# Chapter 2

# 2021 Hydrogen supply and demand

**September 2021**

FUEL CELLS AND HYDROGEN OBSERVATORY

## Disclaimer

This report is based on data gathered as part of the Fuel Cells and Hydrogen Observatory as of 31 May 2021. The data aims to reflect reality as of end of 2019.[1] The authors believe that this information comes from reliable sources, but do not guarantee the accuracy or completeness of this information. The Observatory and information gathered within it will continue to be revised. These revisions will take place annually and may also be done on a case-by-case basis. As a result, the information used as of writing of this report might differ from the changing data in the Observatory.

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This report was prepared for the Fuel Cells and Hydrogen 2 Joint Undertaking as part of the Fuel Cells and Hydrogen Observatory. Copies of this document can be downloaded from https://www.fchobservatory.eu/

The Fuel Cells and Hydrogen Observatory has been prepared for the FCH 2 JU under a public procurement contract.



[1] The data only reflects end of 2019 as some of the sources did not have 2020 data available during the data collection process.

# TABLE OF CONTENTS

## Executive Summary

**Purpose:** The purpose of the hydrogen supply and demand data stream is to track changes in the structure of hydrogen supply capacity and demand in Europe. This report is mainly focused on presenting the current landscape that will allow for future year-on-year comparisons to assess the progress Europe is making with regards to deployment of clean hydrogen production capacity as well as development of demand for clean hydrogen from emerging new hydrogen applications in industry or mobility sectors.

**Scope:** The following report contains data about **hydrogen production capacity and consumption in EU countries**, together with **Switzerland, Norway, Iceland,** and **the United Kingdom**. Hydrogen production capacity is presented by country and by production technology, whereas the hydrogen consumption data is presented by country and by end-use sector. The analysis undertaken for this report was completed using data reflecting end of 2019.

**Key Findings:** The current hydrogen market (on both the demand and supply side) is dominated by ammonia and refining industries with three countries (DE, NL, PL) responsible for almost half of hydrogen consumption. Hydrogen is overwhelmingly produced by reforming of fossil fuels (mostly natural gas). Clean hydrogen production capacities are currently insignificant with hydrogen produced from natural gas coupled with carbon capture at 0.5% and hydrogen produced from water electrolysis at 0.14% of total production capacity.

Total hydrogen production capacity in the included countries at the end of 2019 has been estimated at **28,854 tonnes per day or 10.5 Mt per year**[2]. The corresponding consumption of hydrogen has been estimated at **8.4 Mt (330 $TWh_{HHV}$)**, which means an average capacity utilization of 80%.

The biggest share of hydrogen demand comes from refineries, which were responsible for 49% of total hydrogen use, followed by the ammonia industry with 31%. Together these two sectors consumed almost 4/5 of total hydrogen consumption in the covered European countries. About 13% was consumed by the chemical industry including methanol production constituting 5%. **Emerging hydrogen applications, like the transportation sector comprised a small portion of the market at 0.02% as of 2019.**

On-site captive hydrogen production was by far the most common method of hydrogen supply, comprising **20,702 tonnes per day** (72%) of all hydrogen production capacity with by-product production of **3,982 tonnes per day**[3] and merchant production of **3,900 tonnes per day constituting 14%** of production capacity each.

Germany was, by a significant margin, the largest European market for hydrogen, with 20% of total European hydrogen production capacity and 20% of total demand. Together with the Netherlands, Poland, and Spain, these four countries were responsible for 51.3 % of the hydrogen demand and 50.4% of production capacity.

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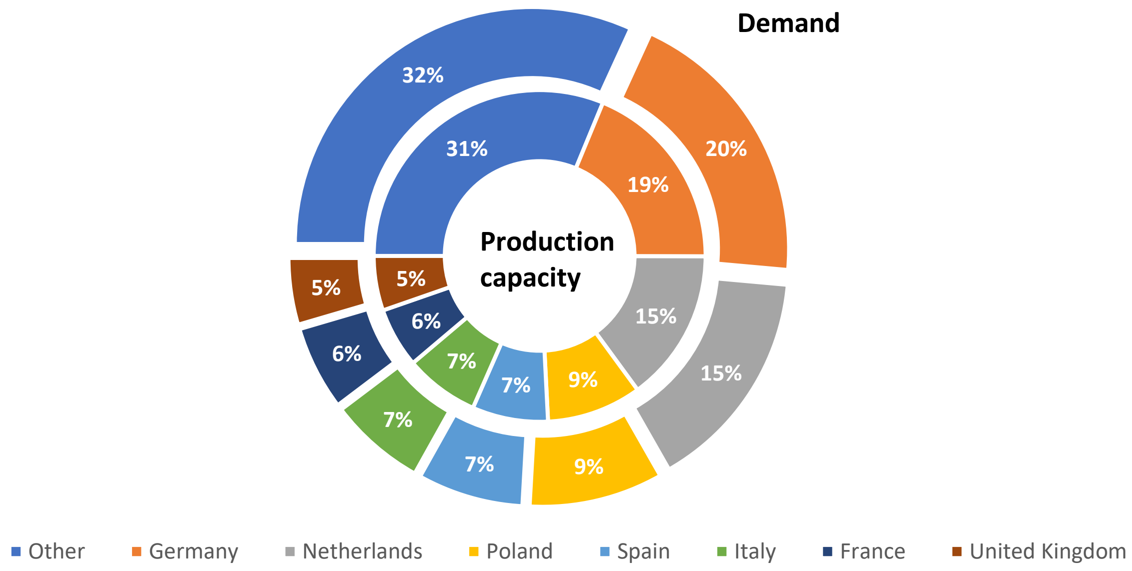
[2] *Excluding by-product hydrogen in the coke oven gas*
[3] *Excluding by-product hydrogen in the coke oven gas*

Figure 1. Total hydrogen production capacity and consumption by country in 2019




*Source: Fuel Cells and Hydrogen Observatory*

The most common method of producing hydrogen is steam reforming of natural gas (SMR). Less common are partial oxidation (POX) and autothermal reforming (ATR). SMR and natural gas are widely used for all applications including oil refining, ammonia synthesis, or any other bulk hydrogen production. Even though natural gas is the most common feedstock, steam reforming is also used with other feedstocks, which include also liquid hydrocarbons like LPG or naphtha.

Out of the 326 identified hydrogen production plants which were using fossil fuels as feedstock, only three were using carbon capture technologies:

- Grupo Sappio hydrogen production unit in Mantova, Italy with a capacity of around 1,500 $Nm^3/h$ that started operating in 2016.
- Air Liquide Cryocap installation in Port Jerome, France, capturing $CO_2$ from hydrogen supplied to an Exxon refinery, with a capacity of around 50,000 $Nm^3/h$ that started operating in 2015.
- Shell refinery in Rotterdam, Netherlands where $CO_2$ from hydrogen production is captured and sold for agricultural use as part of the OCAP project since 2004.

**Total share of hydrogen production from fossil fuels with CCS/CCU was around 131 tonnes per day equating to 0.5% of the total hydrogen generation capacity**.

By the end of 2019, 95 operational power-to-hydrogen (water electrolytic) projects were identified for hydrogen production. Total power of those electrolysers was **92 MW** equalling to hydrogen generation capacity of ~**1.7 t of electrolytic hydrogen per hour (0.14% of total production capacity)**. This represents a 33% increase in capacity compared to 69 MW operating in 2018.

# 1. Hydrogen production capacity

## 1.1. Summary

Hydrogen production capacity analysis has been undertaken, building on work completed by the Roads2HyCom project and ongoing work by the Hydrogen Analysis Resource Centre (HyARC). Results of this data collection include **536 hydrogen production sites**, which have been categorised by:

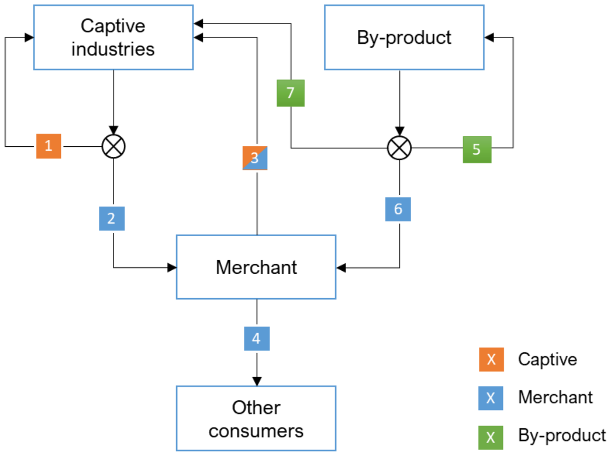
- type of production (captive, merchant, by-product);
- technology;
- application (only for captive hydrogen production capacity);
- country.

The hydrogen production plants have been divided into three main categories: captive production facilities[4], merchant production facilities[5] and plants where production of hydrogen is a by-product of other processes. It should be noted though, that in some cases, the boundaries between different hydrogen streams are extremely blurry. The reason is that in many cases many types of installations are clustered within the same area and it is not uncommon for an industrial park to contain all three types of installations. In this case, the flow of hydrogen between installations is more a result of current capacity utilization than a fixed design and can therefore change over time. For example, a captive hydrogen generation unit (HGU) can be used to supply hydrogen to merchant companies during times when it is underutilized for its primary purpose. As a result, the amount of hydrogen that can be used for merchant supply from excess hydrogen from captive industries, varies depending on the actual demand for hydrogen from its primary use.

[4] On-site production of hydrogen for own consumption.
[5] Hydrogen production dedicated for sales.

For the purpose of this analysis we have defined the boundaries between the three hydrogen production types as follows:

Figure 2. Definition of hydrogen production types by availability



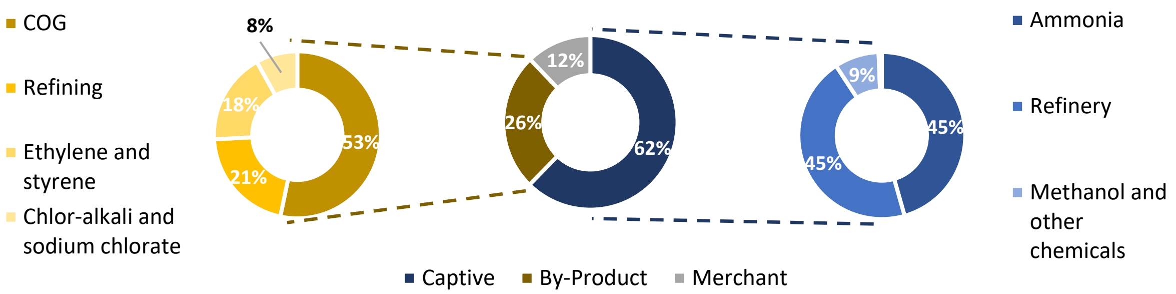

Where:

1. Captive hydrogen production on-site used exclusively for own consumption within the same facility.
2. Excess hydrogen production capacity in dedicated installations, that can be valorised and sold to external hydrogen merchant companies for resale. This has been applied only to installations, which are dedicated to supply hydrogen merchants.
3. Hydrogen produced in large industrial installations usually dedicated to serve a single customer or an industrial cluster. Usually produced in close vicinity or distributed with pipelines. Whenever we could identify that the installation was serving a single customer those installations were categorised as captive. In other cases, it was categorised as merchant.
4. Hydrogen produced for retail purposes and sold in relatively small volumes, that does not warrant building its own HGU. Usually distributed in compressed form, in cylinders or using tube trailers (200 bar), in few cases liquefied, also mostly using trucks.
5. By-product hydrogen that is vented to the atmosphere or used as feedstock for internal processes or for on-site energy generation.
6. By-product hydrogen that is purified and sold to merchants for further resale.
7. By-product hydrogen that is sold directly to nearby captive industry.

Total hydrogen production capacity in the covered European countries at the end of 2019 has been estimated at **33,125 tonnes per day**. Excluding coke oven gas hydrogen, the remaining capacity is **28,584 t per day**.

Sixty two percent (62%) of all hydrogen production capacity was designated for captive production. In reality it is even more than that, as a large portion of the merchant plants are dedicated entirely to supplying large industrial customers on-site, with only a small proportion of production capacity available to supply the wider market. By-product hydrogen provides 26% of total hydrogen production capacity, of which 53% is coke oven gas hydrogen.

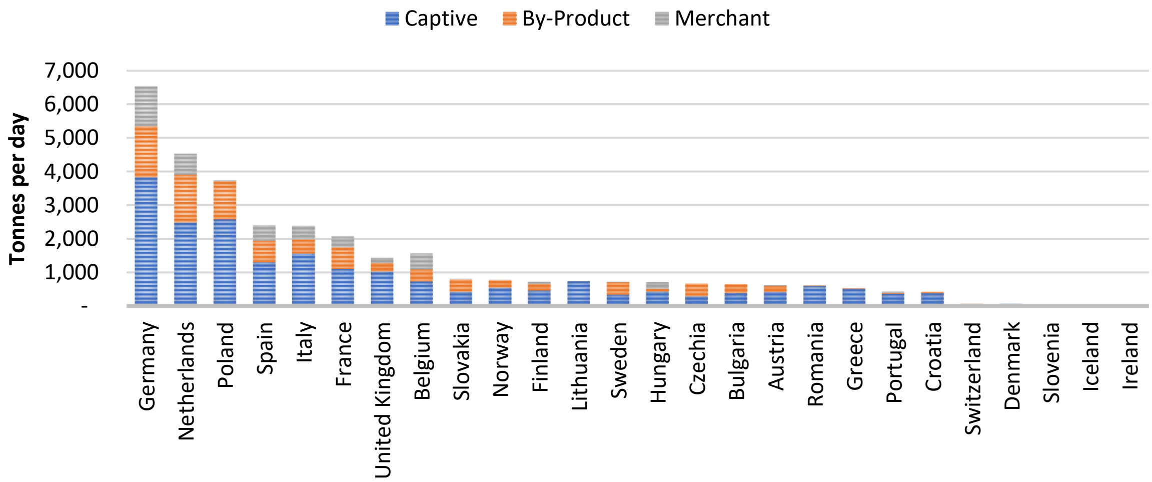
Figure 3. Structure of hydrogen production capacity




*Source: Fuel Cells and Hydrogen Observatory*

With almost 6,524 t per day (20% of total), Germany has by far the largest hydrogen production capacity from among the analysed countries. The Netherlands follows with 4,523 t per day (14% of total. Other countries with significant hydrogen production capacity are Poland (3,741 t per day, 11%), Spain (2,402, 7%), Italy (2,386, 7%), France (2,071, 6%), and United Kingdom (1,429, 6%).[6]

Figure 4. Total hydrogen production capacity by country




*Source: Fuel Cells and Hydrogen Observatory*

## 1.2. Captive production

On-site captive hydrogen production is by far the most common method of hydrogen supply for large hydrogen consumers. This is mainly the case for refineries, ammonia plants, methanol, and hydrogen peroxide production plants. In all those cases, the high volume of hydrogen consumed, justifies the investment in a dedicated HGU. The predominant technology for this type of installations is hydrocarbon reforming – mostly steam methane reforming (SMR).

### 1.2.1. Refining

The oil refining sector is the biggest hydrogen producer and consumer in the EU. Hydrogen in refineries is used for the purpose of hydrotreating and hydrocracking processes. Hydrotreatment is one of the key stages of the diesel refining process and relates to several processes such as hydrogenation, hydrodesulphurization, hydrodenitrification and hydrodemetalization. Hydrocracking involves the

[6] Including by-product hydrogen in the coke oven gas

transformation of long and unsaturated products into products with a lower molecular weight than the feed.

Hydrocracking is by far the most common hydrogen consuming process, needing around 300 $Nm^3$ $H_2$/t of product. Hydrotreating processes usually require only around 20-50 $Nm^3$ $H_2$/t of product. It is also important to note that refineries not only consume but also produce hydrogen at various stages of crude oil refining, with the most hydrogen yield being generated during catalytic reformulation which produces hydrogen at a rate of 200 $Nm^3$ $H_2$/t crude oil [1].

The volume of production can be substantial to the point that refineries that do not use hydrocracking usually are self-sufficient in terms of hydrogen consumption and do not require any additional dedicated hydrogen production.

All large EU refineries use fossil fuels (most commonly natural gas) as a feedstock to produce hydrogen through one of the following processes:

- reforming operations for hydrotreating;
- steam reforming or autothermal reforming of light ends or natural gas;
- partial oxidation (gasification) of heavy oil fractions.

Refineries with the simplest configuration may produce enough hydrogen only through catalytic reforming. Complex plants with extensive hydrotreating and/or hydrocracking operations typically require more hydrogen than is produced by their catalytic reforming units and it is those refineries that have dedicated HGU's. The feed of the hydrogen plant consists of hydrocarbons in the range from natural gas to heavy residue oils and coke. The conventional steam reforming process produces a hydrogen product of a maximum of 97 – 98 % v/v purity and higher if a purification process is applied (99.9 – 99.999 % v/v) [2].

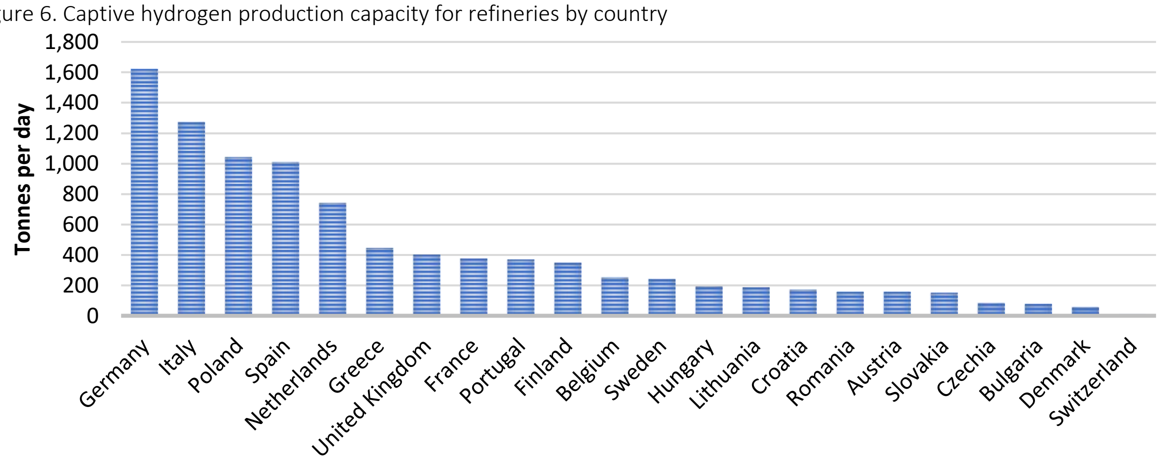
The total captive production capacity of HGU's installed at refineries (excluding merchant plants, even if dedicated to supply hydrogen to refineries) is approximately **9,376 t per day** split between **93 facilities.**

Germany has the largest share with 17% of total EU, EFTA, and UK hydrogen production capacity in refineries, followed by Italy (11%), Poland (11%), Spain, (11%), and the Netherlands (8%).

Figure 5. Captive hydrogen production units installed at refineries

*Source: Fuel Cells and Hydrogen Observatory*

Figure 6. Captive hydrogen production capacity for refineries by country




*Source: Fuel Cells and Hydrogen Observatory*

### 1.2.2. Ammonia

Next to refineries, the ammonia industry is the second largest hydrogen consuming sector in the EU. The ammonia production process involves a synthesis of hydrogen with nitrogen according to the following formula:

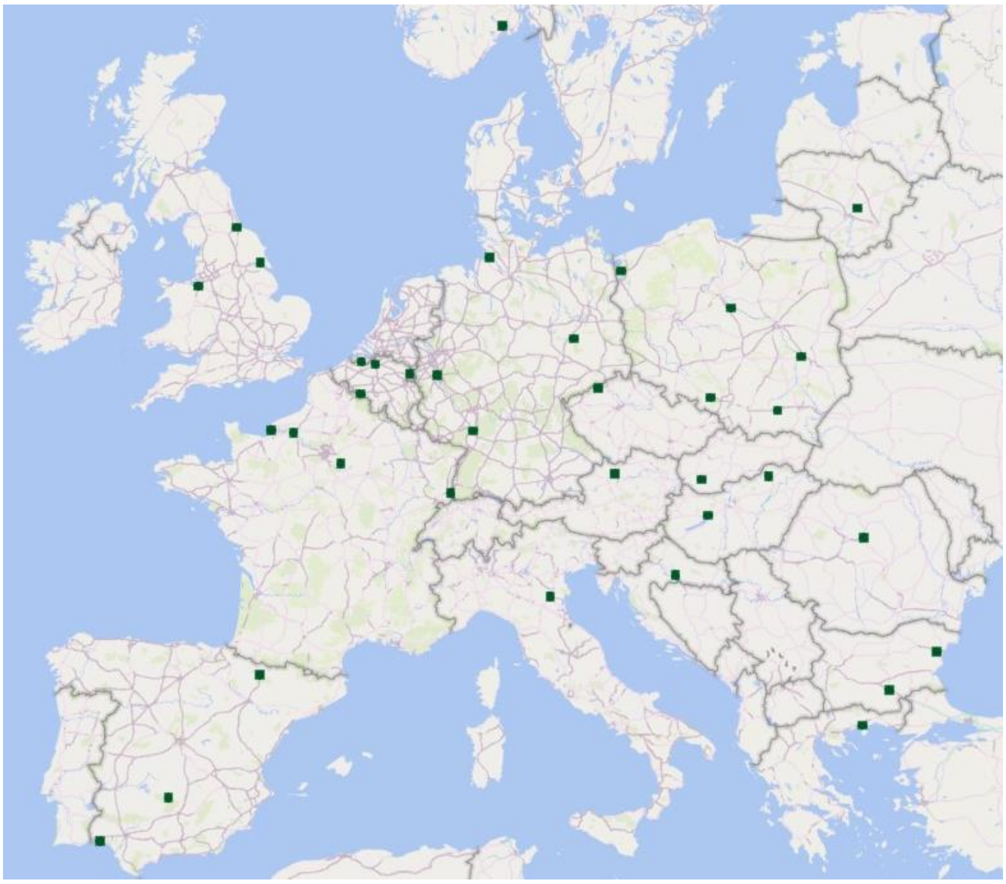
$$N_2 + 3\ H_2 \rightarrow 2\ NH_3$$

This process consumes about 175-180 kg of hydrogen per t of ammonia.

Total ammonia-related hydrogen production capacity in Europe was approximately **9,489 t per day** split between **36 facilities**. All of them were using either steam methane reforming or partial oxidation (POX) to generate hydrogen.

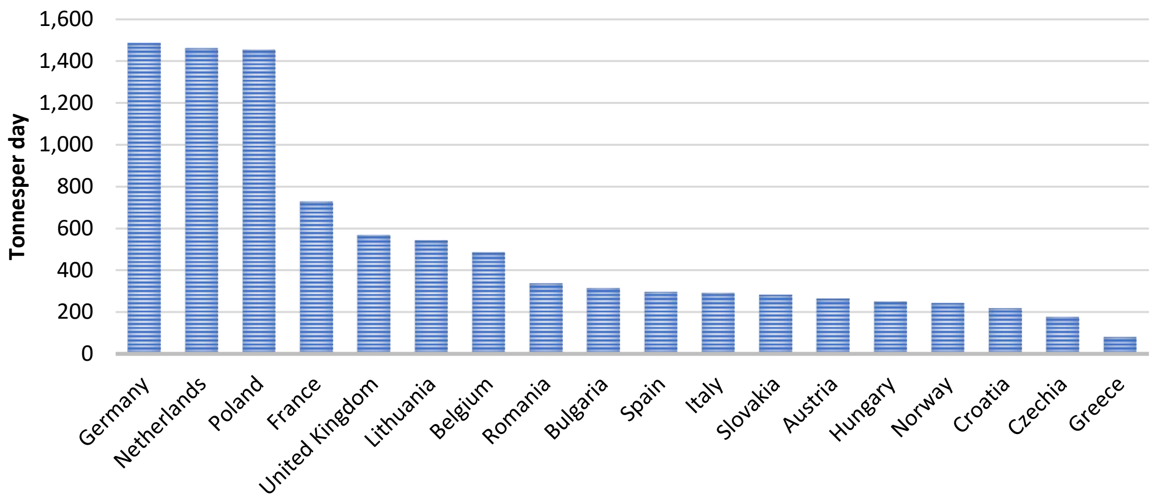
Similar to refining, Germany had the largest share with 16% of all Europe's hydrogen production capacity dedicated to ammonia production, closely followed by the Netherlands (15%), Poland (15%), France (8%), and the United Kingdom (6%).

Figure 7. Captive hydrogen production units installed for ammonia production



*Source: Fuel Cells and Hydrogen Observatory*

Figure 8. Captive hydrogen production capacity for ammonia by country




*Source: Fuel Cells and Hydrogen Observatory*

### 1.2.3. Other captive hydrogen production plants

The captive hydrogen production sites located in refineries or ammonia plants comprise around 91% of total captive hydrogen production. Other than these processes, hydrogen is produced at scale also for the production of a number of other chemicals, including methanol and hydrogen peroxide.

The most common methanol production method is steam reforming of methane and subsequent synthesis, and follows the following process:

$$1st\ step: CH_4 + H_2O \rightarrow CO + 3\ H_2 \text{ and } CO + H_2O \rightarrow CO_2 + H_2$$

$$2nd\ step: 3\ H_2 + CO_2 \rightarrow CH_3OH + H_20$$

This production consumes about 1,400 $Nm^3$ $H_2$/t of methanol [1]. Methanol is an important chemical raw material used for the production of formaldehyde, acetic acid and MTBE or fatty acid methyl esters (FAME), adhesives and solvents.

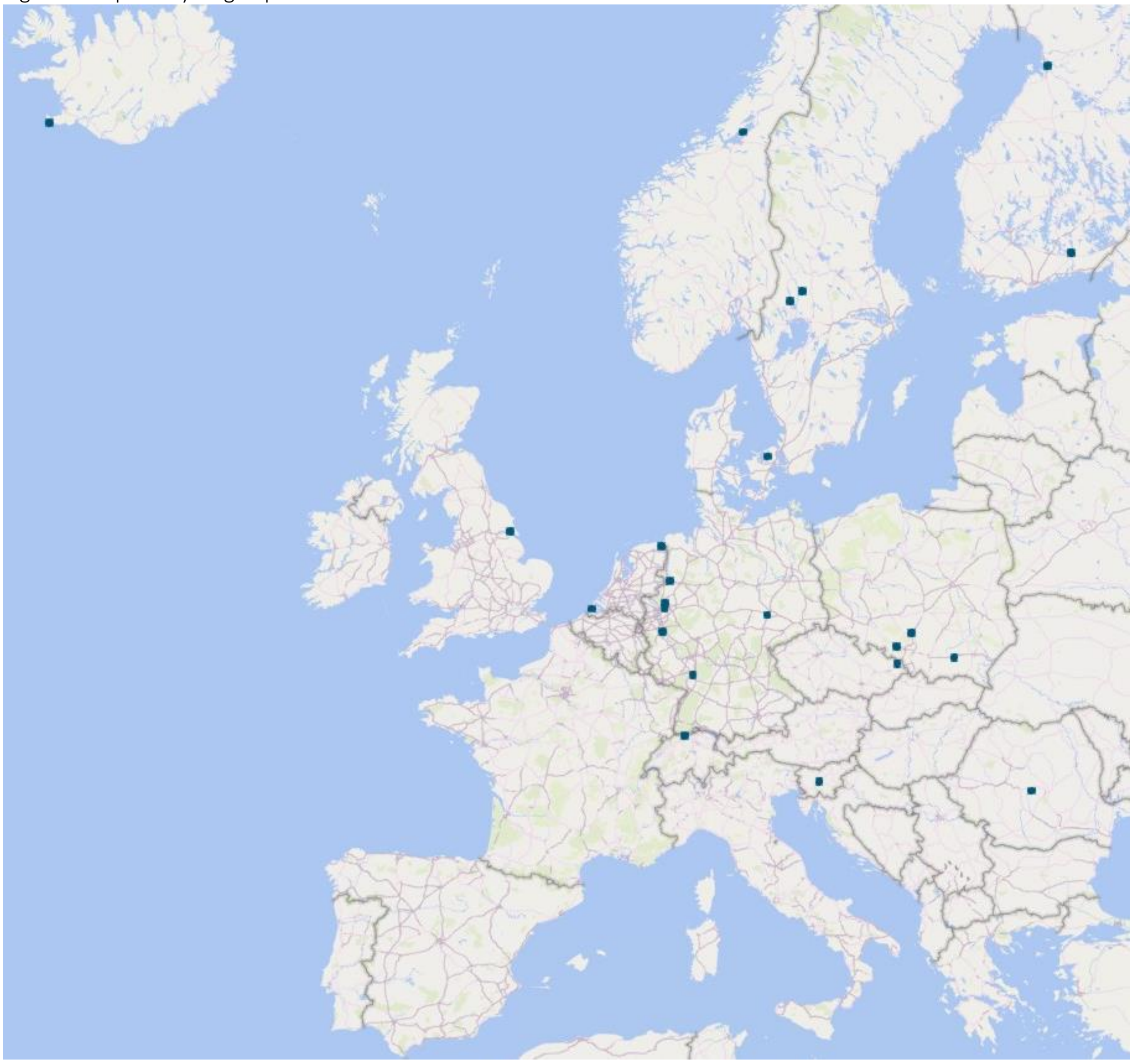
Other uses of hydrogen in the chemical industry include the production of such high-volume chemical products as hydrogen peroxide, for which hydrogen consumption is approx. 735 $Nm^3$ $H_2$/t [1], hydrogen chloride, aniline, cyclohexane, TDI and oxo-alcohols. In most cases, production of those chemicals takes place at large integrated chemical or petrochemical plants.

As is the case with hydrogen produced for the oil refining or fertilizer industry, the overwhelming number of installations today use fossil fuels as feedstock for production of hydrogen.

One notable exception is Carbon Recycling International's George Olah Renewable Methanol Plant in Svartsengi (Iceland). The plant is able to produce 5 million litres of methanol per year and uses hydro and geothermal energy for producing hydrogen from water electrolysis, which is then reacted with $CO_2$ from flue gases to produce methanol [3].

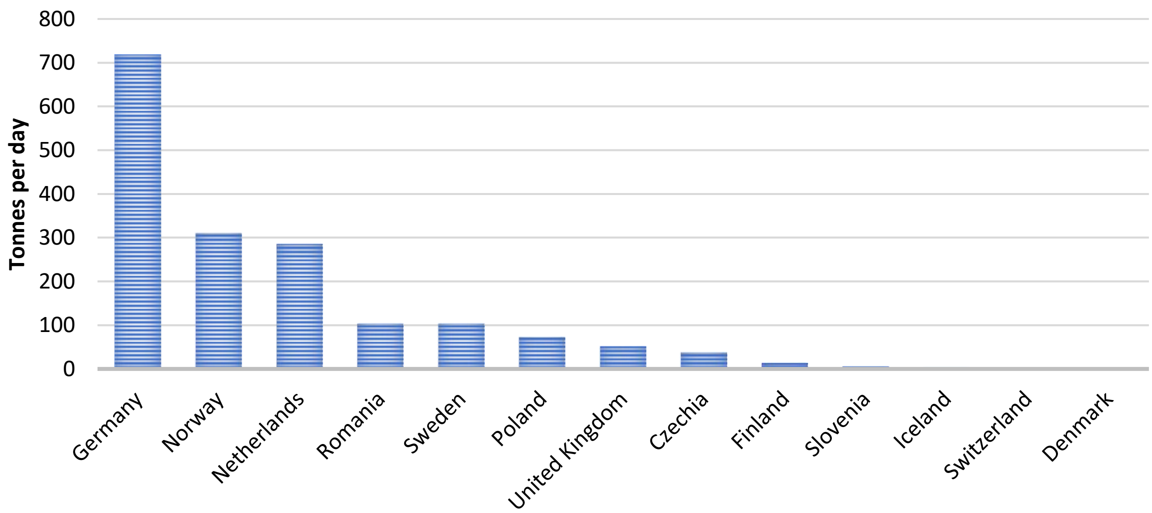
Total captive hydrogen production capacity in Europe dedicated to methanol and other chemicals is approximately **1,707 t per day** split between **23 facilities**.

Figure 9. Captive hydrogen production units installed for methanol and other chemicals



*Source: Fuel Cells and Hydrogen Observatory*

Figure 10. Captive hydrogen production capacity for methanol or other chemical plants, excluding ammonia.




*Source: Fuel Cells and Hydrogen Observatory*

## 1.3. Merchant hydrogen production

The merchant hydrogen plants can be divided into two main categories:

- plants dedicated to supply a single large-scale consumer with only excess capacity available to supply the retail hydrogen market; and
- small and medium scale hydrogen production sites designed for the purpose of supplying mostly retail customers.

While the first type can be comparable in scale to the largest captive hydrogen production facilities, the installations designed with the hydrogen retail market in mind are an order of magnitude smaller in terms of their maximum capacity.

The report identified 108 merchant hydrogen plants operational in Europe in 2019. **Total capacity of those plants has been estimated at 3,865 t per day.**

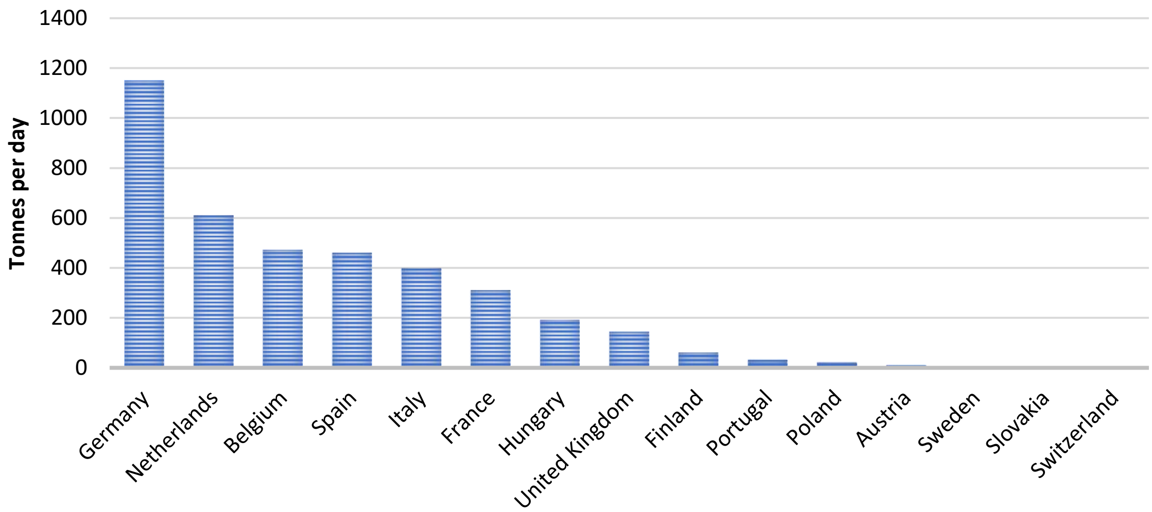
Figure 11. Identified merchant hydrogen plants

*Source: Fuel Cells and Hydrogen Observatory*

The merchant hydrogen market in Europe is dominated by 4 groups: Linde Gas, Air Liquide, Air Products and Messer, that own a combined 81% of plants and 90% of total merchant hydrogen production capacity.

As was the case with captive hydrogen production, most merchant hydrogen production capacity is located in Germany (29%), the Netherlands (15%), Belgium (12%), Spain (11%), Italy (10%), and France (8%).

Figure 12. Merchant hydrogen production capacity.




*Source: Fuel Cells and Hydrogen Observatory*

From a technology perspective, while most production capacity is still fossil fuel based, 11% of the merchant hydrogen production capacity also comes from by-product production from the chlor-alkali and sodium chlorate processes.

## 1.4. By-product hydrogen production

By-product hydrogen production capacity, by which we mean hydrogen produced as a by-product of other processes, has been estimated at **8,523 t per day**, including:

- 4,541 t per day of hydrogen mixed in coke oven gas,
- 1,777 t per day of hydrogen as by-product from refining operations[7],
- 581 t per day of hydrogen produced by the chlor-alkali process,
- 108 t per day of hydrogen produced by the sodium chlorate process,
- 1,105 t per day of hydrogen produced during ethylene production,
- 412 t per day of hydrogen produced during styrene production.

The hydrogen production rate for ethylene and styrene production processes is around 190 $Nm^3$ $H_2$/t ethylene and 220 $Nm^3$ $H_2$/t of styrene [1]. By-product hydrogen from those industries is almost universally used on site as a feedstock for other chemical or petrochemical processes further downstream.

The by-product production rate from the chlor-alkali industry is around 300 to 270 $Nm^3$ $H_2$/t chlorine [1]. On average, the industry vents around 15% of produced hydrogen into the atmosphere with the

[7] This number is significantly higher in real life and the authors continue to improve the data quality between captive hydrogen production capacity at refineries from dedicated HGUs and its by-product production at refineries

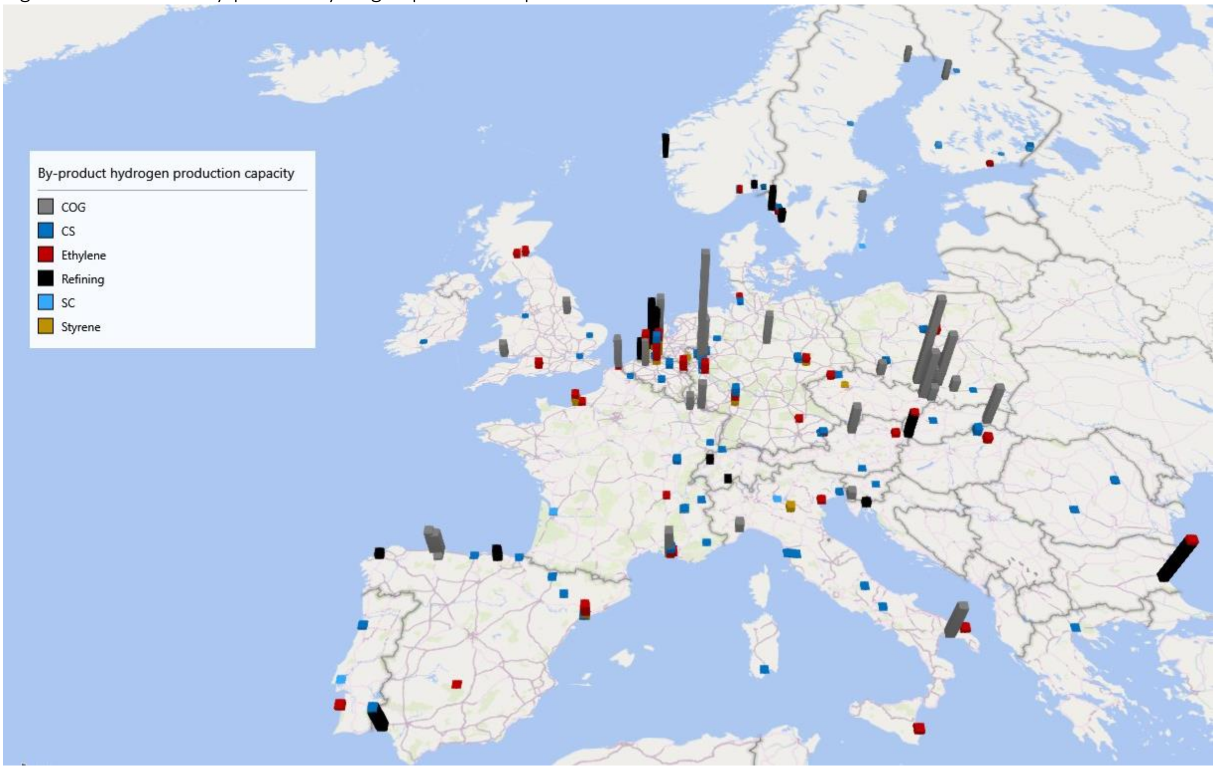
remaining 85% usually burned for heat or used in a CHP unit to generate both heat and power. Because by-product hydrogen from the chlor-alkali industry has high purity, if a pipeline network is available, by-product hydrogen can also be sold to other industrial users or sold to hydrogen merchants. In the case of the chlor-alkali plant in Cologne, Germany, some by-product hydrogen is also used as a fuel for FCEV buses.

The biggest potential source of by-product hydrogen is coke oven gas (COG), where the hydrogen production rate is about 450 $Nm^3$ $H_2$/t of product. In this case though, the output gas is not pure hydrogen but rather a mixture of hydrogen (55%-65%) and methane, carbon monoxide, $CO_2$ and nitrogen. Coke oven gas is used to enrich the calorific value of the other process gases for use in blast furnace stoves, the reheating furnaces of hot strip mills, for other high temperature processes, or for the under-firing of coke ovens. The surplus COG may be utilised at the blast furnace as an alternative reducing agent and is also used in power plants [4].

Other, smaller by-product hydrogen sources include:

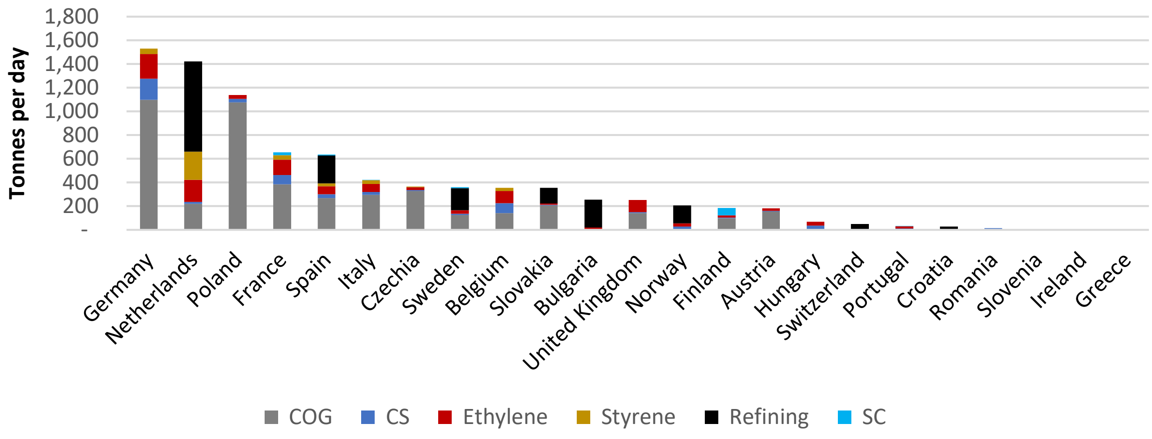
- Acetylene production: 3,400 – 3,740 $Nm^3$ $H_2$/t product
- Cyanide production: 2,470 Nm3 $H_2$/t of product (Degussa´s BMA process) [1].

Figure 13. Identified by-product hydrogen production plants




*Source: Fuel Cells and Hydrogen Observatory*

Figure 14. By-product hydrogen production capacity[8]




Source: Fuel Cells and Hydrogen Observatory

## 1.5. Clean hydrogen production capacity

The most common method of producing hydrogen is steam reforming of natural gas (SMR). Less common are partial oxidation (POX) and autothermal reforming (ATR). SMR and natural gas is widely used for all applications including oil refining, ammonia synthesis, or any other bulk hydrogen production. Even though natural gas is the most common feedstock, steam reforming is also used with other feedstocks, which include also liquid hydrocarbons like LPG or naphtha.

Out of the 326 identified hydrogen production plants which were using fossil fuels as feedstock, only three were using carbon capture technologies:

- Grupo Sappio hydrogen production unit in Mantova, Italy with a capacity of around 1,500 $Nm^3/h$ that started operating in 2016.
- Air Liquide Cryocap installation in Port Jerome, France, capturing $CO_2$ from hydrogen supplied to an Exxon refinery, with a capacity of around 50,000 $Nm^3/h$ that started operating in 2015.
- Shell refinery in Rotterdam, Netherlands where $CO_2$ from hydrogen production is captured and sold for agricultural use as part of the OCAP project since 2004.

**The total share of hydrogen production capacity from fossil fuels with CCS/CCU is ~0.5% equating to 131 tonnes per day.**

Hydrogen can, of course, also be produced with electricity by splitting water via **water electrolysis**. There is a significant number of electrolysers installed in Europe. In the past, electrolysers have been employed whenever the volume of hydrogen demand is high enough to warrant building a dedicated installation onsite, instead of external supplies in cylinders or tube trailers, but not high enough to invest in an SMR + PSA unit, especially whenever high purity grade hydrogen is required. This includes for example electrolysers installed for captive hydrogen production at food processing facilities (fat hardening) or power plants where hydrogen is used for cooling purposes. According to the JRC [5] the total installed capacity of electrolysers in Europe is around 1 GW, which would amount to around 1.4% of total hydrogen production capacity. But since those electrolysers are quite numerous and relatively

[8] The lack of by-product hydrogen production capacity from refining processes in some countries stems from limited data availability. For countries where refining is not included in this by-product chart, this by-product capacity is captured as part of the captive production capacity.

small scale (rarely exceeding the tens or hundreds of kW range), they are extremely hard to track and have been excluded from detailed analysis.

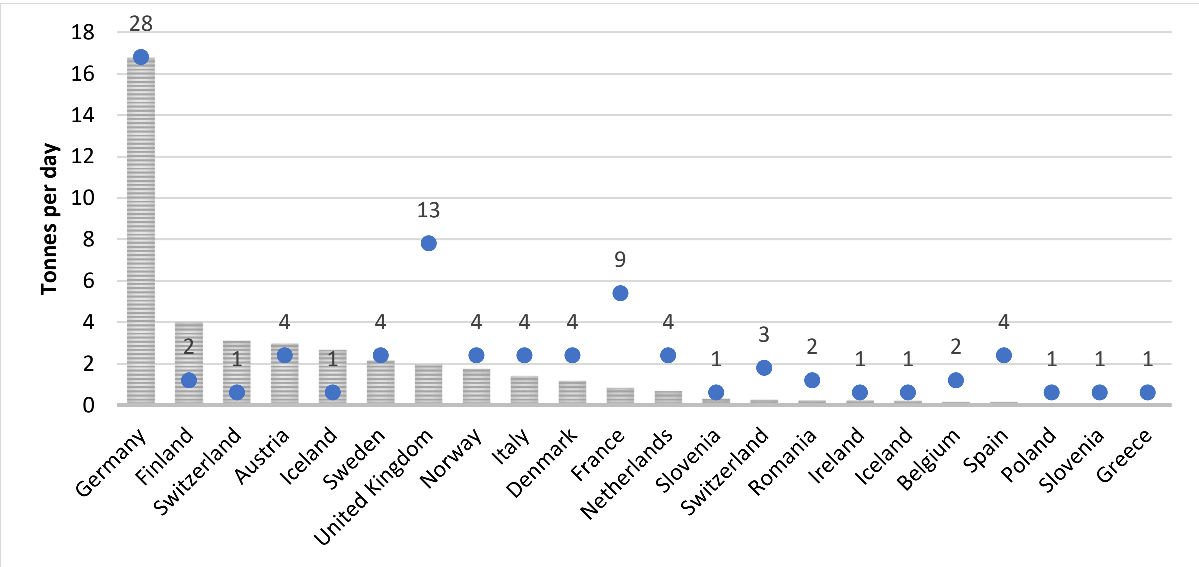
Beyond the established hydrogen use cases mentioned above, there is increased activity in development of power-to-hydrogen projects, where electricity is used to produce hydrogen via water electrolysis. By the end of 2019, the authors identified **95 operational power-to-gas** (water electrolytic) projects. Total power of those electrolysers was around **92 MW** equalling a hydrogen generation capacity of ~41 t of electrolytic hydrogen per day **(0.14% of total production capacity)**.[9] Compared to 69 MW in 2018, this represents a 33% increase in operational power-to-hydrogen capacity between 2018 and 2019.

While some are commercial plants, others were built as part of R&D or demonstration plants destined to be decommissioned after only a few years of operations.

Most of them produce electrolytic hydrogen for merchant sales, on-site industrial consumption, mobility applications, or energy storage for renewable energy grid balancing.

Countries with the largest number of installations are Germany (28), United Kingdom (13), France (9). Countries with the largest installed water electrolytic production capacity are Germany with 17, Finland with 4, Switzerland with 3, Austria with 3, and Iceland with 3 t per day.

Figure 15. Hydrogen production capacity and number of projects using water electrolysis in 2019




*Source: Fuel Cells and Hydrogen Observatory*

[9] The production numbers from electrolysis reflect maximum technical production capacity. Actual production numbers are significantly lower due to the various operating conditions of the individual electrolyzers.

# 2. Demand for hydrogen

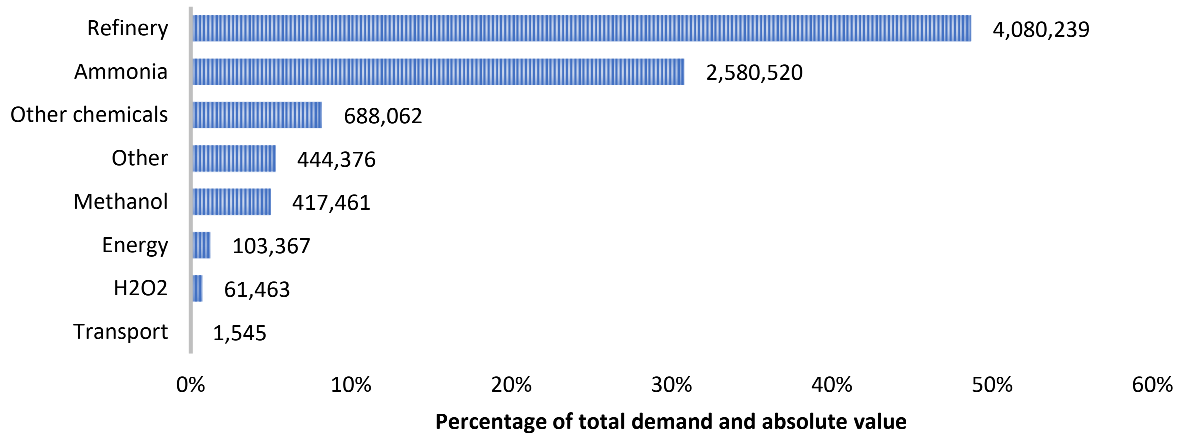
## 2.1. Summary

Hydrogen consumption data in this report has been collected and estimated based on available information gathered from a number of sources as well as calculations based on hydrogen production capacity at different hydrogen production plants. The external sources include EUROSTAT supplemented by information published or received from a number of trade associations (Eurochlor, Fertilizers EUROPE, Fuels Europe, CONCAWE, Petrochemicals Europe, Cefic).

Total demand for hydrogen in the analysed countries in 2019 has been estimated at 8.4 Mt. The biggest share of hydrogen demand comes from refineries, which were responsible for 49% of total hydrogen use, followed by the ammonia industry with 31%. Together these two sectors consumed 80% of total hydrogen consumption in the EU, EFTA, and UK. About 13% is consumed by the chemical industry, with methanol production accounting for 5% of that.

Emerging hydrogen applications, like the transportation sector, comprised a very small portion of the market (0.02% in 2019).

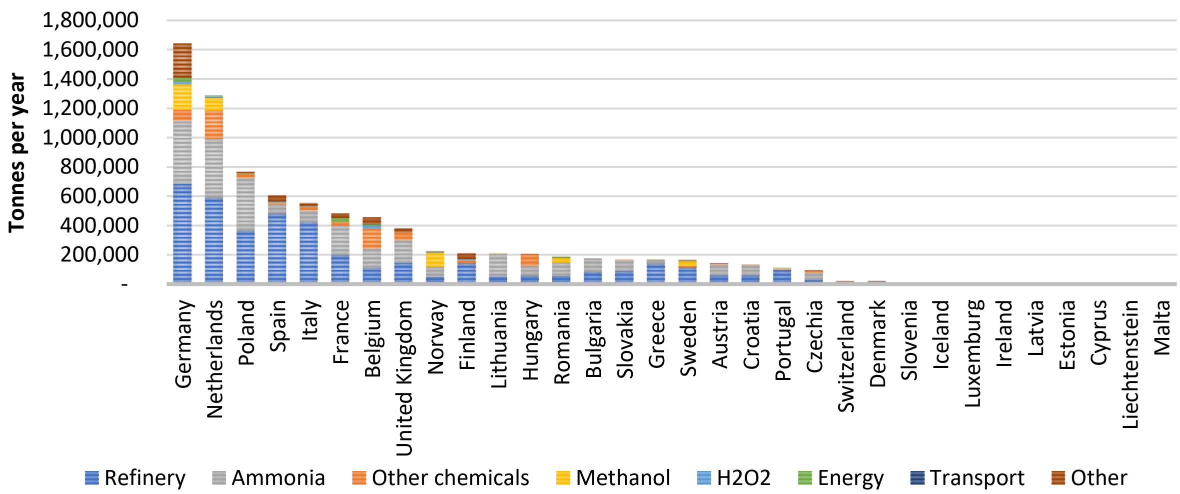
Figure 16. Total demand for hydrogen in 2019 by application




*Source: Fuel Cells and Hydrogen Observatory*

More than half of total hydrogen consumption takes place in just four countries: Germany (20%), the Netherlands (15%), Poland (9%), and Spain (7%).

Figure 17. Total demand for hydrogen in 2019 by country



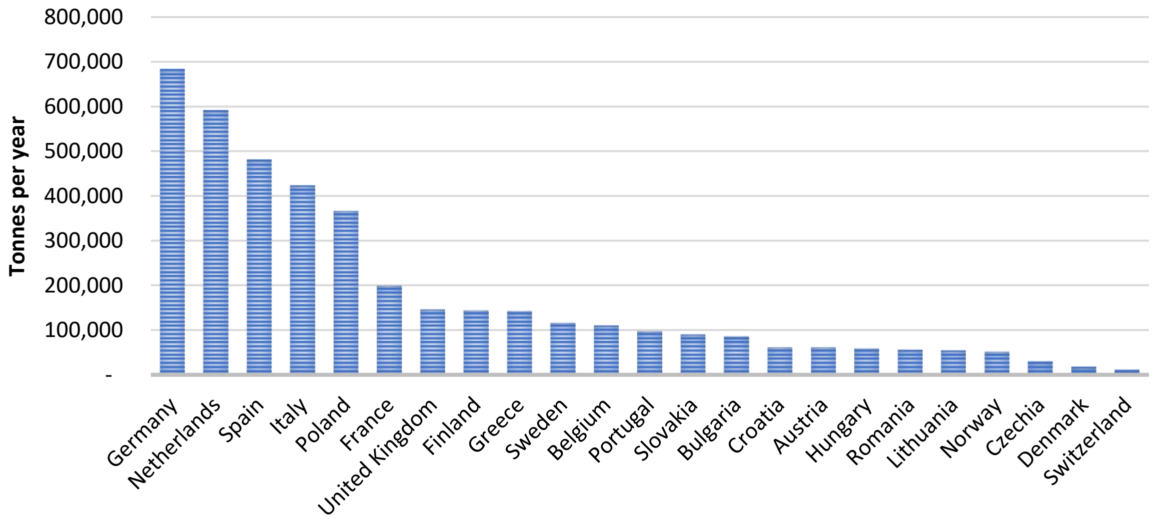

*Source: Fuel Cells and Hydrogen Observatory*

## 2.2. Refining industry

As mentioned in Section 1.2.1, refineries use hydrogen mostly for hydrocracking and hydrotreating processes, including hydrodesulphurisation. As legislative requirements require ever lower sulphur content in fuels, more desulphurisation is needed to achieve these targets, driving up hydrogen consumption in the sector [2]. Similarly, as demand for distillates such as jet fuel, kerosene, high-quality lubricating oils and diesel increases worldwide, so does the importance of hydrocracking. As a result, even though some refining processes generate hydrogen, most refineries are net consumers of it. Yet, because the net hydrogen balance of a refinery depends strongly on the specific processes involved and the mix of output products, it is extremely challenging to precisely estimate the actual demand for hydrogen, which cannot be simply calculated based on production volumes alone.

Nevertheless, based on gathered information about hydrogen production capacities at refineries, together with information about their capacity utilization, we estimate that the total hydrogen demand from the oil refining and petrochemical industry, in 2019, was **4.1 Mt**.

Figure 18. Estimated hydrogen demand from the oil refining industry



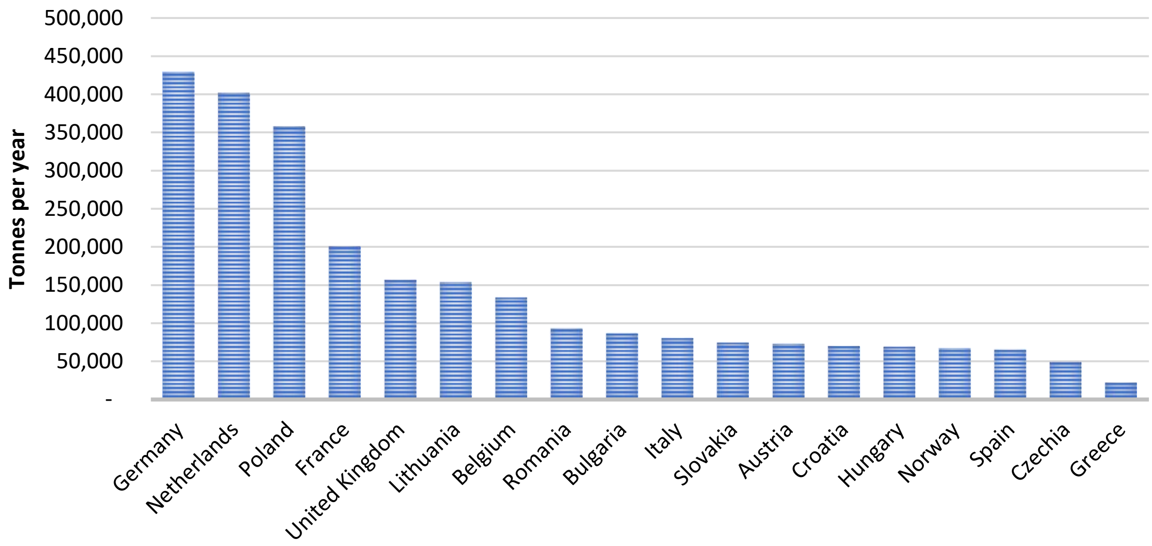

*Source: Fuel Cells and Hydrogen Observatory*

## 2.3. The chemical industry

In the chemical industry, the largest consumers of hydrogen are the ammonia manufacturers. Ammonia is used for the production of fertilizers and nitric oxide, which is an intermediate product for the production of nitric acid. In addition, ammonia is used for the production of sodium carbonate (soda ash), explosives, hydrogen cyanide, synthetic fabrics, and other products.

Total demand for hydrogen by the ammonia industry in 2019, based on Eurostat data, can be estimated at **2.6 Mt**. Due to confidentiality issues, detailed statistics about ammonia production are not available for some EU Member States. In those cases, hydrogen production capacity in the ammonia industry in those countries and utilization rates were used instead.

Figure 19. Estimated hydrogen demand from the ammonia industry

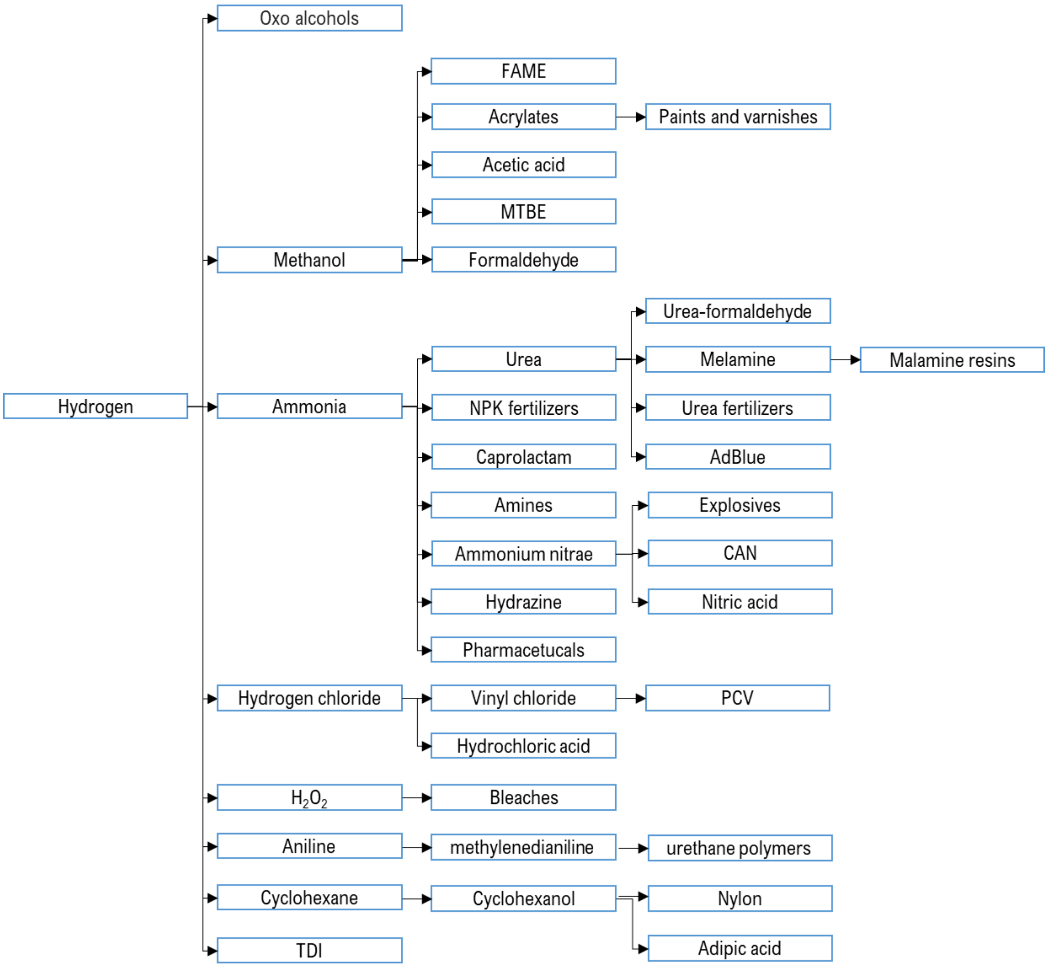



*Source: Fuel Cells and Hydrogen Observatory*

Even though the ammonia industry dwarfs other applications, it is by no means the only source of demand for hydrogen from the chemical industry. Other chemicals that require hydrogen input in their production process are (among others):

- Methanol
- Cyclohexane
- Aniline
- Caprolactam
- Hydrogen Peroxide
- Oxo Alcohols C8
- Oxo Alcohols C4
- Toluene Diiscocyanate (TDI)
- Hexamethylenediamine
- Adipic acid
- Hydrochloric acid
- Tetrahydrofuran

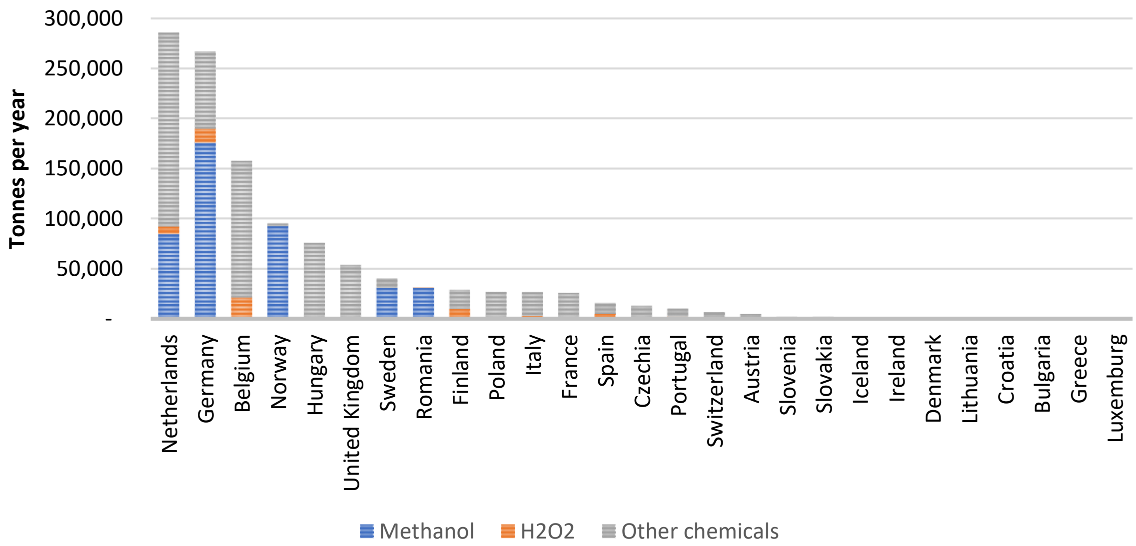
Figure 20. Chemical industry value chain dependant on hydrogen supply




*Source: own elaboration.*

Total demand for hydrogen, in 2019, from the chemical industry (other than ammonia production) has been estimated at around **1.2 Mt**, with almost half coming from Germany and the Netherlands.

Figure 21. Estimated hydrogen demand from the chemical industry other than ammonia manufacturing



*Source: Fuel Cells and Hydrogen Observatory*

## 2.4. Other industries

The oil refining and chemical industries are responsible for over 93% of total demand for hydrogen. The remaining demand comes from the following applications:

### Steel manufacturing and metals processing

Mixture of hydrogen and nitrogen (5% to 7% hydrogen) is used commonly as an inert protective atmosphere in conventional batch annealing in annealing furnaces. Batch annealing with 100% hydrogen is also possible and results in better productivity, improved mechanical properties, surface, and product quality.

### Manufacture of Glass

In the glass industry, hydrogen is an inerting or protective gas in flat glass production. It is also used in the flame polishing process of glass products.

### Food processing

By hydrogenating unsaturated fatty acids in vegetable oils, hydrogen is used in the production of margarine. Hydrogenation is usually carried out by dispersing hydrogen gas in the oil, in the presence of a finely divided nickel catalyst supported on diatomaceous earth.

### Energy sector

While hydrogen can be used in a fuel cell to generate heat and energy with high efficiency, currently hydrogen use in the energy sector mostly consists of:

- Burning hydrogen in boilers or CHP units for heat or heat and power generation – mostly done onsite where hydrogen is generated as a by-product of other processes (chlor-alkali).
- Using hydrogen for generator cooling. The amount of hydrogen demand depends on the installed power of turbines, their age and technical condition – especially the condition of the generator's hydrogen seals. Depending on those factors, and resulting hydrogen demand, some power plants have their own HGU's and only use external suppliers to cover additional needs, while other supply all of the required hydrogen from external sources.

### Transportation

Hydrogen can also be used as a fuel – both directly in fuel cells or in an internal combustion engine, or indirectly when renewable hydrogen is used to synthesise other more complex synthetic fuels. While this application currently forms an insignificant part of hydrogen consumption (below 0.1%), it is expected to grow in the future.

# Appendix 1: List of acronyms

| | |
|---|---|
| *ATR* | *Autothermal reforming* |
| *BMA* | *Blausäure (hydrogen cyanide) from Methan (methane) and Ammoniak (ammonia)* |
| *CCS* | *Carbon capture and storage* |
| *CCU* | *Carbon capture and utilisation* |
| *CHP* | *Combined heat and power* |
| *COG* | *Coke oven gas* |
| *CS* | *Chloralkali* |
| *EEA* | *European Economic Area* |
| *EFTA* | *European Free Trade Association* |
| *EU* | *European Union* |
| *FAME* | *Fatty acid methyl esters* |
| *FCEV* | *Fuel cell electric vehicle* |
| *HGU* | *Hydrogen Generation Unit* |
| *HyARC* | *Hydrogen Analysis Resource Centre* |
| *JRC* | *Joint Research Centre* |
| *LPG* | *Liquefied petroleum gas* |
| *Mt* | *Million tonnes* |
| *MTBE* | *Methyl tert-butyl ether* |
| *POX* | *Partial oxidation* |
| *PSA* | *Pressure swing adsorption* |
| *SC* | *Sodium chlorate* |
| *SMR* | *Steam methane reforming* |
| *TDI* | *Toluene diisocyanate* |

# Appendix 2: References

[1] G. Maisonnier, J. Perrin, R. Steinberger-Wilckens y S. C. Trümper, «European Hydrogen Infrastructure Atlas" and "Industrial Excess Hydrogen Analysis",» Roads2HyCom, 2007.

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