Whitepaper
Expectations for the first phase of the fuel cell truck and infrastructure deployment

In a previous whitepaper, the H2Accelerate collaboration outlined phases through which it expects the hydrogen trucking system to progress, the first of which is the 'R&D and Deployment' phase. This is a whitepaper setting out in more detail the expectations for the first phase of deployment. It outlines the truck and hydrogen refuelling station (HRS) deployment plans of the H2Accelerate members in the period up to 2027, while highlighting expected advancements in the other elements of the system, such as the hydrogen production and the supporting maintenance and service networks for the deployed vehicles.

This paper was published by the H2Accelerate Collaboration in May 2023 as the fifth in a series of whitepapers in support of the use of hydrogen in long-haul trucking.

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The H2Accelerate collaboration

The H2Accelerate collaboration has been formed between Daimler Truck AG, Iveco Group, Linde, Shell, TotalEnergies, and Volvo Group to work collaboratively to develop the evidence base and public funding programmes which can help move Europe towards a commercially viable hydrogen trucking system. Each of these major industrial players, from both the fuel supply and trucking sectors, have made their own organisational commitments to achieving net zero carbon in line with Europe's ambitious decarbonisation targets under the Paris climate agreements.

H2Accelerate members agree that achieving the decarbonisation of the heavy-duty trucking sector will require the use of hydrogen as a fuel for many of the vehicles used by the continent's vehicle operators.

Engagement with logistics operators by members of the H2Accelerate collaboration indicates significant demand for fuel cell trucks in the near term, as well as a clear role for fuel cell trucks as part of a low carbon fleet in the long-term. In order to enable the use of hydrogen to decarbonise the trucking system, joint commitments are required from infrastructure providers, vehicles OEMs, end users, and policymakers. Currently, information on the vehicles and refuelling infrastructure that will be available in the early years of deployment is sparse, making it difficult for both policymakers and trucking end users to make informed decisions and commitments on hydrogen trucking.

This paper aims to remedy some of the information gaps by providing information on H2Accelerate member plans and expectations for the early deployment of fuel cell trucks and infrastructure.

The publication of this paper follows the announcement that H2Accelerate members acquired funding for the deployment of 150 fuel cell trucks from the Clean Hydrogen Partnership, and 29 HRS from the Connecting Europe Facility. This funding will enable deployment of the systems described below, and unlock the next scale of truck and refuelling station deployment.

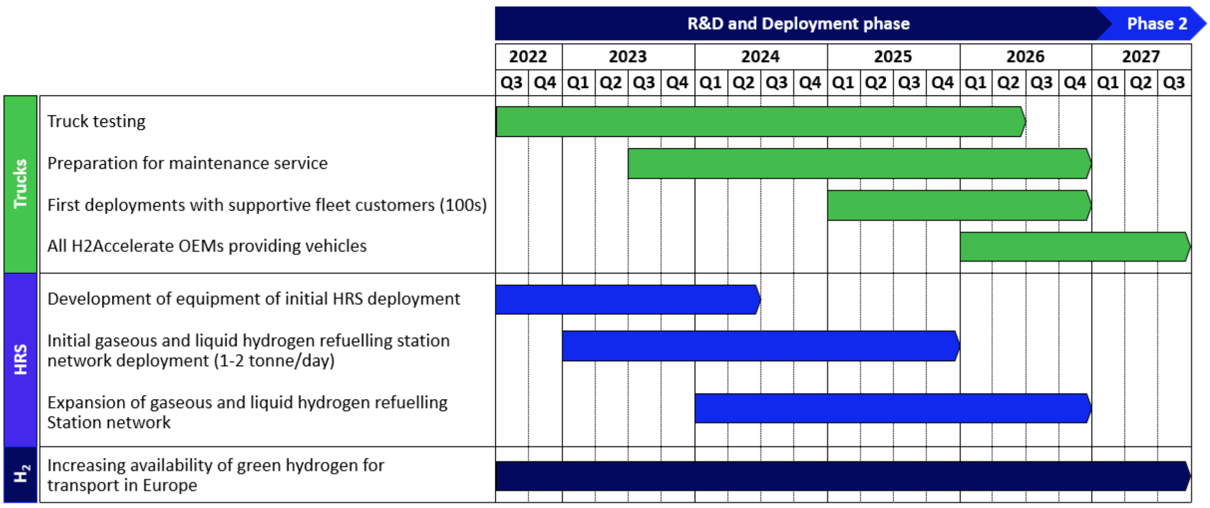
R&D and Deployment phase

As discussed in a previous whitepaper on 'Expectations for the fuel cell truck market', H2Accelerate envisions the deployment of hydrogen trucks occurring in phases, with each stage providing the evidence base, technological improvements, and cost reductions needed to support the advancements in the subsequent phases.

R&D and Deployment (2023 – 2026)	Industrial Scale-up (2026 – 2028)	Sustainable Growth (2028 – 2035)	Full Industrialisation (2035 onwards)
• First 100s of trucks in the hands of customers • Limited (but high reliability) refuelling network in clusters • Learning about customer attitudes and interactions with the trucks	• First series produced vehicles emerge • Networks start to expand • High capex/risk • Vehicles still carry a cost premium	• Series produced vehicles available from many manufacturers • Pan-European network on major corridors • Vehicles trending towards an affordable cost base	• Supply chains for trucks and green hydrogen have fully matured • Fuel cell trucks sales make up >20% of heavy-duty vehicle sales • Cost of operating fuel cell trucks minimised

These phases span the period from today to the 'Full Industrialisation' phase, reached mid-way through the 2030s, where hydrogen trucks become ubiquitous throughout Europe. The first 'R&D and deployment' phase of the hydrogen trucking system will be used to establish the technology and commercial readiness of trucks and infrastructure before larger-scale deployment in the following phases. A crucial element of the preparation for commercialisation is ensuring that the overall sector is capable of meeting and exceeding customer expectations, which will then create increased demand for vehicles and fuel in subsequent phases.

A viable hydrogen trucking system includes upstream green hydrogen production, a network of HRS that provide hydrogen at an acceptable cost and with high reliability and convenience, and trucks that are able to provide at least equivalent performance to the incumbent diesel vehicles. By working together, H2Accelerate members aim to deploy all elements of this first phase in a way that creates sustained market demand for the vehicles and fuel, and prepare for the successful implementation of subsequent phases.



Indicative timeline for the R&D and Deployment phase

Hydrogen Fuel Cell Truck Deployment

The early ‘R&D and Deployment’ phase of truck deployment must include an iterative feedback loop of research and development, internal testing, and testing of the vehicles in real-world conditions through deployment. This combination will ensure that reliable hydrogen trucks are in the hands of customers as early as possible, thereby enabling immediate emissions savings and providing real-world operational data that can be used by hardware suppliers to improve equipment. It will also ensure that these learnings can be combined with advancements in research and development to enable the fuel cell truck offerings to attain operational performance equivalent to that of a diesel vehicle. This is important because although potential hydrogen end users appear to be tolerant of teething periods in the deployed vehicles, consistently unreliable or inadequate early vehicle offerings will be damaging to the technology’s future adoption rates.

Before the trucks are deployed with customers, they undergo intensive testing in-house and on public roads to ensure the vehicle is fit for its intended use cases and the climates within which it may operate. This testing process is already underway for H2Accelerate OEMs[1], and this ensures that the trialled vehicles are at the necessary technology readiness to fulfil customer expectations.

Since 2021, Daimler Truck has been intensively testing its Mercedes-Benz GenH2 Truck fuel-cell prototype on its in-house test track and public roads and now testing the use of liquid hydrogen with another prototype[2]. Source: Daimler Truck

[1] Vehicle suppliers are also referred to as vehicle OEMs are also referred to as vehicle suppliers

[2] Daimler Truck, 2022, ‘Development milestone: Daimler Truck tests fuel-cell truck with liquid hydrogen’

Volvo has commenced testing its fuel cell trucks in advance of its customer pilots, which will start in a few years, and its commercialisation plans in the latter part of this decade[3]. Source: Volvo

Various models of hydrogen fuel cell heavy-duty trucks are being tested by vehicle suppliers and trialled in demonstration projects (similar to H2Accelerate TRUCKS), mostly in North America, Europe, and Asia. The early deployment phase will benefit from the variety of these demonstration projects, in both the heavy-duty truck models and the operational conditions trialled. Early demonstrations will help prepare the vehicle models and the supporting infrastructure for their commercial rollout. Several manufacturers have announced plans to produce fuel cell truck models in series, some of which will have been demonstrated through trial projects. A sample of some of the early heavy-duty hydrogen trucks currently being tested is shown in the table below.

Deployment timeline	Maker-model	Hydrogen storage	Gross Train Weight (tonnes)	Range (km)
2022	Hyundai - Xcient	350 bar	42	~400
2023	Hyzon HyMax - articulated vehicles	350 bar	46	~680
2024	IVECO heavy duty fuel cell electric truck	700 bar	44	up to 800
Second half of the decade	Daimler Truck - Mercedes-Benz GenH2 Truck	LH_2	40	>1000km

The H2Accelerate TRUCKS project: what to expect

As highlighted in a previous H2Accelerate whitepaper analysing the total cost of ownership of fuel cell trucks, project-based support for the first hundreds of trucks is needed through

[3] Volvo Group, 2022, 'Volvo Trucks has started tests of fuel cell electric trucks'

European and national funding to enable vehicle OEMs to attain higher deployment levels and hasten the sector's scale-up. With funding support from the Clean Hydrogen Partnership, the H2Accelerate TRUCKS project will conduct a six-year project to address a significant bottleneck to the rollout of the hydrogen trucking system: the availability of multiple, reliable hydrogen fuel cell truck offerings.

Through the H2Accelerate TRUCKS project Daimler Truck, Iveco Group, and Volvo Group will deploy 150 heavy-duty long-haul trucks across nine European countries. All H2Accelerate OEMs have selected the heaviest vehicle class for the deployment of their fuel cell truck, as it is a) the most challenging operating environment for a truck and hence provides a rigorous test of the technology, b) represents the largest distance driven by trucks in the European fleet and hence could achieve the highest CO_2 impact with a complete conversion of the existing fleet and c) it is the segment which will be the hardest for battery-only vehicles to address given the range and charging time limitations.

This project will build on the prototype testing and pre-production design validation done by the H2Accelerate OEMs in previous demonstration projects and internal trials. The vehicles deployed to customers will be capable of fulfilling long-haul operations, requiring a range of at least 400km, under the different climates and topographies. Nonetheless, during the project, the vehicles' performances will be monitored to generate learnings for further design improvements.

Previously, the trial and demonstration projects for heavy-duty hydrogen fuel cell trucks have typically tested a small number of vehicles under regional use-cases. H2Accelerate members aim to accelerate the sector development by expanding the testbed, testing trucks capable of operating at weights (including vehicle load) of 40-44 tonnes. Such a comprehensive testbed has previously not been possible due to a lack of HRS infrastructure and the time required to develop a reliable customer-ready 44-tonne heavy-duty fuel cell truck.

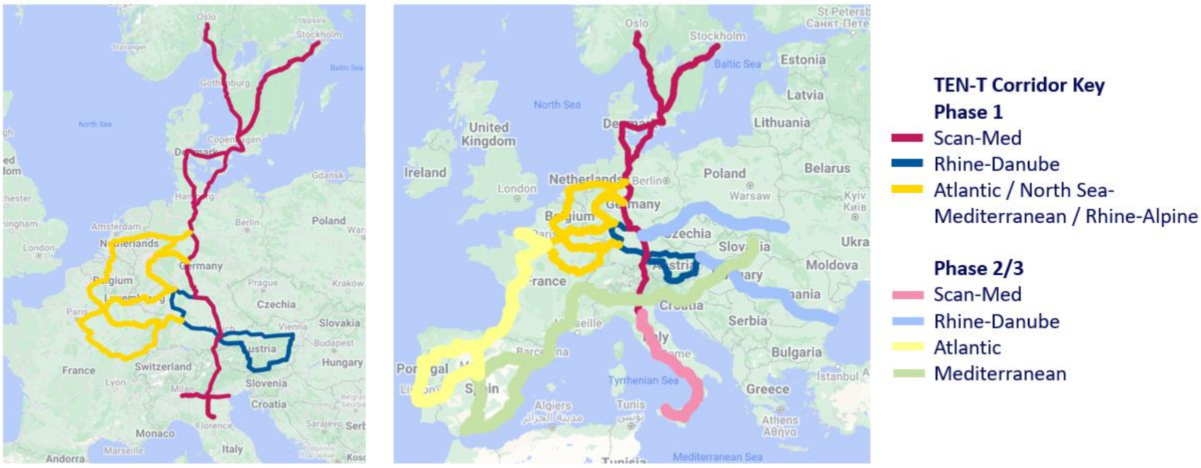
Parameter	Daimler Truck	Volvo	Iveco Group
Truck type	4x2 articulated vehicle	4x2 and 6x2 articulated vehicles	Tractor 6x2 sleeper cab
Hydrogen storage	Liquid Hydrogen	700 bar	700 bar (350 bar compatible)
Use cases	Long haul	Long haul	Long haul
Gross vehicle weight	40t	41-44t	44t
Time for complete fill	< 20 minutes		
Range	>600km (700 bar) and >1000km (Liquid Hydrogen)		
On-board H2 storage (kg)	>80 (sLH2)	Up to 80	70 usable capacity

The IVECO heavy duty fuel cell electric truck represents IVECO soon-to-come zero propulsion transport solution in long-haulage. Iveco Group will further develop and commercialise in Europe its range of fuel cell electric-born trucks and buses.

The H2Accelerate OEMs will deploy trucks with a range of international transportation and logistics providers in nine countries across Europe, thereby allowing for a diversity of use cases to be tested during this early phase. The vehicle roll-out will focus on the SCAN-MED corridor (Italy to Sweden), RHINE-ALP corridor (France/Germany to Benelux), RHINE-DAN corridor (Austria to Germany), ATLANTIC corridor (France to Germany), and NORTH SEA-MED corridor (France to Benelux).

The country deployments have been selected based on:

- **Available and planned infrastructure deployments.** The trucks have been deployed to match the planned infrastructure deployment from H2Accelerate infrastructure members and other infrastructure providers outside the collaboration. By doing so, the vehicle suppliers minimise the customer's risk of stranded assets while improving the utilisation of the HRS deployed during the early deployment phase.
- **Proximity to OEM headquarters.** Another factor considered was the proximity to OEM headquarters as this will allow the vehicle suppliers to easily ensure that the early adopters of the technology receive tailored and consistent support.
- **Availability of supporting policy.** The initial truck roll-out will be in regions with an emerging, but not fully developed policy support framework for hydrogen trucking. Although this case applies to many European countries, there is a geographical discrepancy in the available support. The resultant focus is on regions where there are already mature national funding schemes, which are able to further develop refuelling infrastructure.



H2Accelerate Phase 1 **H2Accelerate Phase 2/3**

Corridors where H2Accelerate members intend to deploy hydrogen trucks and refuelling infrastructure

Hydrogen Refuelling Station deployment

Currently, most of the existing HRS are equipped for passenger vehicles, with some capacity for 350 bar compressed hydrogen refuelling for a small number heavy-duty vehicles. However, to achieve operational and commercial viability of hydrogen refuelling infrastructure, a new generation of HRS capable of serving large volumes of hydrogen (>1 tonne/day) to heavy-duty vehicles with fast refuelling (<10 minutes) and high reliability (99%+) will need to be deployed in convenient locations (close to either TEN-T corridors or urban nodes) across the continent.

As with the trucks, the deployment activities within this R&D and Deployment phase will provide learnings on technology and operational best practise. This will allow stations to achieve a high level of reliability by testing and improving equipment, design, and operational and maintenance models. By enabling the development of more reliable and higher capacity stations, the HRS deployed by stakeholders such as H2Accelerate members in this phase will catalyse further investment in hydrogen mobility.

The H2Accelerate collaboration: what to expect

H2Accelerate infrastructure members have successfully acquired individual funding from the Connecting Europe Facility's Alternative Fuels Infrastructure Fund to deploy 29 such stations in locations compatible with the planned truck deployment, as shown in the table below.

Project/Operating body	**Targeted operational timeline**	**Number of HRS**	**Potential countries of deployment**	**Technical features (capacity/refuelling technology)**
Lighthouse One: TotalEnergies	2024	9	Belgium, Netherlands, France, Germany, Spain	0.4 tpd - 2 tpd Hybrid compressed gas 350 bar and 700 bar
H2Accelerate Inaugural Station Deployment: Shell	2025	8	North-West Europe	>1 tpd per station, Hybrid compressed gas 350 bar and 700 bar

H2Accelerate Expansion Network: TotalEnergies	2025	12	Belgium, France, Germany, and the Netherlands	>1 tpd per station, Hybrid compressed gas 350 bar and 700 bar

Each of these projects will develop technologies for innovative dual-pressure HRS, capable of providing over 1 tonne/day of either 350 bar or 700 bar hydrogen. This use of two pressures is to accommodate future truck manufacturer technologies and provide key lessons on the distribution, compression, and refuelling technology associated with hydrogen at both pressures. These systems will then have their reliability demonstrated in the field to gain real world data and learnings on the optimum refuelling technology choice for the future roll-out.

The early deployments will trial different station configurations to test and optimise the business case for hydrogen delivery, including connection to a hydrogen pipeline and on-site electrolysis, as well as the typical delivery via tube trailer from large-scale hydrogen production sites. This will provide learnings on the operational and logistical benefits and challenges of different hydrogen distribution pathways, which will inform future roll-out.

With the provisional agreement on the Alternative Fuels Infrastructure Regulation (AFIR) in place, increased certainty on the hydrogen refuelling network that will be in place latest end of 2030 for heavy-duty vehicles is provided to the market, and additionally a steer on the technology and standards that will be available. While further infrastructure beyond the minimum requirements set out in AFIR will be required to enable pan-European hydrogen freight, the clarity provided along with other necessary EU-policy announcements is nessecary to kickstart the hydrogen mobility economy and support the commercialisation of the business case.

The early HRS deployments will occur amidst a nascent renewable hydrogen supply chain and growing heavy-duty hydrogen demand across Europe. As such, the station siting has been decided based on a combination of customer convenience and operational costs. Four key factors will likely influence the station siting:

- **Truck customer demand.** Especially in the first deployment phase, HRS will be deployed in regions with early adopters of hydrogen-fuelled trucks to ensure high utilisation of these sites and therefore a business case for their construction. Further, alignment on deployment geographies between fuel cell trucks and infrastructure is crucial to ensure end user needs are met in the early scale-up of the sector. The H2Accelerate HRS are planned to be deployed in parallel to the truck deployment within the group along the Scandinavian-Mediterranean, Rhine-Alpine, Rhine-Danube, Atlantic, and North Sea-Mediterranean TEN-T corridors.
- **Proximity to the TEN-T corridor.** The heavy-duty trucking sector is a highly cost-sensitive industry and early HRS deployments will have to be strategically located to avoid the additional expense and inconvenience associated with driving far from motorways to reach refuelling sites. HRS will be rolled out close to key European transport corridors for trans-European logistics and in alignment with the requirements of AFIR.
- **Proximity to hydrogen production.** To minimise the price of hydrogen at the pump, the first refuelling stations will be sited near large-scale green hydrogen production plants. Large-scale production is vital to reduce the price of green hydrogen, while

reducing transport distances from production sites to HRS minimises the cost of distribution. In future, the cost of distributing hydrogen may be reduced by transporting hydrogen either in liquid form or through the gas grid, and early stations can be sited with proximity to the gas grid in mind to future-proof investments in developing these sites.

- **Viable network spread.** The network will be deployed to prevent trucks from being stranded due to the absence or downtime of HRS - a average distance between stations of 200km is targeted in the design of the network.

The published plans of the H2Accelerate collaboration through members' funded projects will ensure that early adopters of these vehicles will be well informed of the deployment locations, timelines, and technology choices available for early HRS networks, and data and feedback from these end users on the performance of vehicles and HRS can be used to improve customer experience over time.

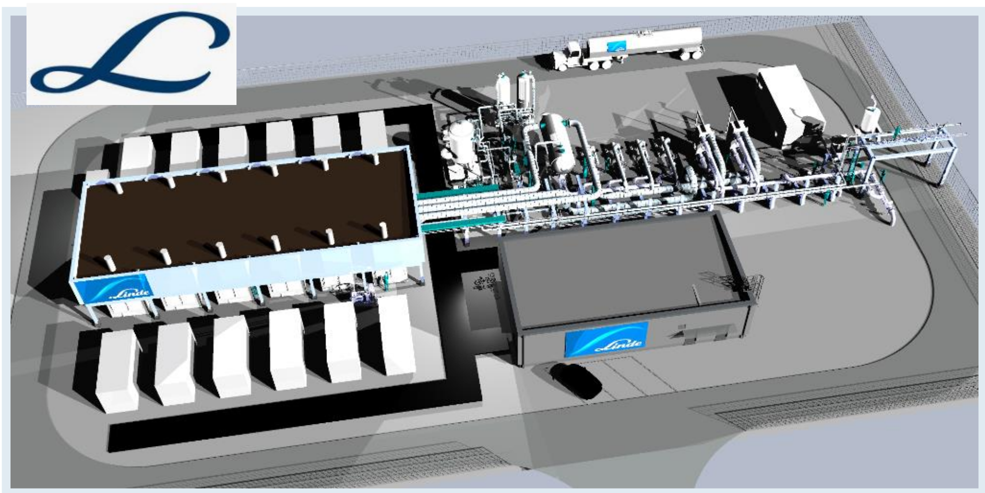
Green hydrogen supply in Europe

As demand for renewable hydrogen for trucking increases, the scale of electrolyser capacity will also need to expand to meet this demand. Given the long (2 years or more) deployment timelines for the development of large-scale electrolysis sites, investment decisions will need to be taken today to meet the growing demand from the trucking sector and meet the targets for renewable energy use in transport.

Fortunately, H2Accelerate members have anticipated the need for a fast ramp-up in green hydrogen production capacity and are already developing electrolysis sites capable of providing supply to mobility offtakers. For instance, through the REFHYNE project, funded by the European Commission's Fuel Cells and Hydrogen Joint Undertaking (now Clean Hydrogen Partnership), Shell is operating a 10 MW electrolyser in Germany, the largest in Europe. Shell has further taken a final investment decision on Holland Hydrogen 1, a 200MW electrolyser in the Netherlands which is expected to become operational in 2025 and provide renewable hydrogen to a combination of industrial and mobility applications.

The REFHYNE electrolyser is currently providing renewable hydrogen supply at Shell's Rheinland refinery

Linde is developing green hydrogen production capacity at its chemical plant in Leuna, Germany, with a 24MW electrolyser plant currently in construction and further capacity expected to be developed to serve industrial and mobility applications. Linde has been supplying both gaseous and liquid hydrogen to industry for over 50 years, has an existing truck fleet to distribute hydrogen, and a project pipeline including more than 100 projects in mobility alone.



The Leuna electrolyser has been the largest built PEM electrolyser globally and the project includes H2 liquefaction

TotalEnergies also have a number of planned green hydrogen production projects in development, including a 40MW plant at the La Mède refinery in France.

Renewably produced hydrogen can be used to decarbonise a number of end uses, including industry, mobility, power generation, and heating. This diversity of end-use opportunities means that investment in Europe's electrolyser capacity does not need to be synchronised with a single sector. As such, there are synergies between the use of hydrogen in industry and mobility, as industry is able to provide a high-volume but relatively low-value offtake for renewable hydrogen while demand from mobility is ramped-up, creating significant economies of scale for renewable hydrogen production. Conversely, the mobility sector offers a higher-value market than industry, but can only justify relatively small-scale production plants in the early years of deployment. The planned deployments of hydrogen trucking within and external to H2Accelerate provide not only a secured demand for renewable hydrogen but also an improved business case for investment in new electrolyser builds.

Preparation for future deployment phases

While H2Accelerate members are fully ready and willing to commit to scaling up the hydrogen trucking sector, achieving the targets set by Europe will require significant investment (hundreds of millions of euros) on the part of both truck manufacturers in research and development and scaling up fuel cell truck manufacturing facilities, and hydrogen suppliers to scale up the green hydrogen supply chain and invest in first high-capacity hydrogen stations. Triggering these investments will require a clear signal of intent from the European Union and its member states, both in terms of capital funding during the high-risk early stage and policy/regulatory support for the subsequent expansion.

This funding will be needed in the short term to help underpin the establishment of infrastructure to support hydrogen trucks at a mass market scale (both refuelling stations and vehicle maintenance and support networks), as well as for the purchase of the vehicles themselves when demand is small and hence unit costs are high. This is now well underway with the funding from the Clean Hydrogen Partnership for 150 fuel cell trucks and Connecting Europe Facility for 29 HRS. At the end of this first 'R&D and Deployment' phase, there will be sufficient demand to justify expanding the hydrogen refuelling network along the major station corridors and providing vehicles to a wider variety of fleet customers.

In addition to stimulating infrastructure deployment, an important expected output of HRS and truck deployment is to promote and inform a Europe-wide approach to supportive hydrogen policy frameworks. Potential support mechanisms, including the Renewable Energy Directive (RED II) for the use of renewable hydrogen in transport, carbon tax, and differential road tolls (through the Eurovignette Directive), were detailed in the H2Accelerate whitepaper on the ‘cost of ownership and the policy support required to enable industrialisation of fuel cell trucks’ [4]. These supportive frameworks will be required to make the financial case for the second phase, where full industrialisation of vehicles and hydrogen supply chains has not yet been achieved. Since the deployment of hydrogen refuelling infrastructure will likely occur in regions with favourable policy environments, there will need to be an increasingly uniform spread of policy support provided across Europe. If this does not occur, the continent risks an uneven distribution of hydrogen refuelling infrastructure and consequently, the adoption of the hydrogen trucking system. As the long-haul trucking sector is inherently cross-continental, the deployment of refuelling infrastructure uniformly across Europe will enable the network to meet market demands. The H2Accelerate collaboration is directly engaging with

4 H2Accelerate (2022) *TCO and policy support analysis whitepaper*

policymakers at both the national and European level to communication on how policy can best be designed to promote the deployment of a viable hydrogen trucking ecosystem.

Conclusions

The first phase of deployment under the H2Accelerate collaboration is vital to bring the first fleets of fuel cell vehicles and hydrogen into the hands of customers, and to validate this technology in real-world operational conditions. Data and feedback from end users gathered in this phase will be used to inform the next phase of deployment, to maximise the speed at which the sector can reach full industrialisation.

Through the Clean Hydrogen Partnership-funded H2Accelerate TRUCKS project, the H2Accelerate vehicle OEMs will deploy 150 heavy-duty long-haul trucks by 2028. These trucks will be operated by logistics and transport customers in intensive operations across nine countries. The project aims for as diverse an operator pool as possible to generate learnings on the vehicles' real-world operation, and these insights will inform the technological developments in future vehicle rollouts.

The first deployment phase will also see an uptick in heavy-duty HRS being built and operated, with H2Accelerate members having secured funding for 29 HRS across 6 countries from the Connecting Europe Facility. These HRS will be sited with both the early truck deployments and hydrogen production sites in mind and will provide high capacity refuelling (1 tonne/day or more) at both 350 and 700 bar to allow different on-board storage types to be trialled.

Renewable hydrogen production is already in development by H2Accelerate members at large-scale sites across Europe, and a number of different distribution models for hydrogen will be trialled in the first phase. The deployment plans developed by both infrastructure players and vehicle OEMs which are members of the H2Accelerate collaboration shows that all necessary elements of industry are ready and willing to invest creating a viable business case and optimised operational experience for end users.