**Pathways** | EU | Industry, Transport, Electricity

# NO-REGRET GREEN HYDROGEN

## KEY MESSAGE

- **Green hydrogen** needs to be used to decarbonise **no-regret applications,** such as **steel, ammonia, refining and chemicals,** to achieve climate neutrality by 2050.
- Hydrogen produced from renewable energy will become the **most competitive option** across Europe. The investment window for fossil-based hydrogen with carbon capture will close by the end of the 2020s.
- The need for a future hydrogen network is smaller than the current natural gas network in all scenarios. Thus, a **risk of infrastructure oversizing** exists, requiring a **no-regret vision for future hydrogen infrastructure.**
- **Four no-regret corridors for early investments** in hydrogen delivery systems are located in **Central-West Europe, East Europe, South-East Europe and Spain,** in order of importance.
- An **ambitious policy framework is essential to ramp up renewable hydrogen:** focused support on rapid cost reductions, in particular the decrease of electrolyser system costs via economies of scale, as well as instruments to close the gap with $CO_2$ prices in the 2020s and kick-start green hydrogen demand.

## OVERVIEW

- A strong consensus exists regarding the hydrogen demand from a **selection of industrial applications (ammonia, methanol, steel, plastics),** and as such constitute a **no-regret hydrogen demand in the future.**
- Industrial processes of ammonia production, methanol production, iron ore reduction, production of petrochemicals for plastics and fuels, and plastics recycling will need hydrogen or hydrogen-derived products because of their **specific chemical properties, high energy density and/or potential for long-term storage.**
- **Available power-to-heat technologies can cover all temperature levels needed in industrial production.** As the performance factor of electric heating is at the very least comparable with and at the very best – such as in the case of heat pumps – considerably better than burning hydrogen from electrolysis, **power-to-heat technologies should be considered first, before producing heat from hydrogen.** A well-known example is the electric arc furnace (EAF) in steel production, which reaches temperatures of up to 3,500°C.
- The expected **rapid growth in demand** for low-carbon hydrogen over 2030 and 2040 in the steel sector is supported by the **current plans of steel producers** all over Europe to move to direct reduced iron (DRI) steel using EAF.
- No-regret corridors for early hydrogen pipelines are identified based on industrial demand. Adding potential hydrogen demand from **power, aviation and shipping sectors** still requires a **no-regret vision for hydrogen infrastructure needs** to reduce the **risk of oversizing.**

## AIMS & TARGETS

### Green hydrogen: no-regret usage

- To achieve climate neutrality by 2050 and the interim target of GHG emission reduction of 55 percent by 2030 in Europe, we need to address the **decarbonisation** of those **industrial applications,** where **direct electrification is difficult,** and **of fossil-based feedstock.**

- → **Demand for process heat** should be covered by **power-to-heat technologies,** as the performance factor for electric heating is at least the same or better than for heat produced using hydrogen from electrolysis.
- → 40 percent of today's industrial fossil gas use in Europe is for **heat up to 100°C,** which can be produced by **heat pumps.** Heat pumps are expected to deliver higher temperature levels in the future (prototypes can already deliver up to 140°C and research is on-going for heat up to 200°C).
- → Physical mechanisms such as **resistance, infrared, induction, microwave and plasma heating** can also be used. A total of eight mechanisms for electric heating are already commercially available, of which six can produce temperatures in excess of **1,000°C.**

### No-regret demand for green hydrogen and production potentials

- → **Industrial hydrogen demand** will be slightly higher than today's and **remain under 300 TWh/year by 2050** in order to reduce and eventually eliminate process emissions from carbon-based industrial applications. Given our climate neutrality target by 2050 and the phasing out of fossil fuels, hydrogen demand from refineries in Europe should decrease substantially by 2040 and vanish by 2050, while demand from steel plants and the chemical industry will increase.
- → Renewable energy potentials in European and neighbouring countries can be used to feed **direct-electric applications and renewable hydrogen production.** While the wind potential is stronger in Central-North Europe, solar PV will become increasingly important in the south. In parts of the Middle East and North Africa (MENA) region, the best potential is reached by combining solar and wind. Green hydrogen will require **major additional renewable energy capacity.**

### No-regret early infrastructure needs for green hydrogen

- → Strong policies for renewable hydrogen, decreasing the cost for renewable hydrogen, **phase out fossil-based hydrogen production, combined with carbon capture a decade earlier.**
- → When combining industrial hydrogen demand with different technology assumptions of hydrogen production, **robust no-regret corridors for infrastructure** emerge.
- → **4 main no-regret corridors for hydrogen infrastructure** deliver hydrogen to industrial demand clusters at the **lowest possible cost,** and provide access to hydrogen storage to facilitate flexibility and seasonality:
  - **Central-West Europe** (Benelux/North-West Germany/North-East France)
  - **East Europe** (Poland and South Lithuania)
  - **South-East Europe** (Romania, Bulgaria and North-West Greece)
  - **South-West Spain**

### The hydrogen network can be based on retrofitting existing natural gas pipelines (Western Europe) or new build (Eastern Europe).

- → These 4 main corridors **linking European industry** can anchor hydrogen demand in the near term while retaining the **flexibility to expand** the network should more hydrogen demand (from renewable energy back-up power, residual load for district heating, long-haul aviation and maritime shipping) add up in the future.

### Targeted policy support for fast scale-up and cost reductions

- → **Ramping up** renewable hydrogen requires **extra policy support focusing on rapid cost reductions.** Electrolyser systems need higher capacity factors to lower costs, as well as economies of scale driven by a **predictable and stable growing demand.** Moreover, the EU ETS **carbon price** will not be high enough in the 2020s to solely incentivise a switch to green hydrogen. Additional policy support instruments will be needed for a considerable period of time.
- → **Beyond 2030, direct support** for renewable hydrogen production or consumption should be **phased out.** In the next decade, the cost gap will be much smaller, and consumers and markets should increasingly shoulder the financing burden.

## POLICY INSTRUMENTS

No-regret green hydrogen developments in Europe require **targeted policy support for fast scale-up and production cost reductions,** at EU and Member Sates levels:

**EU sustainability criteria for climate neutral hydrogen are essential:**

- → Define the **criteria** together with a **roadmap for adoption**
- → Make it **binding** through legislation and a certification system
- → Define separate criteria for fossil-based hydrogen as a **bridge technology**
- → **All** hydrogen must be **climate neutral** over mid to long term at the latest

**The revision of the third energy package for gas in late 2021 needs to cover the following elements of market design:**

- → European-wide **standards** for hydrogen and hydrogen transport, including renewable hydrogen
- → **energy storage definition** to be expanded to include uses beyond the electricity sector, i.e. sectoral integration and sector coupling;
- → **compatibility** between dedicated hydrogen networks developing in individual Member States;
- → **cross-border trade,** with a uniform EU-wide Guarantee of Origin system for gas that governs renewable hydrogen and other low-carbon and renewable gases; and
- → **third-party access** to transport grids and a clear legal and organisational separation between hydrogen producers and grid operators ('unbundling').

**EU Hydrogen strategy:**

- → **Infrastructure needs for transport and storage** will be limited initially, but will become significant over time.
- → At the early stage of development, **financial support** will be essential to ensure adequate incentives for investment.
- → At the following stage, **investment risks mitigation** would be needed to lower the cost of capital, expected to remain relatively high.

**A strong policy framework is also needed to ramp up the market for renewable hydrogen and target initially the applications where hydrogen is clearly needed and a no-regret option. The following instruments are thus necessary:**

- → **carbon contracts for difference** in industry
- → **quotas** for aviation;
- → **auctions** to support combined heat and power plants;
- → measures to encourage **markets** for decarbonised materials; and
- → hydrogen **supply contracts.**

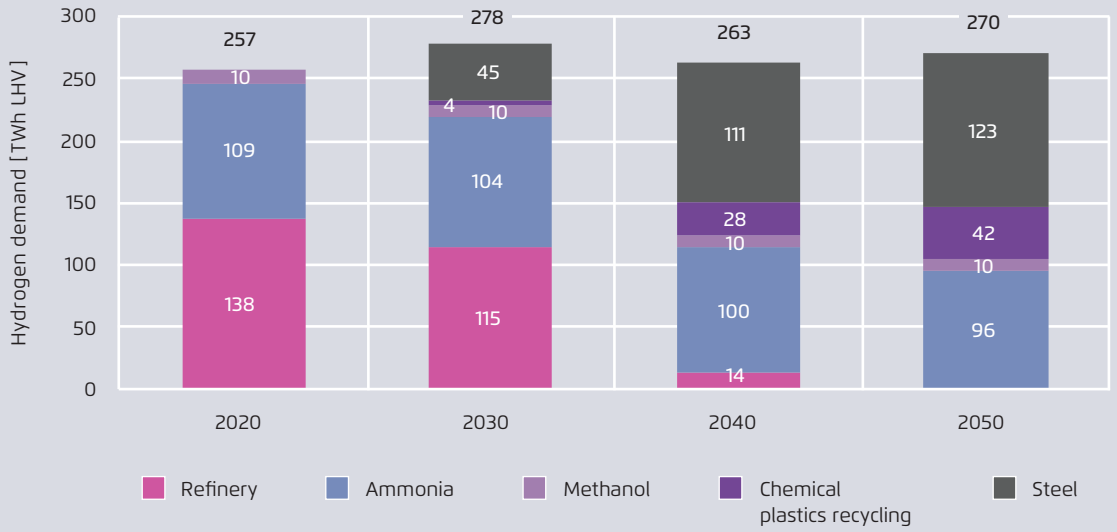
A green hydrogen economy requires **major renewable energy growth in addition** to the renewable energy needs identified for other sectors and applications, such as heat pumps (for heating and cooling in the industry and building sectors) or electric vehicles.

**Sources**

**Agora Energiewende and AFRY Management Consulting (2021):**
*No-regret hydrogen: Charting early steps for $H_2$ infrastructure in Europe*

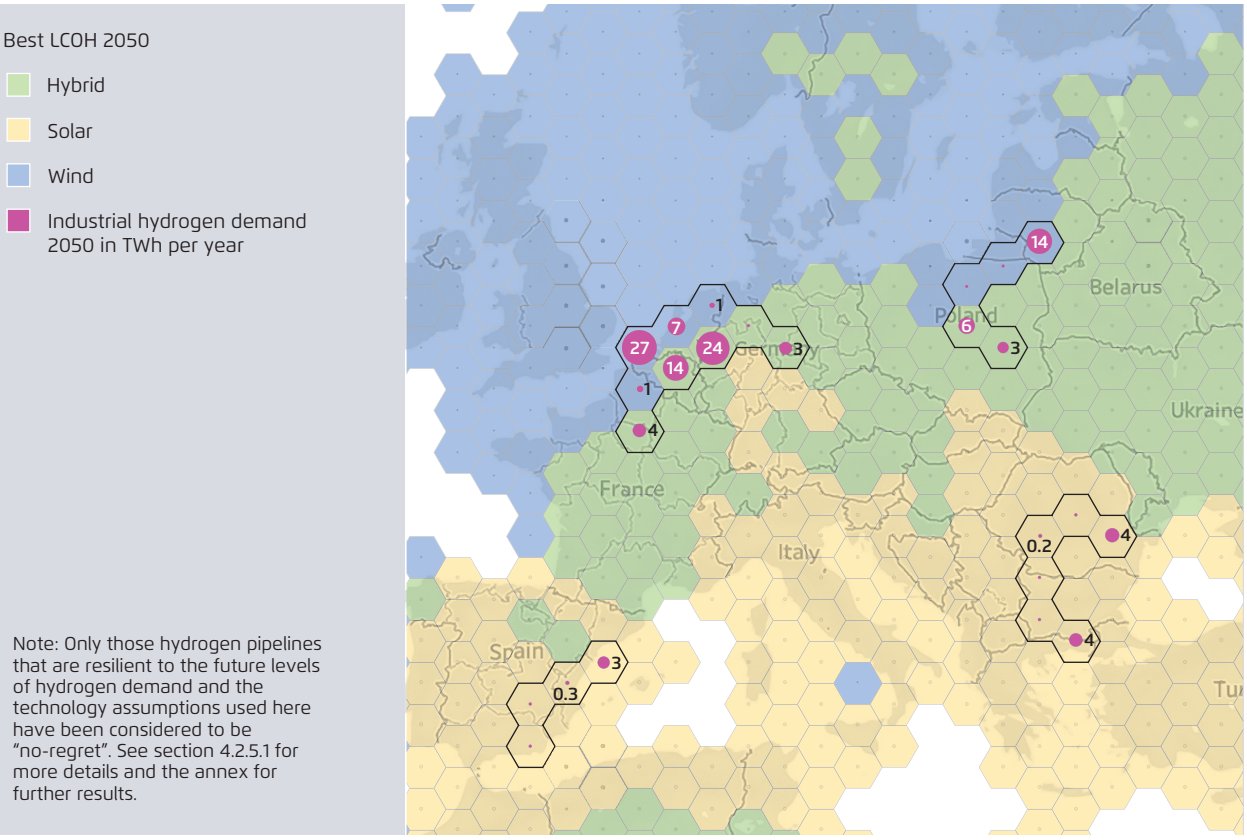
**Agora Energiewende and Guidehouse (2021):**
*Making renewable hydrogen cost-competitive: Policy instruments for supporting green $H_2$*

Industrial hydrogen demand from 2020 to 2050 within the specific demand sectors in TWh per year Figure 1




Agora Energiewende and AFRY Management Consulting (2021): No-regret hydrogen: Charting early steps for $H_2$ infrastructure in Europe

No-regret pipeline corridors with industrial hydrogen demand in TWh per year in 2050 Figure 2




Agora Energiewende and AFRY Management Consulting (2021): No-regret hydrogen: Charting early steps for $H_2$ infrastructure in Europe

Applications that really need green molecules to become climate-neutral, in addition to green electrons

Figure 3

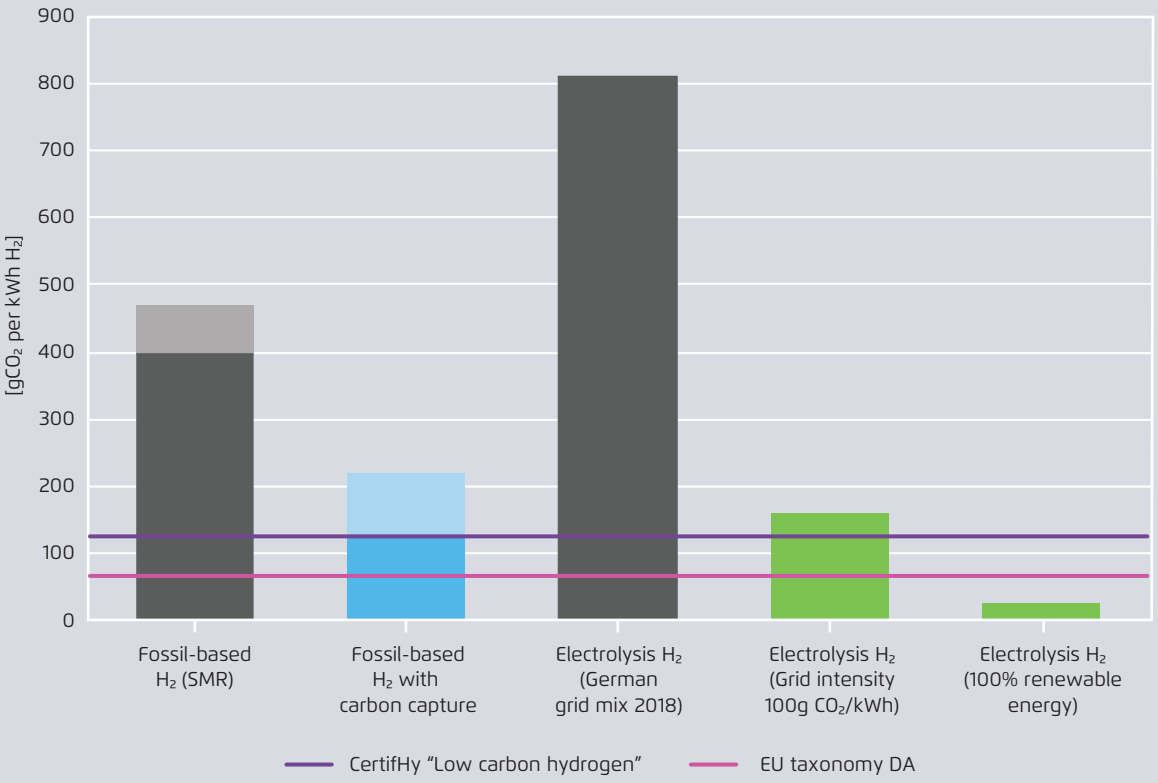
| Green molecules needed? | Industry | Transport | Power sector | Buildings |
|---|---|---|---|---|
| **Uncontroversial** | · Reaction agents (DRI steel)<br>· Feedstock (ammonia, chemicals) | · Long-haul aviation<br>· Maritime shipping | · Long-term storage for variable renewable energy back-up | · District heating (residual heat load *) |
| **Controversial** | · High-temperature heat | · Trucks and buses **<br>· Short-haul aviation and shipping | · Absolute size of need given other flexibility and storage options | |
| **Bad idea** | · Low-temperature heat | · Cars<br>· Light-duty vehicles | | Individual buildings |

* After using renewable energy, ambient and waste heat as much as possible. Especially relevant for large existing district heating systems with high flow temperatures. Note that according to the UNFCCC Common Reporting Format, district heating is classified as being part of the power sector.

** Series production currently more advanced on electric than on hydrogen for heavy duty vehicles and busses. Hydrogen heavy duty to be deployed at this point in time only in locations with synergies (ports, industry clusters).

Agora Energiewende and Guidehouse (2021): Making renewable hydrogen cost-competitive: Policy instruments for supporting green $H_2$

Lifecycle emission intensity by $H_2$ production route in $gCO_2$ per kWh $H_2$ (LHV) Figure 4




Climate Action Network (2021), EC (2020), ÖkoInstitut (2019), Greenpeace Energy (2020), CertifHy (2019)
Agora Energiewende and Guidehouse (2021): Making renewable hydrogen cost-competitive: Policy instruments for supporting green $H_2$

Lower heating value. Assuming a capture rate for fossil-based $H_2$ with carbon capture between 65% (for existing SMR) and 90% (for new ATR)

Learn more:
www.agora-energytransition.org/success-stories

**241/06-DO-2021/EN**
November 2021, Version: 1.0

**Agora Energy Transition**
www.agora-energytransition.org
info@agora-energytransition.org

Agora Energy Transition