

Hydrogen can also be used to produce to synthetic fuels. 'Synthetic fuels' refer to a variety of gaseous and liquid fuels on the basis of hydrogen and carbon monoxide. 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.