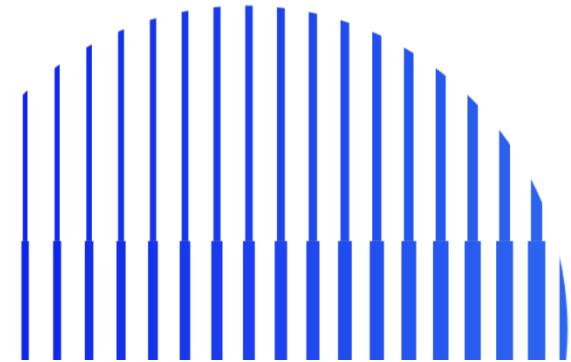
H2Accelerate

Whitepaper

Expectations for the fuel cell truck market

A whitepaper setting out the expectations for the development of the fuel cell truck market in Europe as it scales up in the years leading up to 2030. Three deployment phases are envisaged, that will result in the mass market deployment of fuel cell trucks and the required supporting infrastructure for long-haul, heavy-duty transport in the following decades.

This paper was published by the H2Accelerate collaboration in August 2021 as the second in a series of whitepapers in support of the use of hydrogen in long-haul trucking.



The H2Accelerate collaboration

The H2Accelerate collaboration has been formed between Daimler Truck AG, IVECO, OMV, Shell, TotalEnergies, and Volvo Group to work collaboratively to develop the evidence base and public funding programs 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 agreement.

The H2Accelerate companies are agreed 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.

Based on learnings from previous hydrogen transport roll-out, the parties believe that joint commitments of infrastructure players and truck manufacturers to implement early deployment projects are essential in order to deliver the roll-out of hydrogen trucks at an accelerated, but deliverable, pace. The companies are clear that this deployment is complex and will require the support of both public and private sectors. The nature of the public support required is expected to evolve over time, as truck and refuelling technology matures and the scale of deployment increases.

This paper sets out the expectations of the H2Accelerate collaboration regarding the timeline of hydrogen truck and refuelling infrastructure deployment. Three phases are set out to describe the number of trucks deployed, the number and specification of hydrogen refuelling stations deployed, and the required policy support during each phase. The success of these three phases will provide the necessary upscaling to allow hydrogen trucks to become competitive on a post-2030 timescale, resulting in significant emissions reductions in the sector.

Planned phases of hydrogen truck deployment

H2Accelerate envisions the deployment of hydrogen trucks up to 2030 occurring in three phases. The deployment in each of these phases progressively increases in scale, with economies of scale, new learnings, and technological improvements allowing the public support required per truck to be reduced over time. These phases span the period from today, when very few hydrogen trucks have been deployed in limited demonstration projects and come at a significant cost premium compared to diesel alternatives, to the post-2030 world where hydrogen trucks become ubiquitous throughout Europe. The envisioned deployment phases are:

- **A first "learning by deployment" phase from 2021 to 2025** where the first hundreds of trucks are placed in the hands of customers, using a relatively limited (but high reliability) refuelling network. In this phase the hydrogen trucking industry will learn about customer attitudes to, and interactions with, the trucks, as well as developing new refuelling stations for high-capacity truck refuelling and standardising around preferred refuelling and vehicle field service solutions. The trucks are still in a developmental phase and are not yet comparable to series products. The vehicles will require a support network capable of servicing the vehicles - a regional repair and maintenance network will therefore be set-up by the truck OEMs providing vehicles, in order to keep the trucks running. During this phase, direct capital subsidies will be required to make an acceptable business case proposition for end users, in addition to private financing from hydrogen providers and vehicle manufacturers. The details of long-term policy solutions to enable the business case for hydrogen trucks will be developed in this phase, to allow industry to prepare for the following decade of scale up.
- **A second "industrial scale up" phase from 2025 to 2028** where the first series production of trucks will occur, and vehicles will be deployed in their thousands. In this phase, the refuelling network will grow across Europe, along key transport corridors. This will be the phase with the highest investment required and also the highest risk, which leads to the need for the greatest financial support. Policy support measures during this period are expected start to transition from capital subsidy for trucks and infrastructure to more sustainable measures, for example in the form of differential road tolls, carbon taxes, etc.
- **A third "sustainable growth" phase beyond 2028** where economies of scale have helped to reduce prices across the supply chain and public funding support can be progressively withdrawn in favour of supportive sustainable policy measures.

Achieving this vision will require joint commitments from truck manufacturers (to commit to industrialising vehicle manufacture), hydrogen providers (to invest in a new refuelling

network, with associated green hydrogen production), vehicle customers (to act as first movers in the use of hydrogen trucks) and member state governments. In the first phase, the focus will be on achieving capital support for the vehicle customers as well as the early station network. During the second and third phase, the focus shifts to less reliance on capital subsidy and increased reliance on mechanisms such as the implementation of the Renewable Energy Directive II to promote green hydrogen, as well as the use of road toll and carbon taxation policies to favour uptake of zero emission freight vehicles.

Investments made during this period will enable the deployment of hydrogen trucks as a key technology option for long-haul heavy-duty road transport after 2030 through:

- Extensive vehicle research & development to bring heavy-duty long-distance trucks to standards required for general use and towards a Total Cost of Ownership which is acceptable to customers.
- Manufacturing facilities to build increasing numbers of fuel cell trucks at prices which become competitive as the supply chain scales up (to over 10,000 trucks/year per manufacturer).
- A network of high capacity, reliable refuelling stations, which is rolled out in advance (but coordinated with) the roll-out of trucks to an increasing number of customers.
- Infrastructure to provide maintenance and service support to the trucks on their long-haul routes across Europe (rolled out in sync with the spread of the hydrogen truck opportunity).
- Large scale hydrogen production systems capable of producing zero carbon hydrogen on a Gigawatt scale.

The H2Accelerate companies are agreed that without the public support and cooperation between hydrogen-producers and truck manufacturers to deliver the planned deployment phases up to 2030, these necessary goals will not be achieved. Since the parties also agree that hydrogen solutions are required to decarbonise heavy-duty trucking, action is required now to deliver on European ability to achieve net-zero carbon goals within the heavy-duty trucking sector.

Phase 1 – Learning by deployment

In the early years, a combination of research, development, and early deployment as well as learning from first field deployments is required. This learning will be used to define the wider market roll-out phase. In this phase, hydrogen trucks will still not be on the level of technical maturity of diesel trucks and the entire development and manufacturing process chain needs to be adapted to this new technology. Whilst vehicle manufacturers and hydrogen providers look to optimise the system for their customers, trucks will use a variety of refuelling technologies, namely gaseous (350 and 700 bar) and liquid hydrogen refuelling.

In this phase, the first trucks will hit the roads in their hundreds. The vehicles will be deployed with medium and large customers who understand that these vehicles are the first mainstream deployments of a new technology and as such will have inevitable teething issues (which will provide learning for next iterations of the vehicle and associated support networks). These first vehicles will operate on defined transport corridors, often near the main production and/or vehicle development facilities of the manufacturers, where they can be supported to a high standard by the vehicle manufacturers. The corridors will be covered by a first network of specialised hydrogen truck refuelling stations with a high daily refuelling capacity (over 1 tonne/day), high filling speed and high reliability. These early stations will be used by a combination of truck customers making regular point to point deliveries along the corridor and customers operating in captive operations based in and around the cities nearest the stations.

The first refuelling stations will be sited near large-scale green hydrogen production plants that are currently in development. These plants will minimise the cost of green hydrogen by producing it at significant scale, while the short distribution distances will allow reliable delivery of hydrogen at low cost.

During this phase, there is a considerable amount of learning required in order to set up the subsequent large-scale roll-out. Specific aspects of the learning in this phase of the roll-out will include:

- Significant research and development necessary to build large scale fuel cells and hydrogen tanks into Europe's heaviest duty long haul tractors.
- Understanding customer attitudes to these first hydrogen trucks and the implications for future roll-out (network design, technology choices, strategy for field support, etc.).
- Testing the economics of and customer attitude to the different hydrogen refuelling options, including both liquid hydrogen and pressurised hydrogen (with pressures ranging from 350 to 700 bar).
- Gaining new knowledge about the longevity and factors affecting failure rates for all of the components within the supply chain (including the vehicles and the hydrogen refuelling stations), with a view to developing more robust systems in the post 2025 roll-out.
- Understanding the support systems which will be required to provide an acceptable customer experience for the truck customers – for example, these trucks will have to travel long distances and rapid support will be required throughout their journey in

the event of any issues with this new technology. This will require new responsive service models.

- Developing stations capable of refuelling liquid hydrogen directly onto trucks and also design concepts for hybrid stations able to dispense both liquid hydrogen and compressed hydrogen.
- Deploying and testing high-capacity hydrogen refuelling stations with 1-2 tonnes per day of refuelling capacity (enough for up to 40 truck fills per day), capable of truck refuelling in 10-15 minutes.
- Developing new designs (and components) for stations with a capacity in excess of 5 tonnes per day, with faster filling than for the 1-2 tonne/day station.
- Piloting a first station with >5 tonne/day capacity.
- Hydrogen production for a network of hydrogen refuelling stations and the strategies which can allow large scale renewable hydrogen production centres to grow along with a rapidly growing fleet of zero emission trucks.
- Learning will be captured and debated amongst the entire European hydrogen trucking industry with a view to achieving a consensus on codes and standards, refuelling protocols, and the overall strategy for the post 2025 period.

In the early years, there is a considerable cost premium for operating a fuel cell truck compared to operating a diesel vehicle. Policy support in the early years of the roll-out is required to explicitly fund the deployment of trucks in order to create genuine early demand for the European hydrogen supply chain. In the learning by deployment phase funding is expected to be largely delivered in the form of capital cost subsidies. This funding will be needed 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 (i.e. before full industrialisation has occurred).

At the end of Phase 1, 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.

Phase 2 – Industrial scale-up

The start of Phase 2 is an important point for hydrogen trucking, as this is the point at which the major European OEMs begin to start scaling up their production facilities. This will partly be driven by the CO2-targets for heavy-duty vehicles requiring fleet-wide emissions reductions of 15% by 2025 and 30% by 2030[1]. The manufacturers will use the learnings in Phase 1 to develop a truly attractive customer proposition for their vehicles and then scale up truck production to thousands per year (which is still low volume compared to current diesel vehicle production). Once hydrogen trucks are being produced in many hundreds to thousands per year, it becomes possible to accelerate the rate of roll-out of stations and the associated support networks for the trucks themselves. This is because the confidence in the technology, the supply chain and (most importantly) the customer appetite will grow and de-risk larger investments to deploy an increasing number of higher capacity refuelling stations.

As a result, the 2025 phase is characterised by increasing the density and capacity of refuelling stations around the initial deployment hubs and expanding along the core TEN-T transport corridors of Europe. Within existing hydrogen truck hubs developed in Phase 1, larger stations will be built with a capacity in excess of 5 tonnes of hydrogen per day (capable of refuelling 100s of trucks each day). These stations will be built along the core routes and will also enable expansion across key routes to enable expanded driving range for hydrogen trucks.

The trucks will be deployed with larger fleet users, expanding the early trials in Phase 1 and attracting new customers as the proposition becomes more concrete and therefore sellable to a wider range of customer types.

A range of regulations and policies can help ensure a rapid acceleration of the take-up of hydrogen trucking in Phase 2. It is expected that a capital subsidy for both vehicles and the required supporting infrastructure will be required as in Phase 1 but reduced in amount compared with the early deployments of Phase 1 on a per vehicle basis, as when volumes increase, costs will fall. It therefore becomes possible to use a smaller incentive to drive deployment of hydrogen trucks over time. As a result, a volume-dependent subsidy is expected to be used in the period to 2028.

In addition to capital subsidies, Phase 2 is when operating cost-based support is expected to be implemented by European governments. This will include positive implementation of the new Renewable Energy Directive (RED II) with respect to hydrogen, the treatment of hydrogen generation within grid codes and energy storage and the favouring of zero emission vehicles in vehicle taxation and road charging policies. These policies will act as the main funding mechanism for hydrogen trucks during Phase 3, and their successful implementation in Phase 2 will provide assurance to hydrogen producers, truck manufacturers, and customers on the business case for the technology[2].

[1] European Commission (2019) Reducing CO2 emissions from heavy-duty vehicles

[2] The H2Accelerate collaboration will publish a paper on the required policy support to facilitate the roll-out of hydrogen trucks in Autumn 2021.

Phase 3 – Sustainable growth

Beyond 2028, hydrogen trucks will be manufactured in series production conditions by multiple manufacturers, with thousands of vehicles per year being produced by each vehicle manufacturer but still not in quantities comparable to diesel trucks. Therefore, a sustainable policy shift providing a competitive business environment using elements such as zero emission vehicle purchasing subsidies, tolls, and a CO2 tax on conventional diesel fuel remains still necessary. In order to allow industrial players to prepare for the upscaling in this phase, the principles of the policy support that will be available must be detailed and clarified in the preceding years.

With a combination of success in the first two phases and assuming supportive regulations are introduced to ensure uptake of zero emission trucks for long haul driving, the H2Accelerate participants anticipate that the following targets can be met by 2030 (note that this will need new hydrogen refuelling providers to begin deploying their own refuelling stations as a result of the momentum created by H2Accelerate):

- 60,000 hydrogen fuelled trucks on European member state roads in day-to-day operation.
- More than 400 hydrogen stations for trucks installed and operational in Europe (note that this will need new hydrogen refuelling providers to begin deploying their own refuelling stations as a result of the momentum created by H2Accelerate).
- Over 2GW of green hydrogen production exclusively from ultra-low carbon sources used in the trucking sector.
- The vehicles, fuel and support costs will have reached the point where they can provide an attractive ownership cost proposition without requiring dedicated funding schemes for vehicle purchase.

By 2028, demand has reached a sufficient level of certainty and costs of hydrogen supply have fallen so that, provided RED II is still favourable, there is less need for capital support for every new station built and the industry is capable of becoming self-financing for the expansion phase. During this phase, it will be possible to use legislative pressures which require a move to zero emission trucking to start to further reduce direct purchase subsidies. Additionally, differential road tolls for zero emission vehicles, different vehicle taxation regimes and mandates requiring zero emission trucks for certain customer types remain necessary.

Looking further ahead into the 2030s, hydrogen is expected to be available on a cost competitive basis without capital subsidy, provided a long-term sustainable policy shift is made to overcome the increased cost of the vehicle technology. This will be achieved due to the ramp up in manufacturing and hydrogen production scale during the 2020s, and the application of lessons learnt during the first three phases to optimise the customer value proposition of hydrogen trucking.

Conclusions

The H2Accelerate collaboration envisions the ramp-up of hydrogen trucking deployment in three phases, initially centred around large-scale green hydrogen production hubs with a limited number of large-capacity, high-reliability hydrogen refuelling stations, that will be connected along key transport routes before expanding to form a pan-European transport network. Initial deployments of 100s of trucks with pioneering customers will help vehicle manufacturers and hydrogen providers tailor their offering to the needs of customers in subsequent roll-out, providing valuable learning that will influence further development of the technology. Over time, an expanded network, improved customer support, and proven technology alongside increasing regulatory pressures to decarbonise will attract new customers and allow hydrogen trucks to transition to series manufacturing. Long term, sustainable policy support for hydrogen trucks will need to be implemented in the ramp up phase to provide greater certainty to companies investing in the scale up. The combination of increasing scale and policy support will improve the business case for hydrogen trucks from today, where they incur a significant additional cost compared with diesel alternatives.

Public support for the initial deployment phases of hydrogen trucks and the supporting infrastructure is required to enable the widespread use of the technology in the 2030s and beyond. Initially, policy support will be required to provide capital funding for both trucks and infrastructure. As volumes of trucks deployed increases, which also provides additional certainty of high utilisation for infrastructure providers, capital subsidies will be reduced based on volume, while operating cost-based subsidies are implemented to support wider roll-out. This will include implementation of RED II credits for renewable hydrogen, differential road tolls for zero emission vehicles, different vehicle taxation regimes and mandates requiring zero emission trucks.

This rapid, but deliverable, ramp-up in the scale of hydrogen truck deployment will allow hydrogen truck technology to become cost-competitive with diesel alternatives on a total cost of ownership basis after 2030, given sufficient policy support. Since hydrogen is key route to decarbonising certain trucking applications, there is a clear case for providing public funding to allow the roll-out of hydrogen truck technology. The H2Accelerate parties agree that providing policy support for hydrogen trucks on this timeline is the fastest and most cost-effective route to decarbonising long-haul trucking on the timescales required to meet net zero targets.