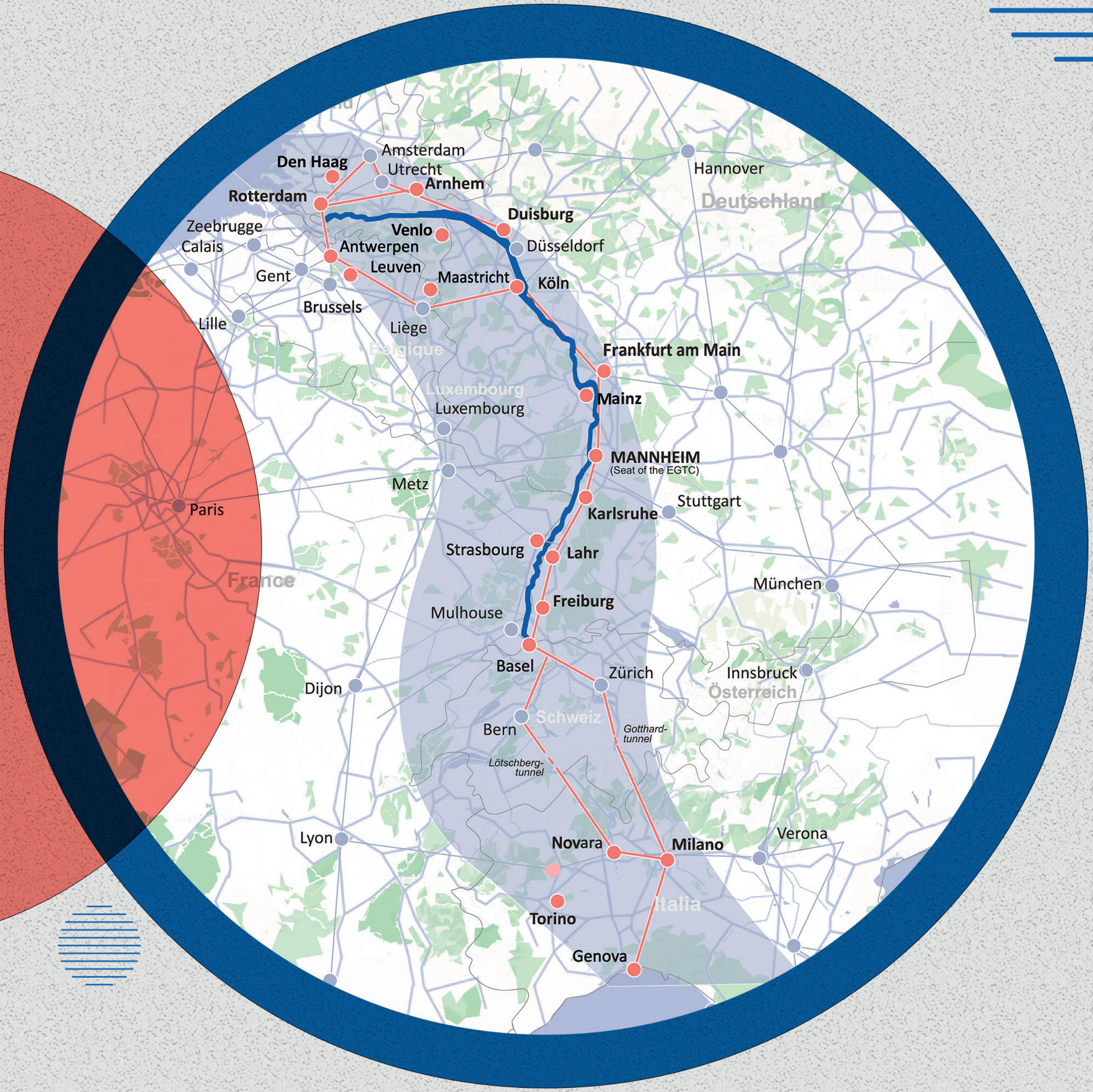


DEVELOPMENT OF A HYDROGEN ECOSYSTEM AND SUPPLY CHAIN

RHINE-ALPINE CORRIDOR – H2 STUDY

Interregional Alliance for the Rhine-Alpine Corridor EGTC

Interregional Alliance for the Rhine-Alpine Corridor EGTC

c/o Verband Region Rhein-Neckar | M1, 4-5
68161 Mannheim – Germany

+49 (0)-621 10708-235

info@egtc-rhine-alpine.eu

egtc-rhine-alpine.eu

Interregional Alliance for the Rhine-Alpine Corridor EGTC

CONTENTS

INTRODUCTION 01.

This study aims at the collection and integrated analysis of national, regional and project specific plans and strategies for transport related H2 infrastructure, thus providing the identification of key elements and missing links towards a comprehensive system along the Rhine-Alpine corridor. This includes in addition to the data collection (latest update spring 2022) about existing and planned H2 projects collating the policy framework, initiatives and key players as well as funding opportunities.

The results are documented in this study report and displayed graphically in an update of the corridor info system of the EGTC.

FRAMEWORK 02.

2.1 POLITICAL FRAMEWORK AND HYDROGEN STRATEGIES

2.1.1 EU framework

Timeline of EU regulations

2019
EUROPEAN GREEN DEAL
- GOAL: no net emissions of greenhouse gases in the EU by 2050

The European Green Deal in 2019 was a political initiative by the European Commission with the aim of reducing net greenhouse gas emissions by at least 55% by 2030 (compared to 1990) and making the European Union climate neutral by 2050.
The concrete implementation started with the "Fit for 55" measures in 2021.

2020
EU HYDROGEN STRATEGY
- Boosting demand & scaling up production
- Designing a supportive framework

Renewable hydrogen is an important factor in achieving a carbon-neutral and pollution-free economy in 2050.
The European hydrogen strategy defined key actions in 5 areas:
1) an investment agenda for the EU
2) boosting demand for and scaling up production
3) designing an enabling and supportive framework
4) promoting research and innovation in hydrogen technologies
5) the international dimension
By the first quarter of 2022, all 20 key actions were implemented.
Also, a roadmap for a European hydrogen ecosystem has been established. It provides that by 2024, there should be at least a capacity of 6 GW of renewable hydrogen electrolysers in the EU with a total production of up to 1 million tons of renewable hydrogen per year. Until 2030, there should even be 40 GW of renewable hydrogen electrolyser capacity with a total production of up to 10 million tons of renewable hydrogen per year.

2021
FIT FOR 55
- Revision of climate, energy and transport - related legislation
- GOAL: 55% greenhouse gas emission reduction by 2030

The "Fit for 55" package includes several proposals to revise and update EU legislation. It also includes proposals for new initiatives to ensure that EU action is consistent with the climate targets agreed by the European Parliament and the Council. Fig. 1 gives an overview of those proposals and highlights the most important one for hydrogen in transportation, the Alternative Fuels Infrastructure Regulation, short AFIR. The concrete implementation started with the "Fit for 55" measures in 2021.

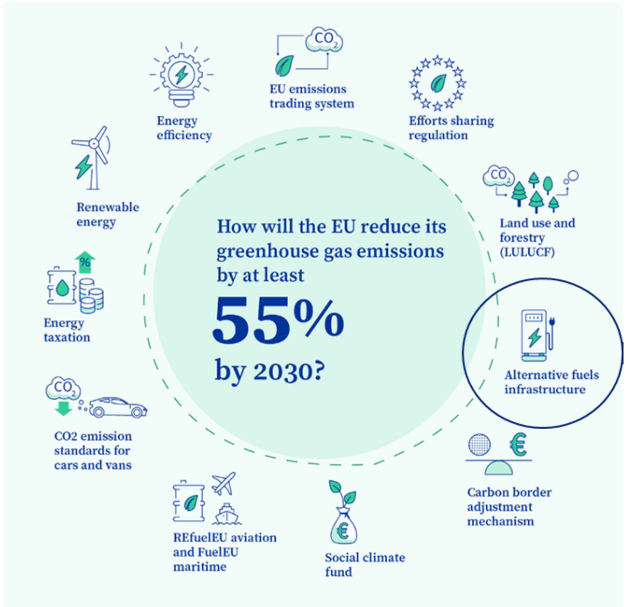


Fig. 1: Fit for 55 overview chart (© European Union 2022)

AFIR

The goal of the AFIR is to ensure that there is enough refueling infrastructure for alternative fuels (e.g. hydrogen), with a focus especially on heavy-duty-vehicles.

It sets minimum requirements that have to be met by the end of 2030:

- one hydrogen station every 150 km along; the TEN-T network with gaseous hydrogen;
- one hydrogen station every 450 km with liquid hydrogen;
- one hydrogen station in each urban node, preferably in multimodal hubs (urban nodes see Fig. 2);
- stations need to be designed to be able to serve heavy-duty vehicles.

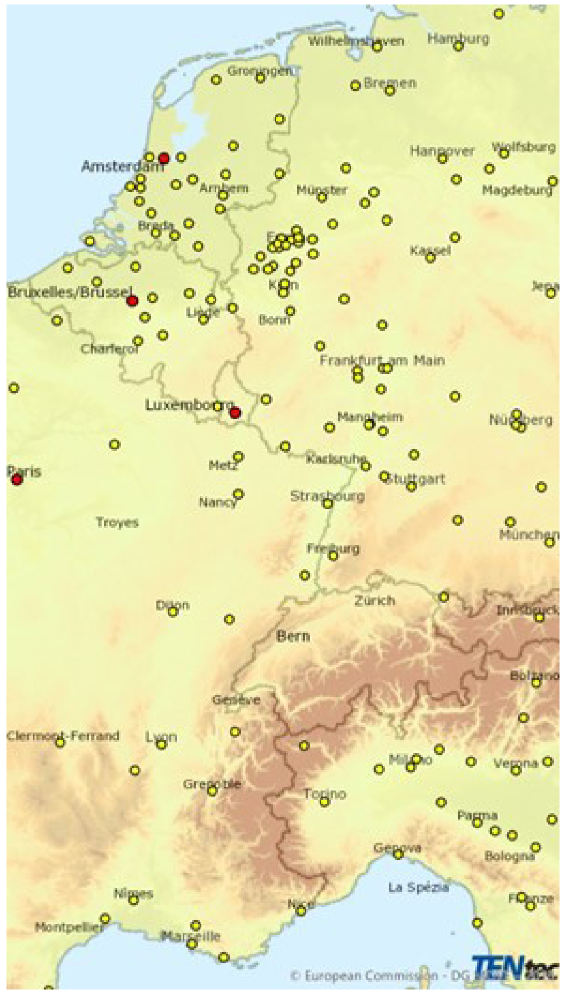


Fig. 2: TEN-T urban nodes within the Rhine-Alpine corridor

2.1.2 National hydrogen strategies

All countries within the Rhine-Alpine corridor have published national hydrogen strategies, except Switzerland.

The Netherlands, Germany, France, and Italy published their hydrogen strategies in 2020, Luxembourg and Belgium in 2021.

The Swiss hydrogen strategy is expected to be completed in 2023 but they also already published a position paper on hydrogen mobility in 2016. Links to all the mentioned documents can be found in the Chapter "References and related links" (Pag. 19) and related links.

2.2 FUNDING OPPORTUNITIES

EU FUNDING & FINANCING FOR HYDROGEN

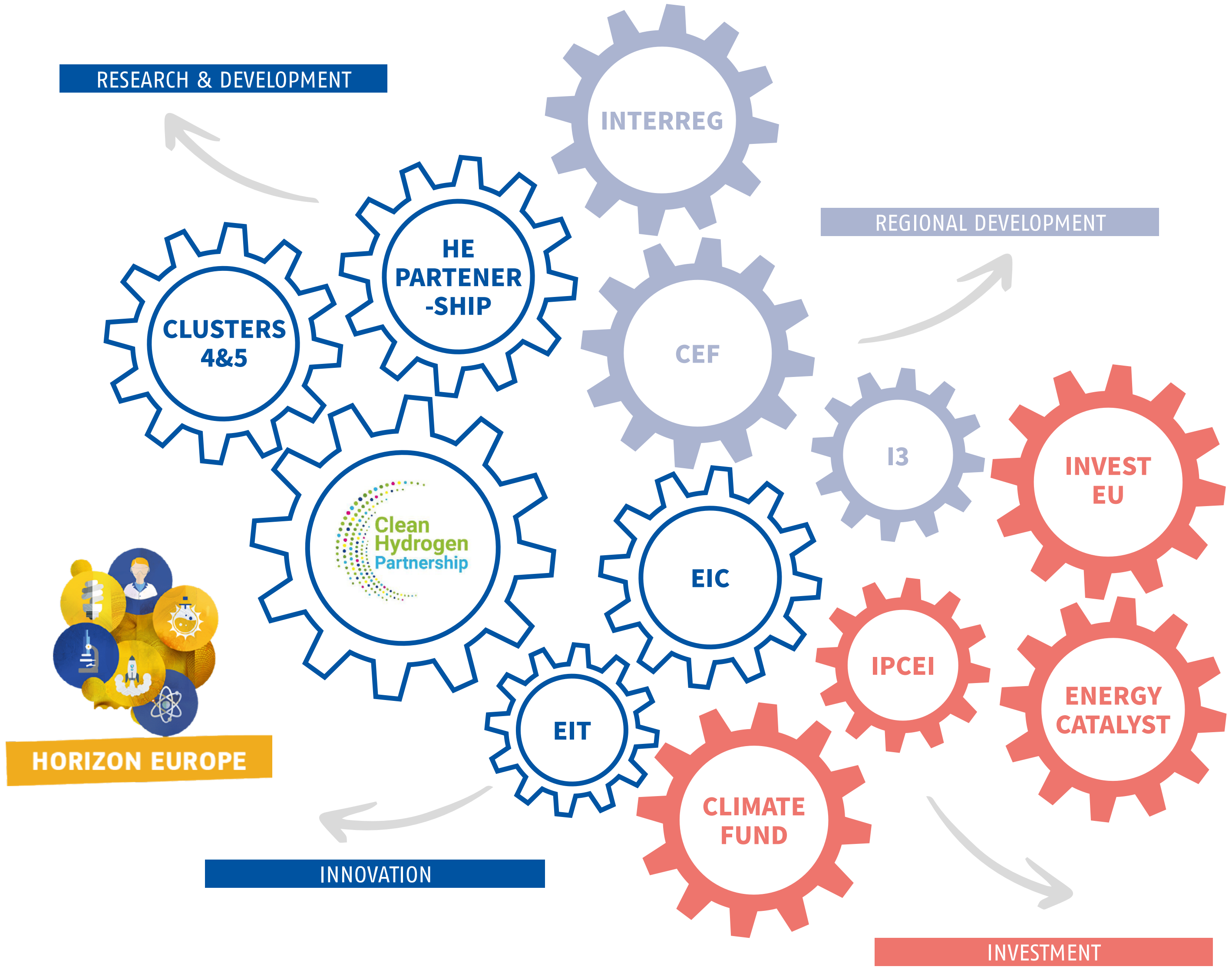


Fig. 3: Overview of EU funding opportunities from the Steinbeis Europa Zentrum

There are many possibilities to get funding for hydrogen projects on national or EU level.

Fig. 3 shows an overview of EU funding opportunities made by the Steinbeis Europa Zentrum, more information from them (in German language) can be found on their website:
https://www.steinbeis-europa.de/de/aktuelles/beitrag/foerderung-fuer-ihr-wasserstoff-projekt

Furthermore, there is a funding compass made available by the European Commission, accessible here:
https://single-market-economy.ec.europa.eu/industry/strategy/hydrogen/funding-guide/eu-programmes-funds_en

The European Commission funding compass also has information about funding on national level made available her:
https://single-market-economy.ec.europa.eu/industry/strategy/hydrogen/funding-guide/eu-countries-funds_en

Additionally, there are national funding databases like this one from Germany:
https://www.foerderdatenbank.de/SiteGlobals/FDB/Forms/Suche/Startseitensuche_Formular.html?cl2Processes_Foerdergebiet=_bundesweit&submit=Suchen&filterCategories=FundingProgram&templateQueryString=Wasserstoff

2.3 INITIATIVES

1 EUROPEAN HYDROGEN BACKBONE (EHB)

The European Hydrogen Backbone initiative consists of 31 energy infrastructure operators that aim to accelerate Europe's path to decarbonization and to highlight the important role of hydrogen infrastructure.
Their infrastructure pathway is a vision based on national analyses of existing gas infrastructure and possible future market developments, though the real development may vary from the maps. The EHB has published scenario maps for 2030, 2035 and 2040 as well as an Interactive online map: https://www.ehb.eu/maps/202205/index.html

2 RHINE HYDROGEN INTEGRATION NETWORK OF EXCELLENCE (RH2INE)

The Rhine Hydrogen Integration Network of Excellence (RH2INE) is an initiative of the Province of Zuid-Holland and the State of North Rhine-Westphalia that aims at realizing market-ready hydrogen applications along the Rhine.
The RH2INE Kickstart study in 2021 found that swappable containers with pressurized gaseous hydrogen are the most feasible solution for inland shipping in the short term with the existing container terminals (Rotterdam, Duisport, Rheincargo) as the preferable swapping locations. Production and filling station close to ports would be ideal for an easy refilling and fast provision of the containers. The demand will be dependent on many factors but especially also on regulatory boundaries and policy measures as standards and regulations for the use of swappable hydrogen containers do not exist yet.
For more see: https://www.rh2ine.eu/rh2ine-kickstart-study

3 HYDROGEN EUROPE

Hydrogen Europe is the leading organization representing European companies and stakeholders in the hydrogen sector towards policy and decision makers. They also are the industrial key partner of the Clean Hydrogen partnership.

4 WATERSTOFNET

WaterstofNet is a knowledge and collaboration platform that offers support and helps with the realization of hydrogen projects in Flanders and the Netherlands.

2030

Emerging regional network

Connecting industrial clusters to an emerging 6,800 km infrastructure

2035

Growing backbone

Expanding network covering more countries, linking sources and sinks across Europe

2040

An European hydrogen highway

A pan-EU backbone stretching into all directions, with a lenght of almost 23,000 km

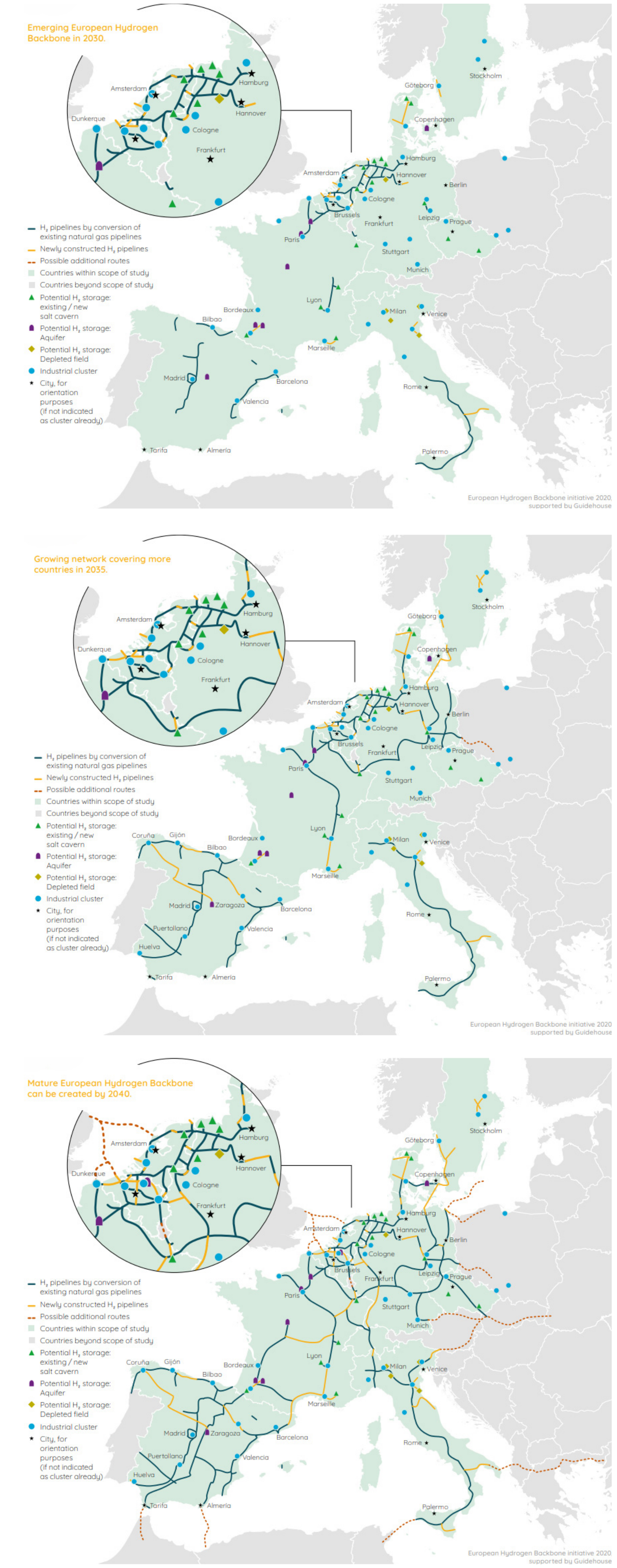


Fig. 4: EHB vision for 2030, 2035 & 2040

DATA INVENTORY 03.

AREA TO BE CONSIDERED

According to Article 3 of our EGTC – Convention the area covered by the EGTC's activities is the multimodal Rhine-Alpine Corridor as shown in the EGTC standard figure (Fig. 5).

Due to the fuzzy delineation, the underlying map of the corridor info system, which is based on the NUTS system, is used as reference for mapping the projects considered.

Projects that are located just outside the boundaries are listed too, if any influence into the corridor can be assumed.

Fig. 5: EGTC standard figure

STEPWISE PROCEDURE

The work on this study was carried out according to the following step-by-step process:

- initial collection of web-available information;
- coordination with EGTC-members to verify and extend the data collection;
- coordination with key transnational projects for evaluation of current developments;
- evaluation of existing information and gap analysis;
- draft synopsis and areal representation via corridor info system.

DEVELOPMENT OF A HYDROGEN ECOSYSTEM AND SUPPLY CHAIN ALONG THE RHINE-ALPINE CORRIDOR – H2 STUDY

DATA COLLECTION

Data of the following project categories were collected:

1. Production, supply and distribution network (pipelines)

2. Transport – filling stations and hydrogen usage on:
- roads;
- railway;
- maritime and Inland Water Ways.

INTRODUCTION TO THE CORRIDOR INFO SYSTEM (CIS)

The collected project data are graphically displayed in the EGTCs Corridor Info System, an interactive web GIS-based instrument.

To get there open:
http://www.urbantoolbox.it/project/egtc-rhine-alpine-corridor

As the CIS is displaying more than just the new hydrogen project data, you first need to select "Hydrogen Facilities" in the menu by clicking on the eye symbol next to it. Now all projects are displayed as clickable points on the map, providing more detailed information.

The data are sortable by different characteristics (e.g. their type), to do that, click on the small box right to the specific characterization. The points on the map are now displayed sorted by colour. To view certain data only, you can select them by ticking / unticking their boxes. To see a list of all selected projects, click on the table icon next to the "Hydrogen Facilities" filter.

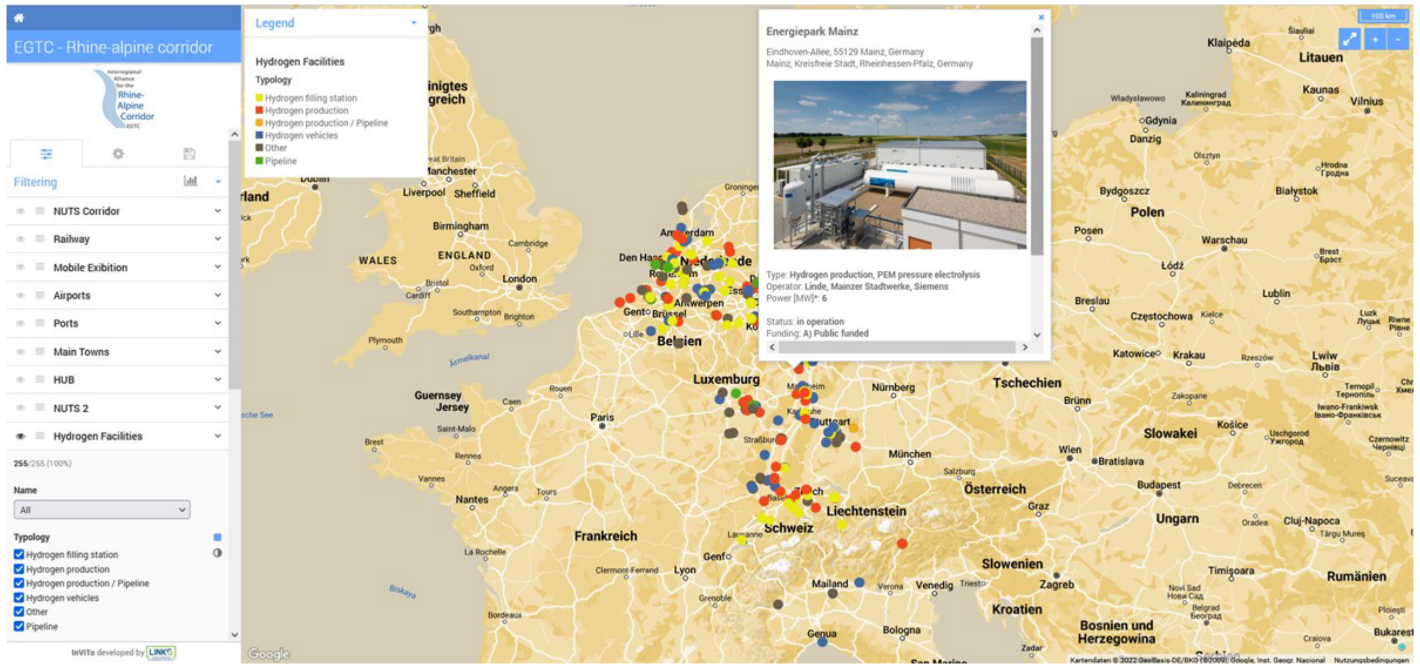
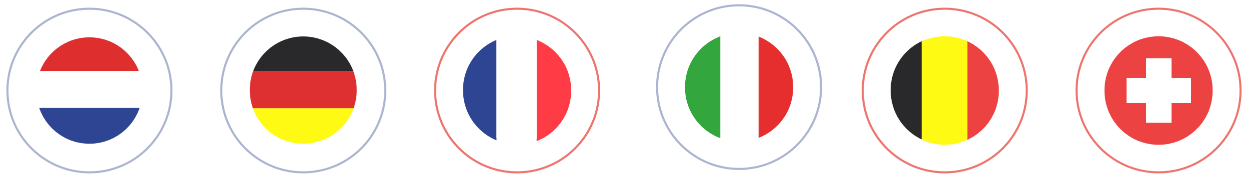


Fig. 6: Hydrogen projects overview in the Corridor Info System

3.1 DATA EVALUATION

Distribution of projects among the individual countries



NETHERLANDS	GERMANY	FRANCE	ITALY	BELGIUM / LUXEMBOURG	SWITZERLAND
95 ENTRIES	89 ENTRIES	30 ENTRIES	11 ENTRIES	20 ENTRIES	20 ENTRIES

Fig. 7: Entries in the database per Country

There is a total of 265 entries in the database, most of them are located in the Netherlands and Germany (see Fig. 7).

Those database entries consist of hydrogen projects and subprojects in the fields of production and supply, distribution and refueling stations. As we were supplied with a lot of detailed information about the H2Rivers & H2Rhein-Neckar projects in Germany, those are above-average well broken down with a total of 16 subprojects and as a result, the total number of entries in Germany appears slightly higher in comparison than it actually is.

Overall, Italy has the greatest need to catch up, as there are the least transport related hydrogen projects out of all the countries in the corridor (except Luxembourg).

Fig. 8 shows an overview of all projects in the corridor in our Corridor Info System sorted by country to give a geographical idea of the distribution of the projects.

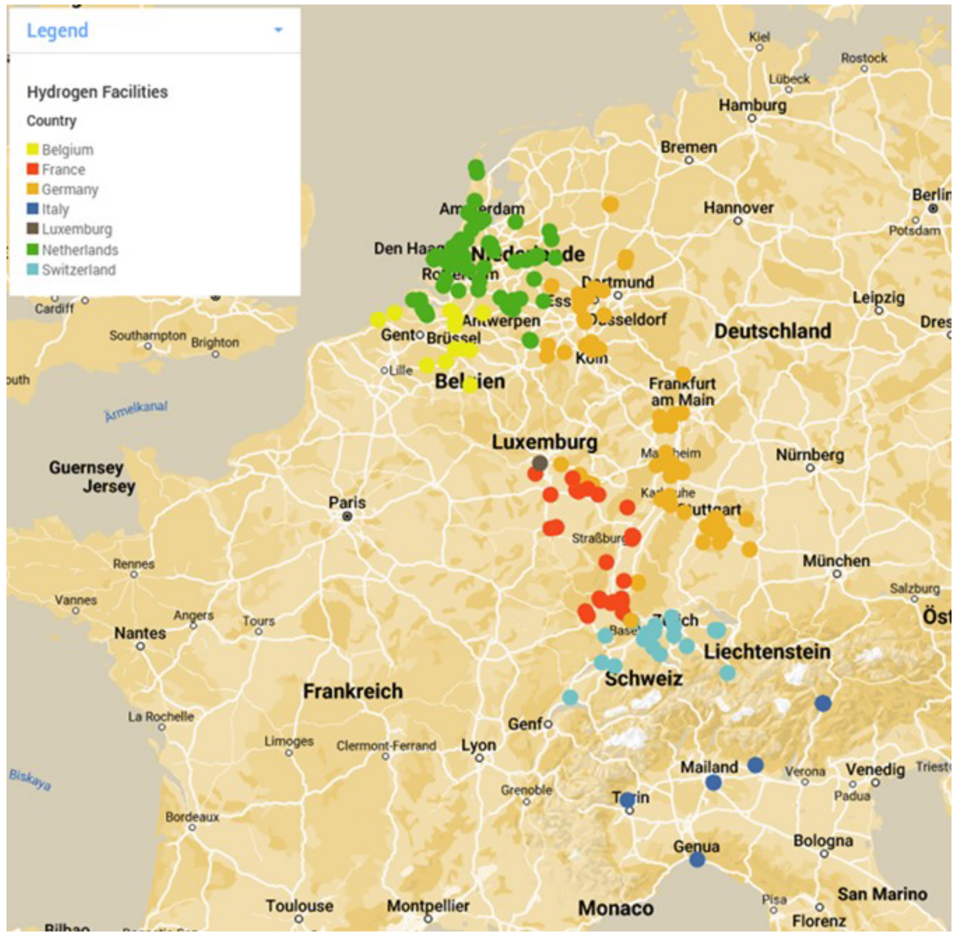


Fig. 8: Overview of all projects in the CIS sorted by country

DEVELOPMENT OF A HYDROGEN ECOSYSTEM AND SUPPLY CHAIN ALONG THE RHINE-ALPINE CORRIDOR – H2 STUDY

3.1.1 Hydrogen production

The currently planned hydrogen production is mainly concentrated in industrial centres. Especially big projects for green hydrogen are planned on the coast of the Netherlands. Italy lacks projects for the production of hydrogen.

An interesting approach is taken by the project "Cyrus Smith 2.0". The goal of this project is to develop and demonstrate a mobile 20 kW electrolyser that supports the local low-voltage grid by drawing power at desired locations and times and converting it to hydrogen.

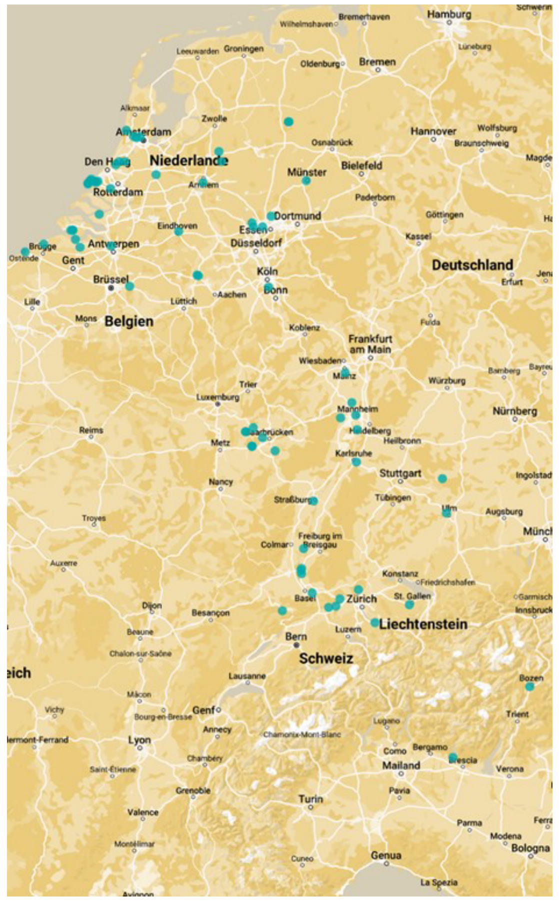


Fig. 9: Hydrogen production projects

3.1.2 Pipeline projects

There are only a few big pipeline projects and in addition some smaller projects. Hydrogen pipelines will therefore still be a major field of work in the future as the speed of the pipeline network expansion plays a crucial role in the overall development of the hydrogen economy. The pipeline networks also play a crucial role for the import of green hydrogen and for the creation of a common European hydrogen market.

In addition to the build-up of pipeline networks there is also the possibility to transport H2 as cargo on inland water ways like the Rhine to bridge the gap until the pipeline system and local production matured.

As our CIS is limited in the representation of pipeline networks, we would like to refer to 2 other interactive online maps with focus on hydrogen pipelines:

- The interactive online map from OGE: https://app.h2connect.energy/map
- The interactive online map from the EHB: https://www.ehb.eu/maps/202205/index.html

Some pipeline projects are presented below as examples.

Fig. 10: Hydrogen pipeline projects

1

DELTA CORRIDOR

The "Delta Corridor" project plans the construction of a bundle of 4 new pipelines between Rotterdam, Chemelot industrial site and North Rhine-Westphalia.
The project will connect major inland industry clusters and provide access to clean hydrogen as well as carbon capture and storage (CCS) capacity.

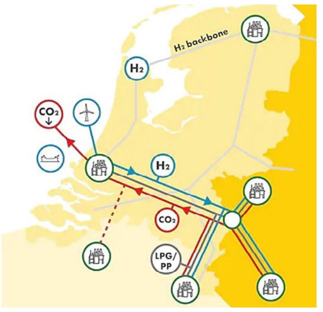


Fig. 11: Planned route of the "Delta Corridor" pipelines

2

GET H2 NUKLEUS

The "Get H2 Nukleus" project plans a publicly accessible hydrogen network for industrial companies. The core network from Lingen to Gelsenkirchen is scheduled to be finished in 2024 connecting a 100 MW electrolyser of RWE in Lingen (Ems) to the Chemiepark Marl and the Ruhr Oel Raffinerie of BP in Gelsenkirchen (see Fig. 12).
Afterwards there are several extensions planned in a time frame up to 2030 including an import point on the border to the Netherlands to create a connection to the "Green Octopus" project until 2025, the connection to a cavern storage facility of RWE in Gronau-Epe and the connection to a 100 MW electrolyser at the Salzgitter steelworks both until 2026.

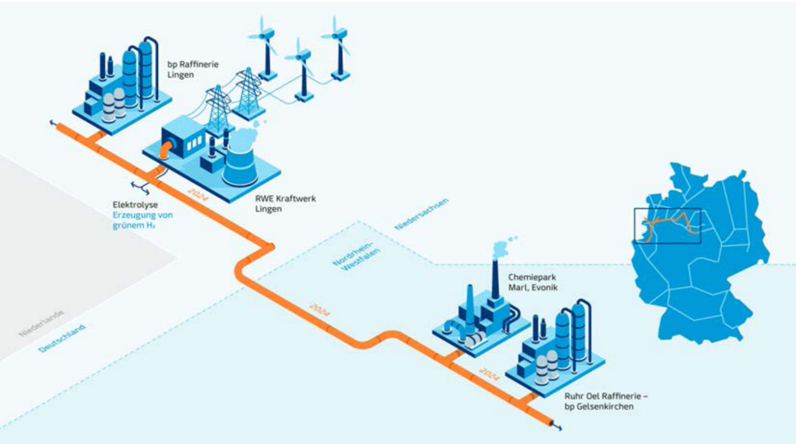


Fig. 12: "Get H2 Nukleus" first project phase until 2024

Fig. 13 shows the currently planned final project status to be achieved in 2030.

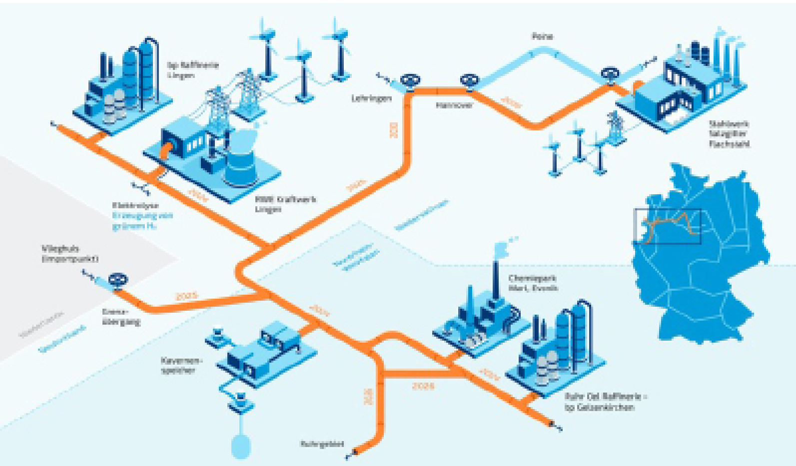


Fig. 13: "Get H2 Nukleus" final project status planned for 2030

3

MOSAHYC

The "MosaHYc" (moselle-saar-hydrogen-conversion) project plans an approx. 100 kilometers long hydrogen pipeline network in the Grande Région. For about 70 kilometres, existing gas pipelines that get converted into hydrogen pipelines will be used, the additional 30 kilometres will consist of newly constructed hydrogen pipelines.

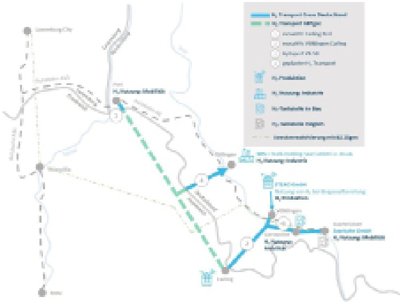


Fig. 14: The "MosaHYc" hydrogen pipelines

4

HYTRANSPORT

The "HyTransPort" project in Rotterdam plans a pipeline connecting the planned Hydrogen Conversion Park in Maasvlakte 2 to the Pernis refinery. Additionally, five branch-offs to other consumers and producers of hydrogen are already planned. The pipeline will also be connected to the national hydrogen backbone of the Netherlands.

Fig. 15: The "HyTransPort" pipeline

3.1.3 Transport

TRANSPORT – HYDROGEN VEHICLES

Projects with hydrogen vehicles exist throughout the corridor. However, they are limited by the availability of hydrogen filling stations. In comparison there are less projects in Switzerland and Italy than in the other countries of the corridor.

Fig. 16: Projects with hydrogen vehicles

TRANSPORT – FILLING STATIONS

There is already a good interactive online map with live information about hydrogen filling stations all over Europe where you can refuel with 350 and/or 700 bars made by H2 MOBILITY, accessible under https://h2.live.

That's why we focused only on filling stations with 350 bars, to create a complete picture of all available filling stations for trucks.

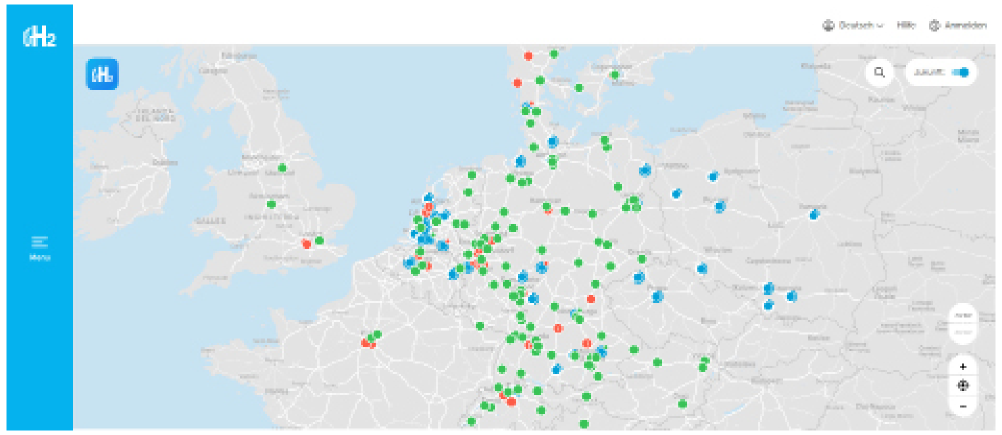


Fig. 17: Look of the h2.live website

When you look at the map of filling stations with gaseous hydrogen at 350 bars that are useable for trucks, you can see that stations in Italy and partly in Germany are missing, with gaps existing between Cologne and Frankfurt as well as between Freiburg and Karlsruhe. The Netherlands and Switzerland however, already show a proper coverage of filling stations. But generally, there are still many more filling stations needed in order to establish a well-functioning network.

According to the AFIR there has to be a hydrogen station in each urban node (also see AFIR) by the end of 2030.

Fig. 19 shows a comparison between the filling stations in our CIS and the TEN-T urban nodes, on the left is the current status, on the right are all the TEN-T urban nodes in the corridor area. It is evident that there are still many urban nodes without a hydrogen filling station that is suitable for trucks, but there is also still some time to go until the target has to be reached in 2030.

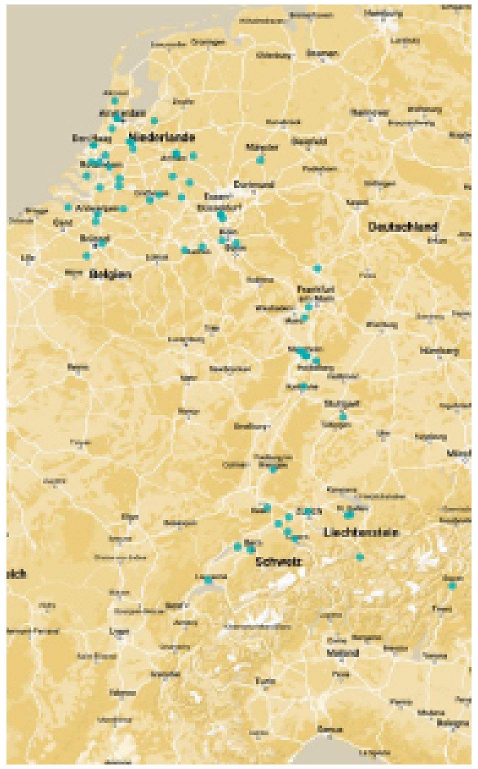


Fig. 18: Filling stations with hydrogen t 350 bars for trucks within the corridor

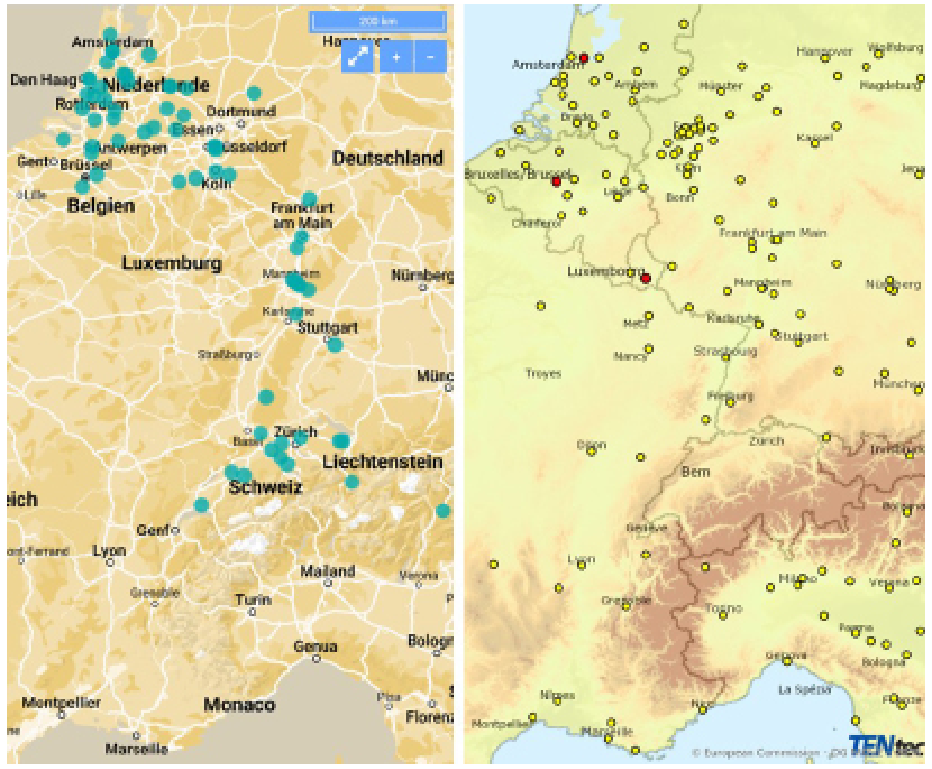


Fig. 19: Comparison between the filling stations in our CIS and the TEN-T urban nodes

TRANSPORT – MOBILE FILLING STATIONS

There are also some auspicious projects with mobile refueling stations that we would like to briefly present as mobile filling stations could represent an important transitional technology until a market-ready hydrogen filling station network has been established.

1

H2-SHARE

The aim of the "H2 Share" project is to build and test a hydrogen-powered truck with a flexible low energy mobile hydrogen filling station. The 27-ton truck will be built by VDL, the mobile filling station will be built by Wystrach GmbH. The truck is going to be tested at six locations in Germany, the Netherlands, Belgium, and France.

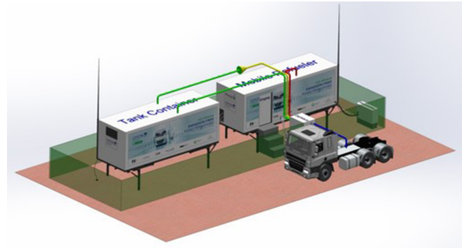


Fig. 20 "H2-Share" mobile filling station

2

H2MILK RUN

The "H2milk Run" project plans the delivery of hydrogen for fuel cell forklift trucks directly to the company locations via a small truck used as a mobile hydrogen filling station.

3

H2 GOES RAIL

The project "H2 goes rail" by Deutsche Bahn and Siemens is using a mobile filling station for trains. The green hydrogen is produced directly on site, compressed, and stored in a mobile storage tank before being processed and cooled in a tank trailer. The refueling procedure takes no longer than for a diesel train. For more information about the H2 goes rail project, see the next chapter about hydrogen trains.

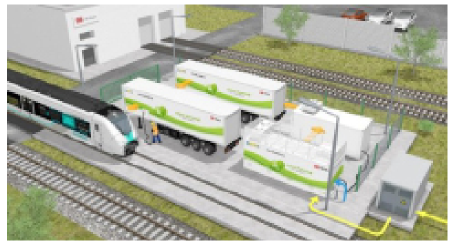


Fig. 21 Mobile filling station

TRANSPORT – TRAINS

Fuel cells are also promising for the use in trains and there are already some major projects for the use of hydrogen trains which we will present in the following.

1

FUEL CELL TRAINS OF THE RMV

The German Rhein-Main-Verkehrsverbund (RMV) operates a fuel cell train fleet of 27 trains of the type iLint from manufacturer Alstom with a range of 1,000 kilometers and a maximum speed of 140 kilometers per hour. The area of operation are four not electrified lines on the Taunus network in the Frankfurt (Main) area. The newly built hydrogen filling station for trains in the industrial park Höchst can do up to 14 refueling operations per day.

Fig. 22: A fuel cell train of the RMV

2

H2ISEO

The goal of the "H2iseO" project is to transform Val Camonica in the Lombardy region into the first Italian hydrogen valley. In the first project phase till 2023, there will be six hydrogen-powered electric trains in use, built by Alstom. In the following project phase 2, there will be an additional eight trains put in operation, thus completing the replacement of the entire fleet with fully green trains.

Fig. 23: Hydrogen train by Alstom

3

REGIOLIS H2

The French region Grand-Est is one of four French regions ordering dual-mode electric-hydrogen trains of the type Coradia Polyvalent with an autonomous range of 600 kilometers from Alstom. The three trains in the Grand-Est region will be in service on the route from Strasbourg to Niederbronn-les-Bains.

Fig. 24: Hydrogen train of the type Coradia Polyvalent

4

H2 GOES RAIL

As explained in the previous chapter, the project "H2 goes rail" is a cooperation by Deutsche Bahn and Siemens and is using a mobile filling station. The used hydrogen-powered train model is called "Mireo Plus H" and has a range of 600 kilometers. There will be one year test phase starting in 2024 on a route between Tübingen, Horb and Pforzheim.

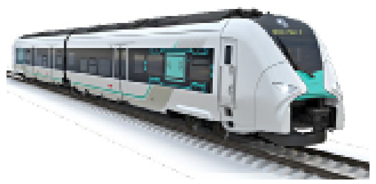


Fig. 25: the "Mireo Plus H" by Siemens

TRANSPORT – SHIPS

Hydrogen can become important in two respects for transportation on inland water ways. On the one hand as fuel for ships but also hydrogen as transported good to bridge the gap until pipeline systems & local production evolved. However, the latter is not yet practiced on a larger scale. Example projects for the use of hydrogen as a fuel in inland navigation can be found below.

1

RH2INE

The "RH2INE" projects aims to build the needed infrastructure for a zero-emission transport corridor all the way from Rotterdam to Cologne. By 2024 there should be at least ten hydrogen ships in service complemented by three hydrogen bunkering locations between Rotterdam and Duisburg.

Fig. 26: RH2INE" transport corridor network diagram

2

H2 SHIPS

"H2 SHIPS" is intended as a demonstration of the technical and economic feasibility of hydrogen bunkering and propulsion for shipping. There are two pilot projects: A hydrogen powered port vessel that is built in Amsterdam and the operation of a newly built hydrogen filling station for ships in Belgium.

3

FUTURE PROOF SHIPPING

Future Proof Shipping (FPS) is a small company with the goal to realize zero-emission shipping at reasonable costs. They currently work on the conversion of three inland container vessels to run 100% on hydrogen that are available for charter after their completion. The first one of the fleet, the FPS Maas will be finished and start sailing by the end of 2022, as soon as the retrofit is fully completed. It will run on a PEM fuel cell system with three 275 kW fuel cell units and will carry two swappable containers with 500kgs hydrogen each.

Fig. 27: The FPS fleet: FPS Maas, PS Rijn & FPS Waal

4

HTWIN

The "HTWin" project works on the establishment of a cross-border green hydrogen infrastructure in the border triangle of Germany, France and Switzerland. The development of the distribution network structures, the hydrogen production and storage as well as the hydrogen filling stations have their focus on shipping and heavy-duty road traffic. The marked points "A1" on the map (Fig. 28) are the planned filling station locations for ships.

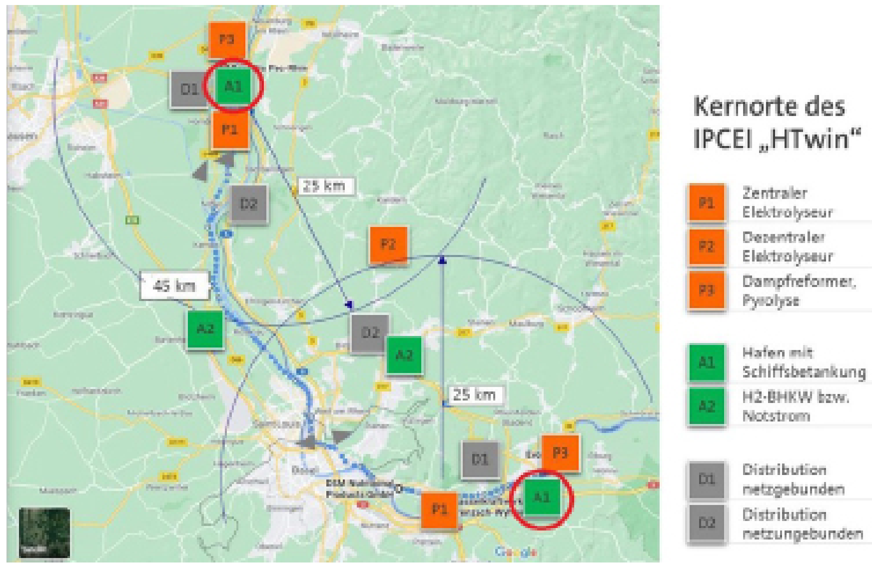


Fig. 28: Locations of the planned hydrogen infrastructure of the "HTWin" project

3.2 DATA INVENTORY - SUMMARY

Overall, the most important issue for hydrogen usage in the transportation sector is the lack of filling stations. More stations are needed, particularly for trains and ships, if emission-free traffic is to be achieved on all nodes.

The hydrogen production ramp up is on its way with a lot of projects in the planning, but still needs some time to develop. A connection of pipeline projects in industrial clusters is needed, initiatives like the European Hydrogen Backbone are trying to help with that.

Of all the countries within the Rhine-Alpine corridor, Italy in particular is lagging behind in the build-up of hydrogen infrastructure.

CONCLUSION AND PROSPECTS 04.

There is still a lot of work to be done to build a functioning hydrogen economy and transportation infrastructure, but the start has been made. If the targets of the "Fit for 55" package are met, there would be a viable start-up network of hydrogen filling stations for road traffic, but for the further development beyond 2030 there would still be the need for more filling stations in the future. More and more hydrogen projects are coming every year, this trend is set to continue, if it is not thwarted by slow planning, funding and approval processes. The energy transition efforts combined with the effects of the Ukraine crisis are accelerating the change even further.

OBSTACLES FOR AN ACCELERATED DEVELOPMENT

The main obstacles for an accelerated development in the hydrogen sector are still the slow planning and approval processes and the limited availability and high prices of green hydrogen.

The main challenges for inland navigation are the knowledge gaps about safety aspects of the handling and storage of hydrogen especially on board of ships but also in ports. Also, the regulatory environment is quite challenging because of a lack of general rules.

For the fleet conversion of trucks and buses the first challenge already lays in the higher costs for equipment and fuel that are prohibitive. A fuel cell truck for example is currently 20-25 % more expensive than a battery electric truck. As the distribution networks and hydrogen filling station networks are not yet fully developed, the limited availability of hydrogen in general and especially green hydrogen are hindering factors as well. In addition, there are several different options of hydrogen fuels and refueling technologies that are still competing on the market. The promising sLH2 technology (subcooled Liquid Hydrogen) for trucks for example is not yet market ready but is currently tested in a project by Daimler Truck called "GenH2 Truck".

FIELDS OF ACTIVITY FOR EGTC AND RH2INE

Main fields of activity for the EGTC deriving from the results of the H2 study should be:

1. acceleration of the development is key -> our role as driver and facilitator;
2. H2 as cargo: IWW on Rhine bridging the gap until pipeline system & local production evolves;
3. coordinated improvement of the network of filling stations for all modes;
4. links between pipelines, filling stations & distribution centres (coordinated approach).

REFERENCES AND RELATED LINKS

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SOURCES OF EXTERNAL IMAGES

Fig. 1: https://www.consilium.europa.eu/media/57689/2206_fit-for-55.png

Fig. 2: https://ec.europa.eu/transport/infrastructure/tentec/tentec-portal/map/maps.html?layerOn=true

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Fig. 4: slides from EHB Madrid Forum presentation, 14 Oct 2020

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OVERVIEW OF COLLECTED PROJECT DATA

The Excel file with all collected data on hydrogen projects in the countries of the Rhine-Alpine Corridor will be made available on the website of the EGTC Rhine-Alpine under:
https://www.egtc-rhine-alpine.eu/files/2022/11/H2-Study-project-data.xlsx.

Interregional Alliance for the Rhine-Alpine Corridor EGTC

c/o Verband Region Rhein-Neckar | M1, 4-5
68161 Mannheim - Germany

+49 (0)-621 10708-235

info@egtc-rhine-alpine.eu

egtc-rhine-alpine.eu

Interregional Alliance for the Rhine-Alpine Corridor EGTC