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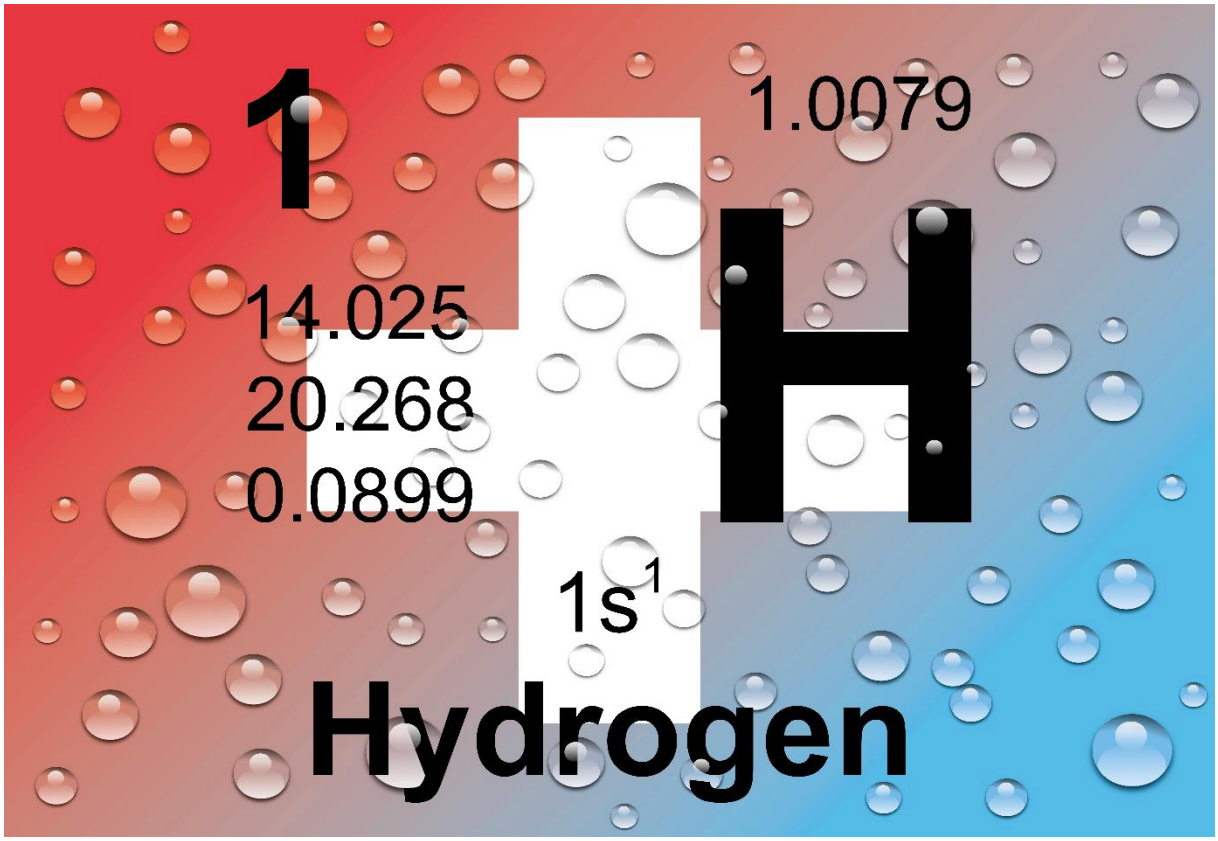
Swiss Federal Office of Energy SFOE
Hydrogen Research Programme

Final report

Swiss Hydrogen Production and Demand

An Overview



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Summary

Hydrogen production in Switzerland is estimated at 21,500 tonnes per year at full capacity. The largest producer is the refinery in Cressier for its own use, followed by the chemical site in Visp and the chlor-alkali electrolysis plant in Pratteln, each of which produces hydrogen as a by-product. In addition, there are several other industrial hydrogen production plants based on natural gas steam reforming, as well as water electrolysis. A comparatively small amount of liquid hydrogen is imported from abroad. Industrial gas companies distribute hydrogen to different customers, and often have access to by-product hydrogen, but also operate their own production facilities. The hydrogen demand in Switzerland is estimated at 13,000 tonnes per year and is spread over various applications. The largest demand is in the refinery in Cressier. The discontinuation of fertiliser production in Visp in spring 2018, which used most of the by-product hydrogen available locally, led to a significant decline in demand for hydrogen.

Zusammenfassung

Die Wasserstoffproduktion in der Schweiz wird bei voller Auslastung auf 21.500 Tonnen pro Jahr geschätzt. Der grösste Produzent ist die Raffinerie in Cressier für den dortigen Eigenbedarf, gefolgt von dem Chemiestandort in Visp und der Chlor-Alkalielektrolyse in Pratteln, wo jeweils Wasserstoff als Nebenprodukt anfällt. Daneben gibt es einige weitere industrielle Wasserstoffproduktionsanlagen basierend auf Erdgas Dampfreformierung, als auch Wasserelektrolyse. Eine vergleichsweise kleine Menge wird als Flüssigwasserstoff aus dem Ausland eingeführt. Industriegasefirmen verteilen Wasserstoff zu unterschiedlichen Abnehmern, und können oftmals auf Nebenprodukt Wasserstoff zurückgreifen, betreiben aber auch eigene Produktionsanlagen. Der Wasserstoffbedarf in der Schweiz wird auf 13.000 Tonnen pro Jahr geschätzt, und verteilt sich auf verschiedene Anwendungen, allen voran jedoch der Raffinerie in Cressier. Die Einstellung der Düngemittelproduktion in Visp im Frühjahr 2018, welche den Grossteil des vor Ort verfügbaren Nebenprodukt-Wasserstoffs nutzte hat zu einem deutlichen Rückgang der Wasserstoffnachfrage geführt.

Résumée

La production d'hydrogène en Suisse est estimée à 21.500 tonnes par an à pleine capacité. Le plus grand producteur est la raffinerie de Cressier, suivie du site chimique de Visp et du site de Pratteln, où l'hydrogène est un sous-produit de l’électrolyse des chlorures alcalins. De plus, il existe plusieurs autres usines industrielles qui produisent de l’hydrogène à partir du vaporeformage du gaz naturel, ainsi que l’électrolyse de l’eau. Une relativement petite quantité d'hydrogène liquide est importée de l'étranger. Les entreprises de gaz industriel, ayant accès a non-seulement leurs propres productions mais aussi à l’hydrogène comme sous-produits, distribuent de l'hydrogène à divers clients. La demande d'hydrogène en Suisse est estimée à 13.000 tonnes par an et se répartit sur différentes applications, avec la raffinerie de Cressier ayant la plus forte demande. L'arrêt au printemps 2018 de la production d'engrais à Visp, a entraîné une baisse importante de la demande d'hydrogène, car le site utilisait la plus grande partie d’hydrogène comme sous-produit dérivé localement.

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List of abbreviations

IGC	Industrial Gas Company
LHV	Lower Heating Value
LPG	Liquid Petroleum Gas
MCP	Manifolded Cylinder Pack
PSA	Pressure Swing Adsorption
PV	Photovoltaics
SFOE	Swiss Federal Office of Energy
SMR	Steam Methane Reforming

1 Introduction

1.1 Context

Hydrogen generation is gaining attention as part of the energy transition in order to make renewable electricity available to other sectors such as transport, heat and as feedstock for industrial users ("Sector-coupling, Power-to-X").

To support informed discussion around this topic, the Swiss Federal Office for Energy (SFOE) commissioned this short study, in order to establish the current status of hydrogen production and generation in Switzerland.

The aim of this project was to quantify the current hydrogen demand in Switzerland, broken down by industry and - where possible - location of use. Hydrogen for transport was not covered as part of this study (e.g. Coop/H2Energy refuelling station[1]).

The study does not address possible future needs, does not examine the regulatory framework, and does not consider the economic viability of novel hydrogen supply and/or its logistics.

1.2 Approach

A global picture of hydrogen generation and consumption in different applications was produced through desk-based research. Little public information is available on Swiss hydrogen production and use. Therefore relevant stakeholders, including large producers, consumers and industrial gas companies in Switzerland were contacted. The inputs from eight experts were collected and where required anonymised through aggregation with other data points.

2 Global overview of hydrogen demand and production

2.1 Hydrogen production

In 2007, the global hydrogen production was estimated at 65 million tonnes per year, broken-down in different production pathways[2]: Close to 50% is made from natural gas steam reforming, 30% as by-product from refinery and chemical off-gases (e.g. naphtha refining), around 18% from the gasification of coal, and the remaining small proportion from electrolysis, mostly as by-product in chlor-alkali electrolysis (Figure 1).

[1] www.coop.ch/hydrogen and https://h2energy.ch/wp-content/uploads/2017/06/Brochure-HRS.pdf

[2] IEA (2007), Hydrogen Production & Distribution. Available at: https://www.iea.org/publications/freepublications/publication/essentials5.pdf

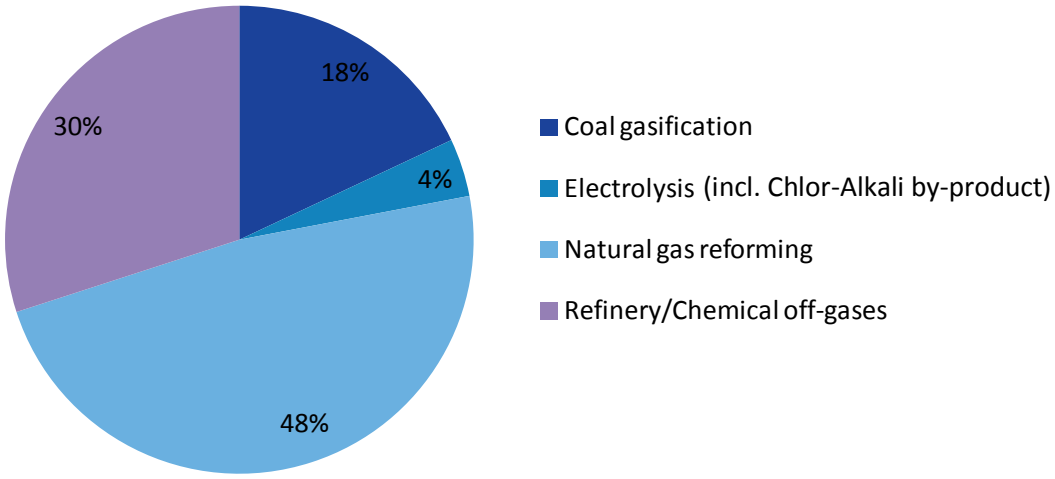


Figure 1: Global hydrogen production source breakdown (Source: IEA, 2007 [3])

Different hydrogen production methods generate hydrogen of different purities, making them usable for different purposes. Very high purity hydrogen, used for example in medical and electronic applications, is usually purified further after production or provided from liquid hydrogen sources, which are intrinsically high purity. Many fuel cells, an emerging and potentially large future hydrogen market, also require high purity hydrogen – or at least hydrogen without particular contaminants, such as carbon monoxide and sulphur.

2.2 Global end-use markets

Globally, end-use markets are dominated by refinery usage of hydrogen (both captive[4], and increasingly merchant) and by chemicals (ammonia – used mainly for fertiliser production – and methanol), but proportions vary considerably by geography. For example, the bulk of hydrogen in Japan today goes to ammonia production (petroleum products are typically imported in their refined state), while it goes to refineries in the Middle East and Africa. Methanol production is the other major single use for hydrogen. The majority of demand in all hydrogen markets is therefore supplied by large-scale industrial processes, requiring mature technologies and very large-scale production capacities. Relatively little of this hydrogen is sourced as a by-product of chlor-alkali electrolysis and to an even lesser extent is made from water electrolysis.

Figure 2 below shows the variation in end-use markets in three key geographies in 2003, when refinery capacity dominated in Europe and North America. Nevertheless the ammonia industry captured the majority market share globally, in part because of high demand from China's very large fertiliser market. Since then, hydrogen demand in refineries has increased in both Europe and North America likely due to increasing environmental requirements for fuels (resulting in higher hydrogen

[3] IEA (2007), Hydrogen Production & Distribution. Available at: https://www.iea.org/publications/freepublications/publication/essentials5.pdf

[4] Captive hydrogen is typically produced and used directly on a site, and detailed figures on quantities are not publicly available, though amounts can be broadly estimated.

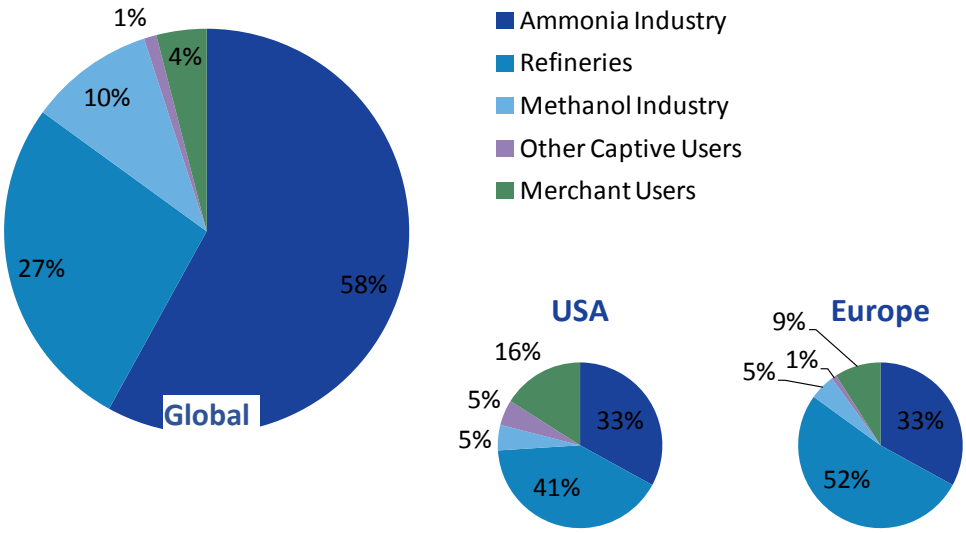
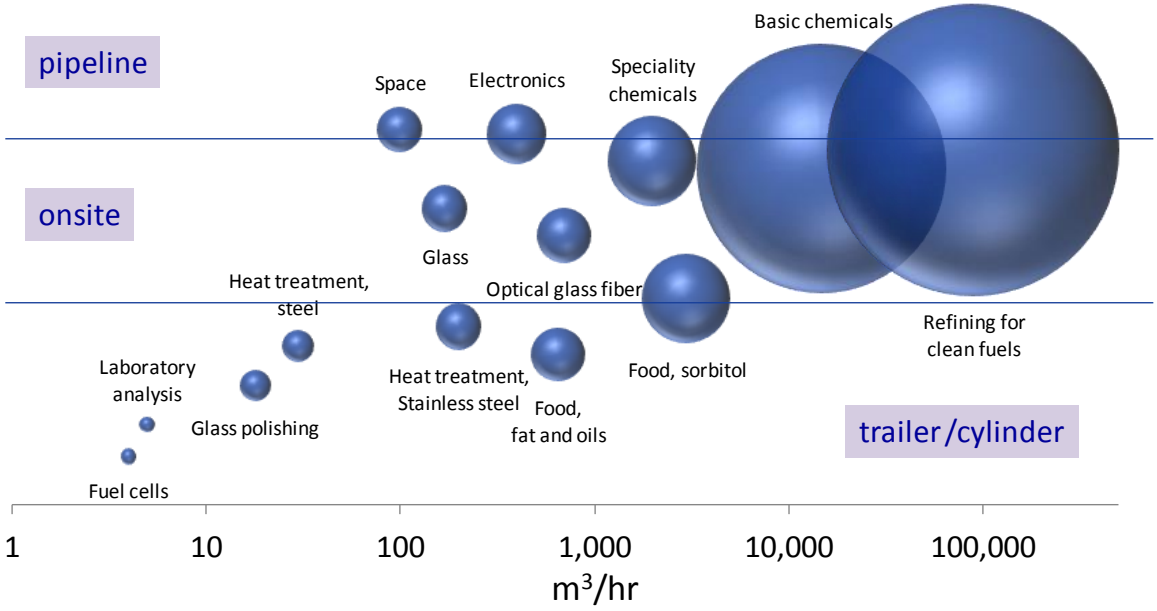


Figure 2: Indicative variation in hydrogen end-uses in different regions (Source: Argonne National Laboratory 2003 [5])

demands for hydrodesulphurisation) and due to heavier crudes use (resulting in higher hydrogen demand for hydrocracking).

The dominant end-use markets for hydrogen (captive) account for at least 90% of quoted hydrogen demand, and sometimes as much as 95%, with the remaining going into typical merchant uses. There is a range of chemical and industrial applications of hydrogen, including electronics, glass manufacture, hydrogenation of vegetable oils and turbine cooling. Splits for these vary significantly by region, in line with local industry, but the bubble chart below is indicative of different end-use market sizes and delivery methods globally in 2005, and the picture is expected to be broadly similar today.

[5] Argonne National Laboratory (2003), Assessing current, near-term and long-term US hydrogen markets. Available at: http://www.dis.anl.gov/news/HydrogenMarkets.html



1. Bubble size denotes relative market size
2. Typical delivery method is indicated

Figure 3: Typical supply requirements and relative market sizes for different hydrogen markets (Source: Schlumberger, 2005 [6])

Markets can be subdivided not only by scale and application but also by typical delivery method. Each has different pricing characteristics that must be considered when evaluating competitive potential. Figure 4 indicates typical supply modes by end-use and by demand. Globally, a few regional areas have hydrogen pipelines in place. Provided customers have access to such pipeline networks, this supply mode is preferred. Most existing hydrogen pipelines were built decades ago in a small number of regional clusters, where they connect large production sites directly with demand sites[7].

[6] Schlumberger (2005), Hydrogen: a future energy carrier? (Oil field review) Available at: http://www.slb.com/~/media/Files/resources/oilfield_review/ors05/spr05/03_hydrogen_a_future_energy.ashx

[7] Robinius et al. (2018), Comparative Analysis of Infrastructures: Hydrogen Fueling and Electric Charging of Vehicles Available at: http://juser.fz-juelich.de/record/842477/files/Energie_Umwelt_408_NEU.pdf (p.5f)

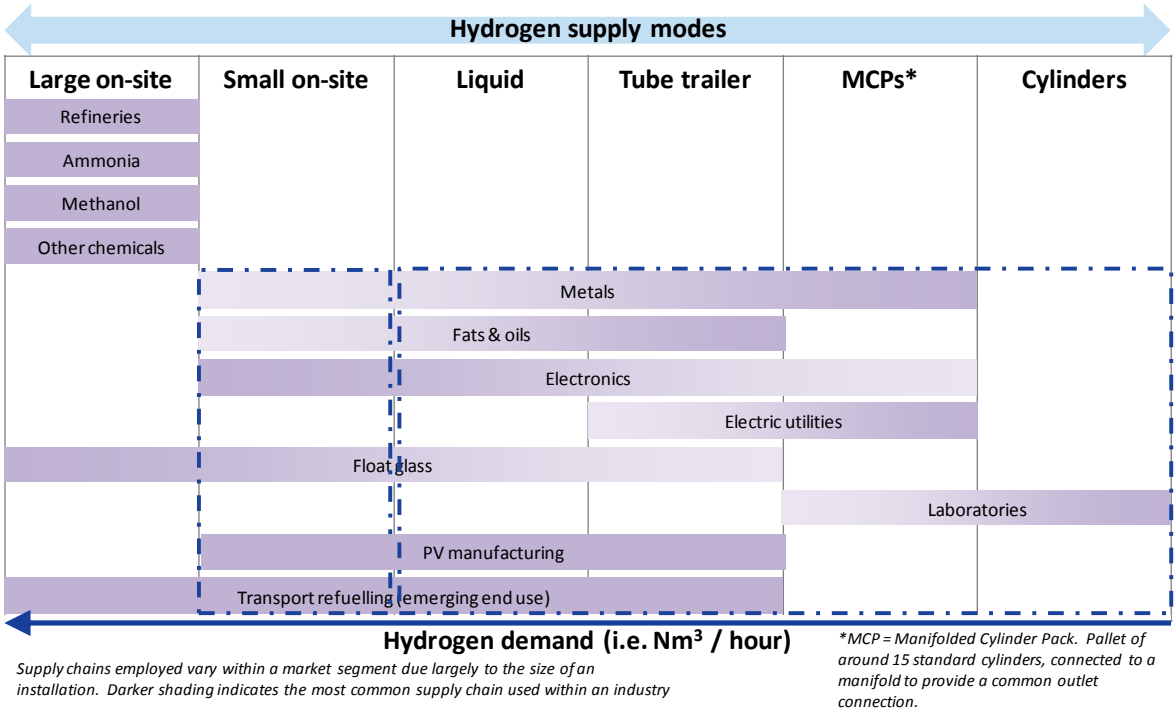


Figure 4: Different hydrogen supply modes in different applications, by demand capacity. Source: E4tech

3 Hydrogen production in Switzerland

Almost 90% of the hydrogen production in Switzerland comes from fossil sources:

- By-product at the Lonza chemical plant site in Visp. The plant is fed by a large LPG cracker and the LPG is being delivered by rail tankers.
- Catalytic reforming of Naphtha and steam methane reforming of natural gas at the only operating refinery in Switzerland in Cressier
- Steam methane reforming of natural gas at several industrial sites and at industrial gas companies.

The majority of the remaining production comes from Chlor-Alkali electrolysis, where hydrogen is a by-product. The only remaining chlor-alkali plant in Switzerland is that of the CABB AG in Pratteln. The previous mercury cell process was upgraded recently and the new membrane process launched in 2016[8]. As part of the upgrade, the annual production of chlorine was increased from 27,000 to 47,000 tonnes. Concurrently, it is estimated that the hydrogen by-product increased from about 800 tonnes per year to ca. 1,400 tonnes.

A small portion, between 550 and 600 tonnes per year, or ca. 3% of the total Swiss hydrogen production comes from water electrolysis. Based on the available information, the two biggest electrolysers are installed in Monthey, each with a capacity of 750 Nm³/hr. Currently, only one of these is in operation to supply hydrogen for synthetic stone production at the same site. Several smaller

[8] http://cabb-chemicals.com/de/news-reader/items/cabb-startet-hochmoderne-chlorproduktion-in-pratteln.html

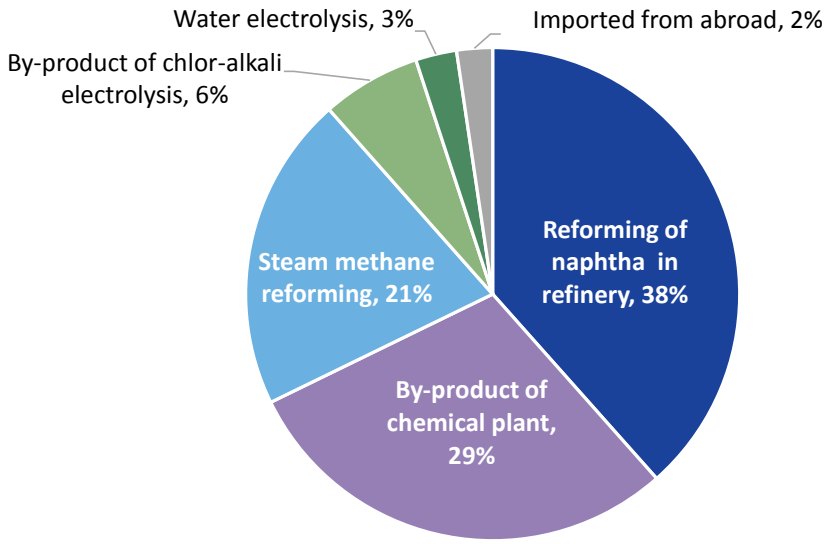


Figure 5: Estimated shares of hydrogen production modes in Switzerland (Source: E4tech analysis)

electrolysers are used in other industries, for example for metal treatment in the watch industry, and their estimated cumulative production is around 50 tonnes per year.

Besides hydrogen production in Switzerland, some liquid hydrogen is imported from abroad and usually then distributed to customers within Switzerland in gaseous form through tube trailers. It is estimated that the imported hydrogen covers a small percentage (~2%) of the total Swiss hydrogen consumption, but precise data is not available.

Overall the supply of hydrogen in Switzerland is estimated at 21,500 tonnes per year (240 million Nm³/year). The approximate distribution of production methods is shown in Figure 5. The major production sites (above 1 million Nm³ per year) are indicated in Figure 6, where the area of the circles is an approximation of the production volume, and listed in Table 1

Production type	**Tonnes H_2 / year**	**Million Nm³ H_2 / year**	**GWh H_2 / year (LHV)**	**Energy source and/or feedstock**
Reforming of naphtha in refinery	8,300	92	276	Crude oil refining
By-product of chemical plant	6,300	70	210	LPG
Steam methane reforming	4,400	49	147	Natural gas
By-product of chlor-alkali electrolysis	1,400	16	47	Electricity
Water electrolysis	600	7	20	Electricity
Imported from abroad	500	6	17	Unknown
Sum	**21,500**	**240**	**716**	

Table 1: Estimated hydrogen production for Switzerland by production type (Source: E4tech analysis)

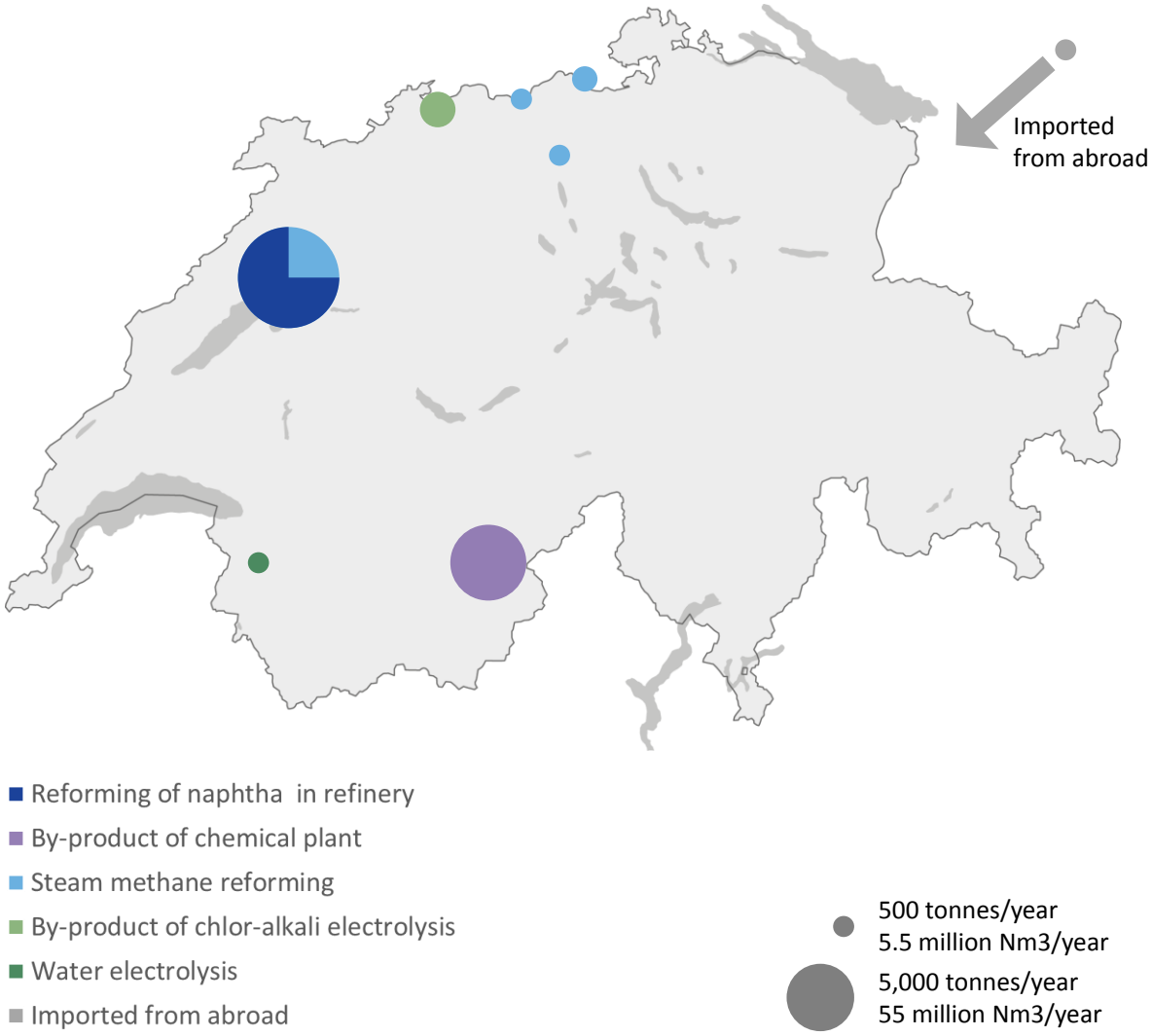


Figure 6: Estimated distribution of major (i.e. above 1 million Nm³/year) hydrogen production sites (incl. by-product) in Switzerland (Source: E4tech analysis)

4 Hydrogen delivery in Switzerland

The largest consumers such as the refinery in Cressier and the chemical plant that used to produce ammonia rely on their own onsite production for hydrogen. Therefore, this hydrogen is not being traded. Other users typically rely on the supply through an industrial gas company (IGC). IGCs will either operate a production site at the client site or deliver hydrogen from a central production site through tube trailers, manifolded cylinder packs (MCPs) or cylinders (see also Figure 4). It is not unusual for IGCs to source hydrogen from a third parties' production site (e.g. a chemical plant site such as a chlor-alkali production plant). However, the hydrogen production at the refinery in Cressier is only used to meet local hydrogen demand for refining operations and no surplus hydrogen is produced or exported. Some small- and medium hydrogen end-users are not supplied by IGCs but instead operate their own production, usually water electrolysis. In general a combination of the different supply modes is used to source hydrogen.

The main IGCs in Switzerland are Messer, Carbagas and Pangas. Carbagas and Messer each have an estimated 20 tube trailers with a capacity of 200-350 kg operating in Switzerland. Pangas is probably the third largest IGC in Switzerland with fewer tube trailers.

5 Hydrogen demand in Switzerland

With the ceased fertilizer production in Visp, the largest hydrogen demand is from the refinery in Cressier. However, it is important to note, that most of that hydrogen demand is covered by integrated processes within the refinery, meaning that the refinery does not create an *external* demand for hydrogen. The remaining hydrogen demand is shared between a range of different end-customers and industries (Table 2). The difference between the estimated demand (13,000 tonnes per year) and supply (ca. 21,500 tonnes per year) is largely related to the plant in Visp no longer requiring hydrogen for fertilizer production. Further, the difference may in part be related to an overestimation of production in Switzerland based on the available production capacity. By way of example, in times of lower demand, less hydrogen will be produced in SMR and water electrolyser plants.

Demand type	**Tonnes H_2 / year**	**Million Nm^3 H_2 / year**	**GWh H_2 / year (LHV)**
Refinery operations	11,000	122	366
Fertilizer production	*ceased in 2018*	*ceased in 2018*	*ceased in 2018*
Watch industry	700	8	23
Chemical and pharma industry	600	7	20
Synthetic stone production	550	6	18
Metal processing industry	50	1	2
Various other uses	50	1	2
Sum	**12,950**	145	431

Table 2: Estimated hydrogen demand by end use type in Switzerland (Source: E4tech analysis)

5.1 Refinery operations

The largest demand for hydrogen in Switzerland comes from the refinery in Cressier. It is produced onsite by Naphtha reforming and natural gas steam methane reforming. It is estimated that the annual hydrogen production and consumption is between 10 and 12 thousand tonnes. The demand for additional hydrogen production at refineries is usually for hydrodesulphurisation and hydrocracking. The former is to meet environmental requirements for sulphur contents, the latter comes from the need to turn heavier crudes (longer chain hydrocarbons) into shorter hydrocarbons.

5.2 Fertilizer production (until 2018)

Until April 2018, the second biggest use of hydrogen in Switzerland was for the production of fertilizers at Visp[9]. A large portion of the ca. 6,000 tonnes per year of by-product hydrogen from the LONZA chemical plant site was used for ammonia syntheses. The by-product hydrogen is produced via a large LPG cracker at the chemical plant site, and a large pressure swing adsorption (PSA) system is in place to purify the hydrogen. An onsite hydrogen distribution network is also in place operating at 10.5 bar. Some of the by-product hydrogen is being distributed further as merchant hydrogen by IGCs via tube trailers. No information is available about planned future uses of the large amounts of by-product hydrogen that is no longer required for fertilizer production.

5.3 Watch industry

Hydrogen is used in the production of high quality glass for the watch industry. It is estimated that around 700 tonnes per year (8 million Nm^3 per year) are consumed by this industry. On-site production via SMR, or delivery by tube trailers is likely the most common supply mode.

5.4 Chemical and pharma industry

At their chemical plant site in Kaisten (Canton Aargau), BASF produces additives for the plastics industry[10]. Although it could not be confirmed directly, the chemical plant site has an estimated hydrogen production capacity of 600 Nm^3/hr, based on natural gas SMR, to supply onsite hydrogen demand.

The DSM production plant in Sisseln produces vitamins, pharmaceuticals, substances for the cosmetics industry, carotenoids, folic acid and many other high-quality products[11]. It is estimated that 100-200 tonnes of hydrogen per year are consumed at the site.

The chemical plant site in Dottikon[12] is estimated to consume about 1-2 tonnes of hydrogen per week (corresponding to ca. 60-120 Nm^3/hr), based on tube-trailer deliveries. No information was available about which processes the hydrogen is required for.

Givaudan[13], the world's largest company in the flavour and fragrance industries, has onsite hydrogen storage at its Geneva production site. However, detailed information on hydrogen demand was not available.

[9] https://www.schweizerbauer.ch/markt--preise/marktmeldungen/agroline-wird-aufgeloest-35225.html

[10] https://www.basf.com/ch/de/company/about-us/BASF-in-Switzerland/local-sites/kaisten.html

[11] http://www.dsm.com/countrysites/sisseln/de_DE/home.html

[12] https://dottikon.com/dottikon-es-en/contact/location/

[13] https://www.givaudan.com/

5.5 Synthetic stone production

At DJEVA in Monthey hydrogen is required for the production of synthetic stones for both jewellery and industrial markets[14]. Hydrogen is produced onsite by two 750 Nm³/hr alkaline water electrolysers, of which only one is currently in operation.

5.6 Metal processing industry

Several metal processing plants in Switzerland have demand for hydrogen (e.g. as atmosphere for heat treatments), often visible through the onsite hydrogen tanks. There are approximately five plants with an average demand of 10 Nm³/hr. However, the demand for these sites could not be quantified individually.

Other metal processing sites also use hydrogen in forming gas mixtures for welding processes. However, these demands are usually small enough to be supplied by gas cylinders.

5.7 Various other uses

During the consultations for this study, nitrate removal was also mentioned as a demand source for hydrogen in Switzerland. However, no further information could be obtained for this use.

In the semiconductor industry hydrogen is used as a protective gas to avoid an oxidative environment. Specific uses and demand in Switzerland could not be identified as part of this study.

Hydrogen is often used as a protective atmosphere in glass production when the float glass process is used. No information was found whether this process (and related hydrogen demand) is currently used in Switzerland.

Several new projects, where hydrogen produced via water electrolysis is used for energy purposes, are currently being planned in Switzerland. The biggest operational one, in terms of hydrogen production, is the Hybridkraftwerk Aarmatt in Zuchwil in the Canton of Solothurn. The installed PEM electrolyser can produce up to 60 Nm³/hr [15] (up to ca. 50 tonnes per year). A larger, 2MW_{el} electrolyser project is planned in Dietikon, in the Canton of Zurich. The hydrogen will be used to produce 18-21 GWh/year of renewable methane.

[14] http://www.djeva.ch/en/

[15] http://www.hybridwerk.ch/fileadmin/regioenergie/Hybridwerk/Dokumente/Factssheet_Hybridwerk_deutsch.pdf