H2Accelerate

Linking Hydrogen Mobility with Industrial Hubs

Executive Summary

By 2030, there will be large-scale supply of renewable hydrogen in Europe linked to four key drivers: large-scale production, renewable hydrogen demand, import terminals, and hydrogen pipelines for transportation. Together, these components will form the 'European Hydrogen Network'. The Europe Hydrogen Network will be most concentrated in northwest Europe, where large-scale hydrogen production and import will supply industrial offtakers via pipeline, targeting specific industries: refineries, chemical production (mainly ammonia), and steel production.

In parallel, the H2Accelerate collaboration expects hydrogen demand from trucking to scale up around 2030 and develop along the strategic Trans-European Transport Network (TEN-T), starting in regions with the strongest policy support and with the heaviest freight routes. The regions which are best suited to the deployment of an early-stage hydrogen trucking network correspond to the regions where large-scale, reliable, and continuous supplies of hydrogen will be available by 2030.

Co-locating early hydrogen refuelling infrastructure with the European Hydrogen Network, and a sufficient supply of hydrogen, offers opportunities to both mobility and the industrial hydrogen suppliers to reduce costs and risk and can significantly improve the business case for these projects. These opportunities are:

- **Lower cost of hydrogen** due to economies of scale and reduced hydrogen, distribution distances.
- **Reduced risk** of renewable hydrogen supply constraints due to increased system redundancies built into industrial-scale electrolysers.
- **Viable business cases for HRS** due to high utilisation of stations from trucking in industrialised regions.
- **Accelerated decarbonisation of industrial supply chains** by making low-cost hydrogen available for the freight operators contracted by industrial hubs.

The regions with the highest demand for trucking overlap with the European Hydrogen Network in northwest Europe. There is therefore a clear opportunity for hydrogen infrastructure providers to **co-locate early HRS with the European Hydrogen Network** to accelerate the sector through **access to lower-cost, lower-risk renewable hydrogen.**

Facilitating an early hydrogen mobility network co-located with hydrogen production or import sites, will unlock synergistic benefits and initiate large-scale hydrogen trucking networks. H2Accelerate members believe that the following policies will support these goals:

- **Identification and facilitation of European Hydrogen Network hubs through the establishment of 'Hydrogen Acceleration Areas' -** providing certainty to industry and mobility on the locations of early hydrogen hubs in Europe and enabling rapid project implementation through simplified permitting.
- **Funding joint deployment of hydrogen refuelling stations and hydrogen trucks at industrial hubs through dedicated Hydrogen Acceleration Area mobility funding** - joint funding will ensure that the roll-out of refuelling infrastructure and trucks are well coordinated and that projects can take advantage of reliable, low-cost sources of hydrogen at industrial hubs.
- **Providing dedicated funding to subsidise hydrogen used in road mobility via the European Hydrogen Bank** - dedicated funding will create certainty on the availability of hydrogen for road mobility across Europe, helping to catalyse demand for hydrogen trucking.
- **National implementation of existing European hydrogen mobility policies to secure the long-term business case for hydrogen trucking.** The full implementation of EU policies supporting the transition to zero emission trucks into Member State laws must be realised to provide certainty to the private sector of the firm long-term business case for hydrogen trucks.

With sufficient policy support to initiate the development of hydrogen trucking supply chains and the availability of large scales of low-cost, low-risk hydrogen, the **full industrialisation of the hydrogen trucking sector can be achieved by 2035.**

Introduction

Hydrogen is well suited for long-distance, heavy-duty mobility applications. The EU has set decarbonisation targets for this sector in the Heavy-Duty Vehicle (HDV) CO_2 standard, requiring emissions to be reduced by 45% compared to 2019 levels by 2030. ACEA estimates that to reach the decarbonisation targets set in the HDV standard, 70,000 fuel cell trucks will need to be on the road in 2030,[1] implying an annual hydrogen demand of 0.8Mt.[2] To ensure sufficient hydrogen refuelling infrastructure is constructed to support these vehicles, the Alternative Fuels Infrastructure Regulation (AFIR) sets requirements for Hydrogen Refuelling Stations (HRS) to be deployed every 200km along the TEN-T network and in all urban nodes by 2030, each with a minimum capacity of 1 tonne/day.

Under the Renewable Energy Directive (RED), industry is required to increase its renewable energy use by 1.6% annually, with at least 42% of the hydrogen used to be produced via electrolysis using renewable electricity by 2030.[3] The total demand for hydrogen in industry was 7.1Mt in 2022, primarily in the refining and chemical production sectors.[4] Achieving a 42% target in 2030 will result in a minimum demand of 3.0Mt/year of renewable hydrogen, with additional hydrogen demand from new green processes in sectors such as steel production, ceramics, and glass production. To meet 3.0Mt/year of hydrogen demand, 12GW of electrolyser capacity will need to be installed in Europe.[5]

While there are differences in the supply chain requirements for mobility and industry, **large-scale demand for green hydrogen** across these sectors **creates opportunities for cross-sector synergies which can reduce costs and accelerate deployment.** This paper explores these opportunities.

1. Renewable hydrogen supply in Europe

Four key drivers lie behind large-scale renewable hydrogen supply in Europe: large-scale production, demand, hydrogen import, and hydrogen transportation. The location and development timelines of these four drivers can be used to map the availability of hydrogen at large scale in Europe.

Electrolytic hydrogen production projects in Europe

As of January 2024, Europe has installed 114 electrolysers, with a total capacity of 190MW, capable of producing 23.4kt of renewable hydrogen per year.[6] While these early small-scale projects were mostly based around small-scale HRS applications, there are now major 100MW production projects planned across Europe, primarily targeting industrial applications.[6]

Large-scale, 100MW+ electrolysis projects aiming to be operational by 2030 and with completed feasibility studies are largely concentrated in northwest Europe, Iberia, and Scandinavia. Northwest Europe contains the highest concentration of early electrolysis projects. Rotterdam, Netherlands, will host Holland Hydrogen I, a 200MW electrolyser, developed by Shell, for their Rotterdam refinery, and Lingen, Germany will host a 100MW electrolyser developed by bp for their nearby Lingen refinery. **Seven 100MW+ electrolyser projects have entered construction stages to date.**

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[1] 'Manifesto for Zero-Emission Trucks and Buses' ACEA, 11 April 2024

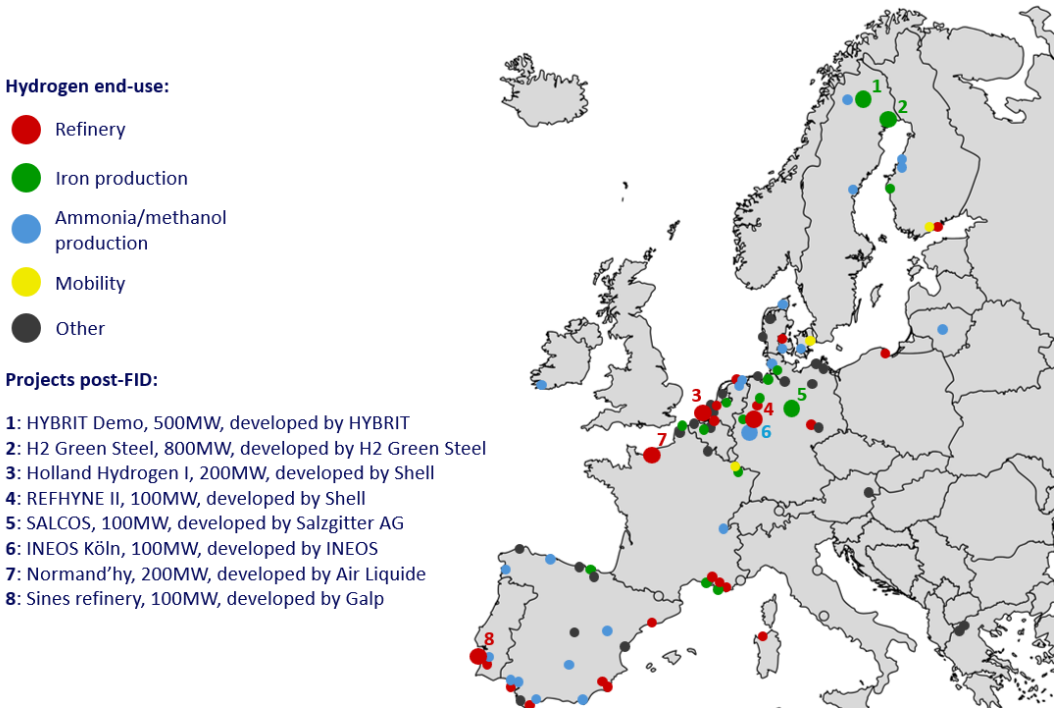
[2] A truck will use an average of 30 kg of hydrogen per day. To supply hydrogen for 70,000 fuel cell trucks, operating 360 days per year will require ~ 800 ktonnes or 0.8Mt of hydrogen.

[3] Renewable hydrogen can be obtained via electrolysis using renewable electricity to split water into hydrogen and oxygen and is referred to as 'Renewable Fuels of Non-Biological Origin' (RFNBO)

[4] 'Annual hydrogen consumption per country in Europe' European Hydrogen Observatory, 2022

[5] Assuming 50% of hydrogen used by EU industry is produced domestically, 1.5Mt of hydrogen will be produced by EU electrolysers. Assuming 50kWh/kg electrolyser energy consumption and a 70% load factor, an electrolyser capacity of 12GW is required.

[6] 'Hydrogen Production Projects Database' IEA, 31 October 2023 (corrected 23 January 2024)



100MW+ electrolysis projects aiming to be operational by 2030[6]

Benefits of supplying hydrogen to large-scale industrial offtakers

Renewable hydrogen projects are typically co-located with energy intensive industries, such as refineries and steel, where low carbon hydrogen will be used to displace fossil hydrogen to reduce carbon emissions. These projects benefit from reduced risk and costs through continuous, guaranteed offtake, economies of scale, and policies that offer financial rewards for using renewable hydrogen.

Europe is building a network of renewable hydrogen producers and users, to ensure a steady hydrogen supply to key industries. Certain industries are focused on different regions: oil refining in Belgium and the Netherlands, ammonia in Germany and Poland, and steel in France, Belgium, and Germany.[7,8,9]

Map of European steel plants[7]

[7] 'Map of EU steel production sites' European Steel Association, 14 June 2021
[8] 'PCI-PMI Transparency Platform' European Commission, 26 June 2024
[9] 'Map of major European fertilizer plants' Fertilizers Europe, 2018

Map of European oil refineries[8]

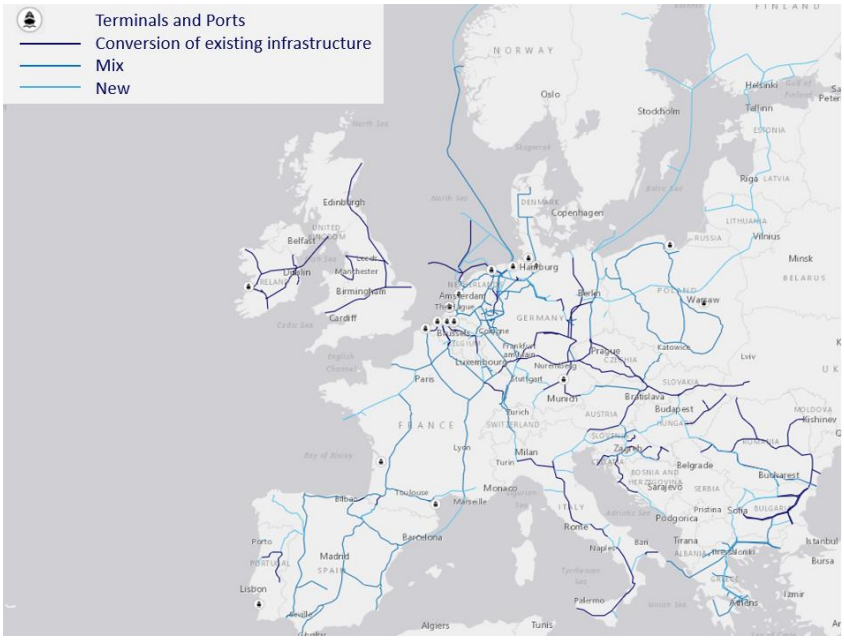
Map of major European ammonia plants[9]

Hydrogen import and transportation

The EU plans to build a hydrogen distribution network that connects industrial hubs to major import terminals. The Netherlands and Belgium have the highest hydrogen import targets, with a combined total of 6.2Mt per year.[10] This imported hydrogen will satisfy their domestic needs as well as supplying neighbouring countries. For example, Germany anticipates relying heavily on imports to meet its hydrogen demand, both from its own ports and from Europe via pipelines, according to its updated hydrogen strategy.[11]

Examples of hydrogen import projects include Amplifhy Rotterdam, developed by VTTI and the NH3 Antwerp terminal, developed by Fluxys and Advario; which will both import hydrogen as ammonia.[12,13]

The EU is developing a pipeline network for the large-scale distribution of hydrogen, connecting both import terminals and production facilities to end-users. The third wave of IPCEI[14] funding, Hy2Infra, will provide up to €6.9 billion in funding supporting the development of 2,700km of hydrogen transmission and distribution pipelines.[15] Projects funded under Hy2Infra complement other hydrogen distribution projects such as MosaHYC and the Hydrogen Core Network, that will supply hydrogen via pipeline to multiple industrial sites.[16,17] On a longer time-frame, the European Hydrogen Backbone, involving thirty-three energy infrastructure operators, is dedicated to coordinating the deployment of a pan-European hydrogen network spanning 57,000km by 2040.[18] These plans give insight into the future locations of Europe's industrial hydrogen network.



Map of planned import terminals and hydrogen pipelines[19]

[10] 'The Netherlands vs Belgium: Who will win the battle as Northwest Europe's leading hydrogen import hub' Westwood Global Energy Group, 16 November 2023

[11] '[German] National Hydrogen Strategy Update 2023' BMWK, July 2023

[12] 'NH3 Antwerp Terminal' Fluxys, accessed 2 August 2024

[13] 'Amplifhy Rotterdam' VTTI, accessed 9 July 2024

[14] IPCEI: Important Projects of Common European Interest

[15] '€6.9 billion of State aid by seven Member States' European Commission, 15 February 2024

[16] 'mosaHYC' GRTgaz, accessed 10 July 2024

[17] 'Commission approves €3 billion German State aid scheme to support the development of Hydrogen Core Network' European Commission, 21 June 2024

[18] 'EHB report on infrastructure development by 2030', EHB 10 July 2023

[19] 'Hydrogen Infrastructure Map', accessed 10 June 2024

Around 2030, the development of the four key drivers (large-scale electrolysers, hydrogen demand, import terminals, and hydrogen pipelines) will lead to large-scale hydrogen supply across Europe and the establishment of a 'European Hydrogen Network'. Mapping regions of large-scale hydrogen production, use, import, and transportation (the European Hydrogen Network) shows a **concentration of these regions in northwest Europe**.

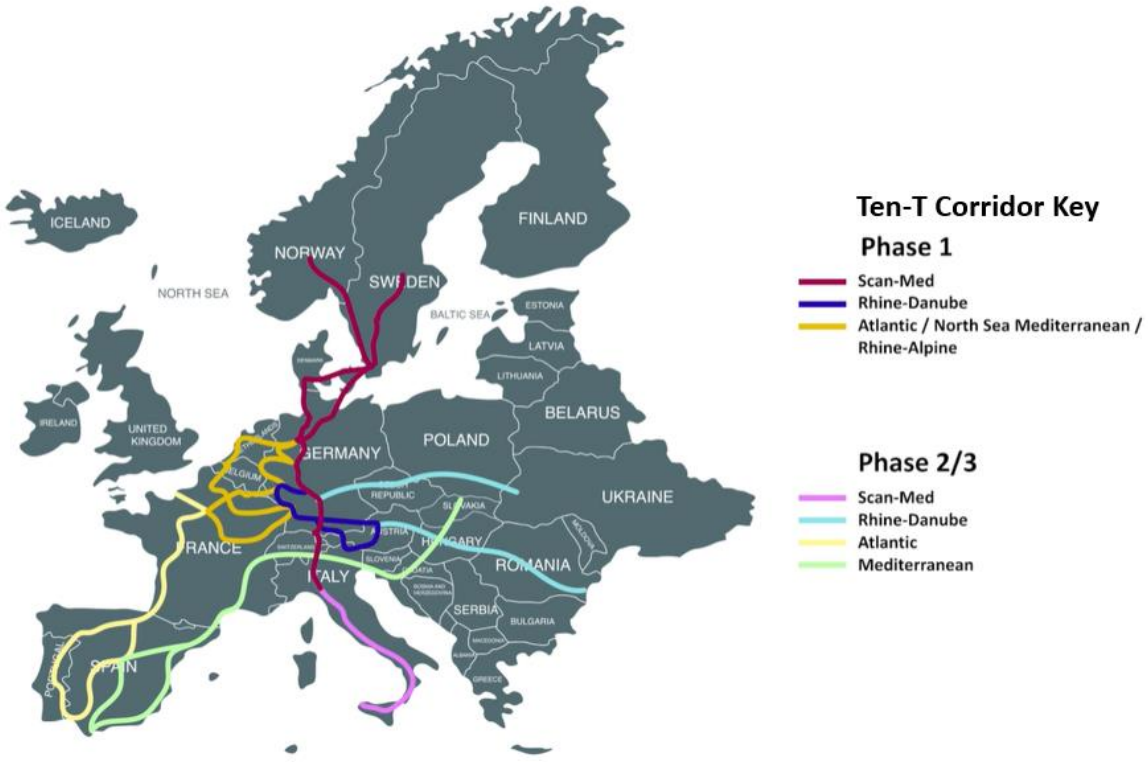
2. Hydrogen demand from mobility in Europe

Hydrogen demand from trucking in Europe is expected to rapidly scale up by 2030, where the HDV CO2 standards are expected to result in 0.8Mt/year of demand for hydrogen for trucking. This demand is expected to be concentrated around existing hubs and corridors for heavy-duty freight.

Development of hydrogen mobility corridors

The H2Accelerate collaboration expects hydrogen refuelling infrastructure to develop along the strategic Trans-European Transport Network (TEN-T) corridors, starting with the corridors located in northeast France, Germany, and the Netherlands. These initial corridors were selected for their heavy use by freight operators and the strong policy support for hydrogen mobility in France, Germany, and the Netherlands.

The H2Accelerate collaboration expects hydrogen demand for mobility to be highest in northwest Europe during the early stages of hydrogen mobility roll-out. This initial network will then expand across the continent to allow pan-European hydrogen mobility.



3. Co-location of mobility and industrial hubs

The gradual ramp-up in hydrogen truck deployment leads to a challenging business case for infrastructure development. Producing and transporting hydrogen in small quantities is costly compared to large-scale production and distribution,[20] and underutilisation of refuelling infrastructure during vehicle ramp-up leads to further increases in the cost of hydrogen at the pump. The cost of hydrogen is a significant factor in the Total Cost of Operating (TCO) for hydrogen trucks, and has a strong influence on end user technology uptake. **Access to more affordable hydrogen will create a catalytic impact on the uptake of hydrogen trucking.**

Comparing the European Hydrogen Network with the development of hydrogen mobility corridors shows that **the dense regions of the European Hydrogen Network are co-located with the regions that the H2Accelerate collaboration expects will have the highest demand for hydrogen mobility - in northwest Europe.** These regions will have large-scale, reliable, and continuous supplies of hydrogen available around 2030. Co-locating early hydrogen refuelling infrastructure with the European Hydrogen Network offers opportunities to both mobility and industry to reduce costs and risk and can significantly improve the business case for these projects.

4. Opportunities for cross-sectoral synergies

Co-location of early hydrogen refuelling networks with the European Hydrogen Network offers the benefits of reduced hydrogen costs, reduced risk associated with the deployment of HRS, increased HRS returns and diversifying fuel supplier offtake.

Reduced cost of renewable hydrogen for mobility projects
The scale of industrial hydrogen demand allows significant reductions in the cost of renewable hydrogen production to be achieved through economies of scale: in equipment procurement, power procurement, and fixed operational costs such as maintenance. By co-locating HRS with the European Hydrogen Network, fuel suppliers will be able to take advantage of these economies of scale and source renewable hydrogen at a lower cost.

Integrating HRS with the European Hydrogen Network will lower fuel distribution costs for suppliers. The cost of transporting hydrogen by tube trailer or pipeline rises with longer distances. Therefore, shortening these distances can markedly decrease hydrogen transportation costs, making it more affordable for end-users.

Directly connecting HRS to the European Hydrogen Network will reduce storage costs and HRS footprint. Industrial hydrogen users will require a steady source of hydrogen, at much larger scales than is required by an individual HRS. By ensuring a sufficient supply of hydrogen is available, small variations in demand at the HRS can be absorbed by the industrial hydrogen user, reducing on-site storage requirements for the HRS.

Reduced risk associated with the deployment of the HRS
Setting up HRS in industrial hubs cuts supply chain risks. Early hydrogen production facilities may face more downtimes with fewer backup options, but large facilities have numerous electrolyser stacks and built-in redundancies. Consequently, downtime impacts are smaller at large hubs compared to small ones, minimizing hydrogen shortages. Additionally, industrial hubs typically host multiple hydrogen plants, boosting supply security.

[20] 'Assessment of Hydrogen Delivery Options' European Commission, 2021

Viable business case for HRS
Industrial hub locations correspond to the regions of highest trucking demand, resulting in a higher demand for hydrogen fuel as the trucking sector converts to zero emission vehicles. Securing high levels of demand for fuels early in the HRS lifetime will lead to a viable business case. This increases confidence in the sector and encourages investments in hydrogen refuelling infrastructure.

Diversified offtake for industrial-scale hydrogen producers
By supplying available industrial hydrogen to mobility, industrial hydrogen producers will be able diversify their offtake and reduce project risk.

While demand for hydrogen from mobility will scale up more slowly than demand from industrial projects, total demand from mobility will be substantial if 2030 HDV CO2 targets are to be met. This additional offtake for hydrogen provides a secondary revenue stream for industrial hydrogen production projects and therefore increases the resilience of their hydrogen demand.

Industrial hydrogen producers will be able to decarbonise both industry and mobility at industrial hubs. Industrial end users in sectors requiring hydrogen often also contract freight operators to support their operations (through transport of feedstocks and products, etc.). By making hydrogen available to mobility offtakers at industrial hubs, industrial sites can deploy zero emission trucks to further decarbonise their operations.

5. Linking mobility to industrial hubs – policies and timelines

Both the European Hydrogen Network and hydrogen trucking are in the early stages of development and must compete with well-established, low-cost fossil-based alternatives. The EU has enacted a strong policy framework to support the long-term business case of industrial hydrogen projects which has enabled the first major (>100MW) electrolyser projects to take FID in Europe.

To unlock the potential of co-locating mobility projects with the European Hydrogen Network and support the early stages of hydrogen trucking in Europe, members of the H2Accelerate collaboration believe that additional policy measures will benefit the co-deployment of industrial and mobility hydrogen projects. Policies and funding have the potential to scale up both sectors together, creating a catalytic impact on the decarbonisation of both industry and mobility:

1. **Identification and facilitation of European Hydrogen Network hubs through the establishment of 'Hydrogen Acceleration Areas'**
   H2Accelerate members assert that identifying large-scale hydrogen production and import hubs, capable of providing affordable green hydrogen, is crucial for Europe's zero emissions mobility goals. The initial large-scale zero emission freight corridors along the TEN-T network will connect these hubs. To promote demand for renewable hydrogen, industrial and mobility hydrogen projects based in these hubs should see accelerated permitting procedures to promote rapid implementation.

   H2Accelerate members are calling for 'Hydrogen Acceleration Areas', geographically defined zones where hydrogen production and utilisation projects can receive fast-tracked permitting to speed up implementation. These zones echo the Renewable Acceleration Areas, which EU countries must designate for renewable energy projects by February 2026 under the RED.[21]

2. **Funding joint deployment of hydrogen refuelling stations and hydrogen trucks at industrial hubs through dedicated Hydrogen Acceleration Area mobility funding**

[21] Under RED III, member states have until February 2026 to identify renewable acceleration areas.

Providing joint funding for hydrogen refuelling stations and hydrogen trucks at industrial hubs through specific Hydrogen Acceleration Area mobility funding will boost the utilisation of these stations and help decarbonise freight in industrial areas. This approach ensures early industrial and mobility projects are co-located, maximising cross-sector benefits and optimising public investment.

Funding dedicated to co-located industrial and mobility projects have previously been implemented through European schemes. The Clean Hydrogen Partnership provides funding to support 'Hydrogen Valleys': regional hydrogen ecosystems producing hydrogen to supply more than one sector.[22] **Further large-scale funding for cross-sectoral Hydrogen Acceleration Areas, which ensures the deployment of highly utilised AFIR-compliant HRS, will enable the rapid development of the industrial hub-and-spoke model of hydrogen mobility.**

3. **Create certainty on the availability of renewable hydrogen for road mobility through dedicated funding via the European Hydrogen Bank.** Large-scale production hubs will help to reduce the cost of hydrogen production, but additional hydrogen subsidies such as those provided by the European Hydrogen Bank and H2Global will further reduce the cost of hydrogen fuel. By increasing total funding under the European Hydrogen Bank, dedicated funding can be provided for road mobility hydrogen, which in turn will increase certainty on the availability of affordable green hydrogen for mobility and catalyse demand for hydrogen trucking.

4. **National implementation of existing European hydrogen mobility policies to support the long-term business case for hydrogen trucking**
   The EU has **already implemented** a framework of policies to support the long-term business case of zero emission trucking in Europe. Firm commitments from Member States to implement the existing and planned EU policy framework in such a way that creates long-term total cost of ownership parity with diesel vehicles for end users, are required to unlock large-scale private investment into zero emission trucking.

Deployment timelines

Around 2030, large-scale (>100MW) electrolysers and import terminals will be deployed, providing a supply of hydrogen into the European Hydrogen Network. Currently over 100 100MW+ electrolyser projects, with completed feasibility studies, are expected to be operational by 2030, with a combined production capacity of 7.5Mt/year.[6] Including the planned import capacity of 6.2Mt/year in the Netherlands and Belgium alone, the European Hydrogen Network will be supplied with a total of 13.7Mt/year across 100 European sites. Making 6% of the 13.7Mt/year annual supply in 2030 available to hydrogen trucking would support 70,000 trucks,[23] enough to fulfil the 2030 HDV CO_2 standard requirements[24] and enable the deployment of hydrogen trucking at large scale.

TCO parity between hydrogen and diesel trucks can be achieved by 2035 through sustainable long-term policy and regulatory measures, including differential road tolls through the EuroVignette Directive, carbon tax through ETS II, and RED credits for renewable hydrogen.

Beyond 2030, economies of scale and incremental technological improvements through industrial-scale manufacturing are expected to enable hydrogen trucks to approach TCO parity with diesel trucks without the need for capital funding for HRS or trucks.

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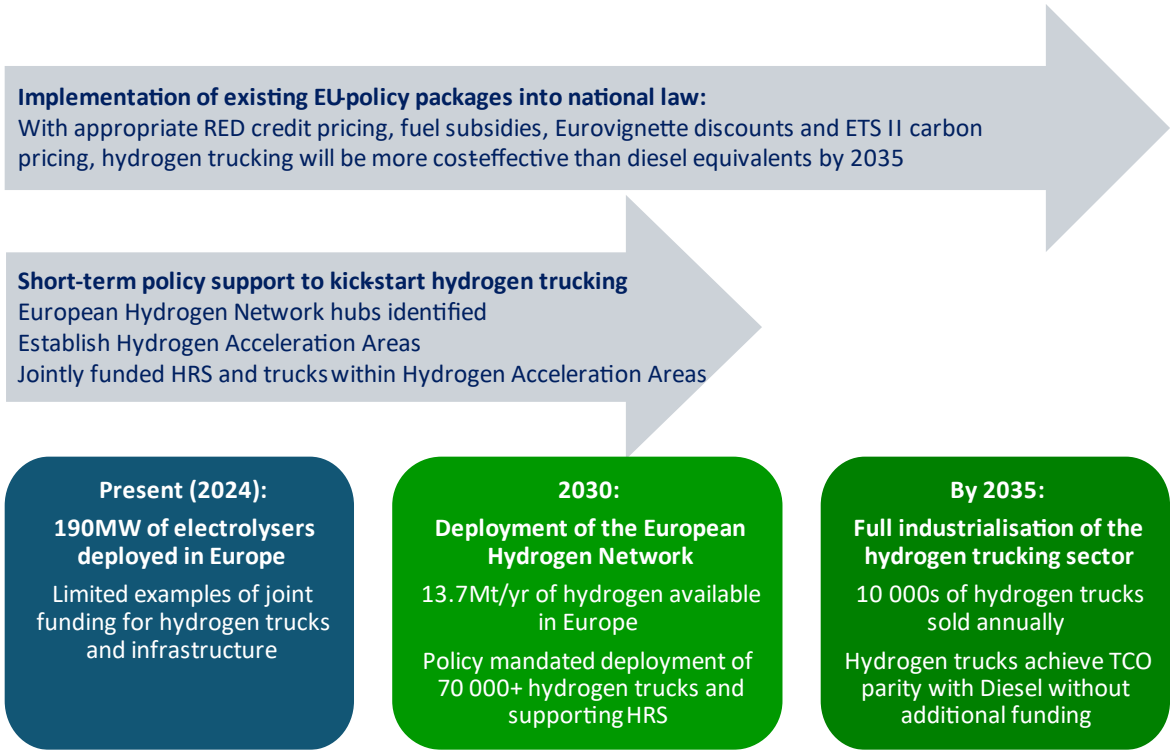
[22] 'Hydrogen Valleys', Clean Hydrogen Partnership, accessed 5 August 2024

[23] A fuel cell truck will utilise around 30 kg of hydrogen per day. 6% of 13.7Mt/year supply (0.8Mt/year or 2,100 tonne/day) is sufficient to support 70,000 fuel cell trucks.

[24] ACEA estimate that 70,000 hydrogen fuel cell trucks are required for Europe to meet the HDV CO_2 Standard: 'Manifesto for Zero-Emission Trucks and Buses' ACEA, 11 April 2024



Conclusions

Co-locating hydrogen refuelling for mobility with industrial hydrogen supply and demand – the 'European Hydrogen Network' - offers multiple benefits:

- **Lower cost of hydrogen** due to economies of scale and reduced hydrogen, distribution distances.
- **Reduced risk** of renewable hydrogen supply constraints due to increased system redundancies built into industrial-scale electrolysers.
- **Viable business cases for HRS** due to high utilisation of stations from trucking in industrialised regions.
- **Accelerated decarbonisation of industrial supply chains** by making low-cost hydrogen available for the freight operators contracted by industrial hubs.

Mapping regions of planned large-scale hydrogen production, import, transportation, and use, shows **a concentration of renewable hydrogen availability expected in northwest Europe.**

The H2Accelerate collaboration expects hydrogen refuelling infrastructure to develop along the strategic TEN-T corridors, in countries where policy support for hydrogen mobility is currently strongest and regions with high volumes of freight transport, starting in Germany, the Netherlands, and France. The regions with the highest demand for trucking overlap with the 'European Hydrogen Network' in northwest Europe. There is therefore a clear opportunity for hydrogen infrastructure providers to **co-locate early HRS with the 'European Hydrogen Network'** to accelerate the sector through **access to low-cost, low-risk renewable hydrogen.**

The existing EU policy framework has enabled FID to be taken on the first large-scale industrial hydrogen projects, but additional support can leverage this hydrogen network to catalyse large-scale hydrogen trucking in Europe. H2Accelerate members believe that facilitating an early hydrogen mobility network co-located with hydrogen production or import sites, will unlock synergistic benefits

for the hydrogen trucking sector and initiate large-scale hydrogen trucking. This can be achieved with the implementation of the following policies:

- **Identification and facilitation of European Hydrogen Network hubs through the establishment of 'Hydrogen Acceleration Areas' -** providing certainty to industry on the locations of early hydrogen hubs in Europe and enabling rapid project implementation through simplified permitting.
- **Funding joint deployment of hydrogen refuelling stations and hydrogen trucks at industrial hubs through dedicated Hydrogen Acceleration Area mobility funding** - joint funding will ensure that the roll-out of refuelling infrastructure and trucks are well coordinated and can take advantage of reliable, low-cost sources of industrial hydrogen.
- **Providing dedicated funding to subsidise hydrogen used in road mobility via the European Hydrogen Bank** - dedicated funding will create certainty on the availability of hydrogen for road mobility, helping to catalyse demand for hydrogen trucking.
- **National implementation of existing European hydrogen mobility policies to secure the long-term business case for hydrogen trucking.** The full implementation of EU policies supporting the transition to zero emission trucks into Member State laws must be realised to provide certainty to the private sector of the firm long-term business case for hydrogen trucks.

With sufficient policy support to initiate the development of hydrogen trucking supply chains and the availability of large scales of low-cost, low-risk hydrogen, **full industrialisation of the hydrogen trucking sector can be achieved by 2035.**