Monitor Deloitte.

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Fueling the future of mobility: hydrogen and fuel cell solutions for heavy duty long-haul freight transportation

Hydrogen Articles Collection

Why does hydrogen stand out, among alternative energy sources, with regards to reducing greenhouse gas (GHG) emissions from heavy-duty long-haul mobility uses? How feasible and realistic is the short-term infrastructure deployment to comply with the EU emissions target for heavy duty vehicles? What is the competitiveness of hydrogen-powered trucks in the mid-term? What is the expected impact on GHG emissions? What are the investment requirements to activate the whole value chain?

Executive summary

The EU committed to reach carbon neutrality by 2050 to comply with the Paris Agreement and limit global warming below 1.5°. Hydrogen is a major pillar of the strategy to address this challenge and is expected to attract major investments.
Beyond overall GHG emissions reduction targets, the EU also set specific objectives for heavy-duty vehicles by 2030, setting a 30% fleet-wide average reduction target.

In the mid-term, Fuel Cell Electric Vehicles (FCEV) appear as a credible solution for carbon-free long-haul trucks:

- Most alternative technologies to ICE face technical challenges (autonomy, charging times, limited load for BEV; heavy infrastructure for catenary and induction systems; modest emissions savings for LNG/CNG),
- FCEV trucks cope with long-haul freight constraints, leverage a set of mature technologies and allow potentially significant GHG emissions reductions, as CCS combined with SMR process can capture up to 89% of CO_2 produced.

The adoption of FCEV trucks requires rapid – albeit, realistic – value chain activation:

- Several hydrogen plants (mainly SMR process) are close to TEN-T corridors, especially in 6 key countries (Fr, Ger., It., and Benelux). Further to fueling first FCEV trucks, such facilities are a platform for brownfield growth and CCS retrofit,
- Transport and storage technologies, in either liquid or compressed gaseous (up to 700 bars) forms, are currently well-known,
- Finally, a network of refueling stations will have to be deployed along Pan-European freight key routes ("TEN-T") and major logistic hubs.

As of 2030, FCEV trucks are expected to become competitive against ICE ones:

- Purchasing cost decrease (from 300k€ down to 120k€ in 2030) will be driven by scale-up and standardization of FCEV truck construction technology,
- Fall in Operating costs will be mainly driven by H_2 delivered cost reductions and result in a 60% cost saving, reaching costs of less than $5 / kg of H_2 by 2030.

On the emissions front, FCEV vehicles will bring major improvements in CO_2 emissions, while staying at par with the best EURO 6 trucks on NOx: about 10-15% in the short term, then up to less 80% when CCS systems will be industrially deployed.

By 2030, a 10% "blue" hydrogen FCEV penetration rate for long-haul freight transport in 6 key EU countries, is achievable, although challenging:

- From a technical standpoint, this objective will require the deployment of 20 000 trucks, 600 refueling points and an additional production of up to 280kt H_2 p.a.
- Total CAPEX required is expected to range from €5b to €6b, a sizeable share of announced public investment, calling also for bold moves from private players (industrial gas producers, highway operators, truck manufacturers, O&G players, power & gas utilities).

By 2030, a 10% "blue" hydrogen FCEV penetration rate for long-haul freight transport in 6 key EU countries, is achievable, but requires significant investments and rapid decisions from public and private players.

Hydrogen and long-haul freight emissions, two pillars of the EU carbon-neutrality strategy

The EU committed to reach carbon neutrality by 2050 to comply with the Paris Agreement and limit global warming below 1.5°. Hydrogen is a major pillar of the strategy to address this challenge and is expected to attract major investments.

The EU roadmap for a sustainable transformation towards low-carbon economies ("the European Green Deal") is being translated into national climate strategies. An intermediary milestone to reduce GHG emissions has been set by 2030 and relies on two key pillars:

- The decarbonation of all sectors with energy-efficient technologies
- Investments in alternative energy sources

Hydrogen stands out as a key pillar in this strategy.

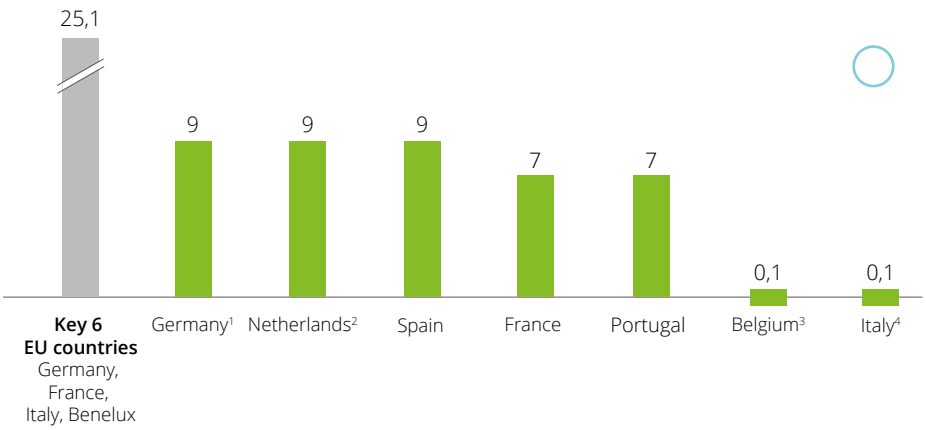
Indeed, European countries recently presented their hydrogen strategies with billion euros investments, totaling up to ca. €45 - €50b by 2030 (out of €180 - €470b by 2050), and €25b for the France, Germany, Benelux and Italy subset of countries. The Covid-19 outbreak strengthened sustainability as a cornerstone of economic recovery and brought GHG emissions reduction back to the fore.

Figure 1.

European hydrogen strategies

European countries are putting hydrogen investments at the heart of their strategies to cut GHG emissions

Announced Hydrogen investments by 2030 (billions euros)



Notes: 1. €9b by 2040; 2. Investment plan presented by Northern Netherlands to the Dutch Parliament pending sign-off; 3. H_2 deployment is mainly financed by the private sector (e.g., Air Liquide); 4. Mainly driven by Snam
Sources: European Commission; OECD; Monitor Deloitte Analysis

Beyond overall GHG emissions reduction targets, the EU has set specific 2030 objectives / targets for heavy-duty vehicles.

Heavy-duty vehicles are major contributors to EU CO_2 emissions: about a quarter of road transport emissions and 5% of EU's total emissions (150 Mt out of 3.1b tons in 2020[1]). Therefore, the EU set a 30% fleet-wide average reduction target for heavy-duty vehicles (i.e., a volume of ca. 54M tons of CO_2 by 2030[2]) and a minimum 2% share of zero or low-emission vehicles among new trucks.

The interim milestone applied to large lorries, with a 15% emissions reduction target by 2025, highlights the urgency to initiate the green transition for long haul road freight.

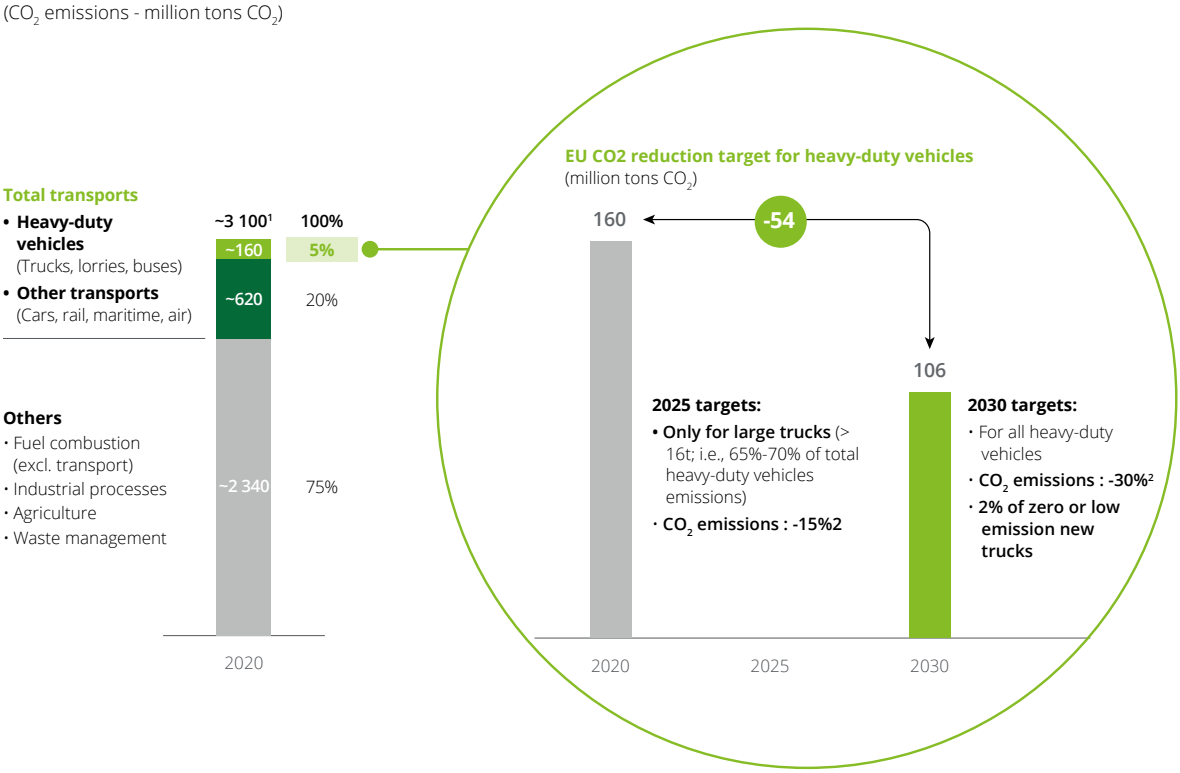
To coordinate the scattered development initiatives and to achieve public-funding targets, governments have set 2030 targets on the number of vehicles in hydrogen-powered fleets, while highlighting ambitions for the deployment of an end-to-end value chain.

Figure 2.

Emissions reduction ambition

The EU set the first CO_2 reduction targets for heavy-duty vehicles by 2030, to curb road transport emissions

Heavy-duty vehicles are key contributors to CO_2 emissions, for which the EU targets a ~54 million tons CO_2 reduction by 2030
(CO_2 emissions - million tons CO_2)



Notes: 1. CO_2: 80% of GHG; Heavy-duty vehicles: 5% of total EU emissions; 2. Vs. EU average in the reference period (1 July 2019–30 June 2020). Sources: European Environment Agency; Monitor Deloitte Analysis

Figure 3.[3 4 5 6 7 8 9 10]

European hydrogen strategies

National hydrogen strategies include key measures to accelerate the deployment of hydrogen mobility

Key measures of the deployment of hydrogen mobility

Country	Germany	Netherlands	Spain	France	Portugal	Belgium	Italy
Production	Construction of **hydrogen production capacities** (5 GW by 2030)	Construction of **green hydrogen production capacities** (4 GW) with electrolyze	Construction of **green hydrogen production capacities** (4 GW) with electrolyze	Construction of **green hydrogen production capacities** (6.5 GW) with electrolyze	Construction of **green hydrogen production capacities** (1 GW) with electrolyze in Sines for €3b	Studies for the construction of hydrogen production capacities	Investments in hydrogen production capacities
Infrastructure	**Development of storage and charging infrastructure:** €3.4bn by 2023	**Development underground hydrogen pipelines for** €1.5b-2b	Installation of **100 hydrogen refueling stations**	Installation of **400-1000 hydrogen refueling stations**	Set-up of a **H_2 R&D laboratory** Development of infrastructure along the value chain	**Power-to-gas projects** H2 refueling stations pilots (e.g., to serve 10 H2 bus in Charleroi from 2021)	Installation of **100 hydrogen refueling stations for buses and 300 for cars**
Uses	**Subsidies for clean vehicles purchase Differentiated truck toll** based on emissions	**H_2-powered vehicle targets:** 15k FCEVs and 3000 heavy duty vehicles	**H_2-powered vehicle targets:** 150 buses, 5k light and heavy vehicles, 2 commercial train lines	**H_2-powered vehicle targets:** 20-50k light commercial vehicles and 800-2,000 heavy-duty vehicles	**Decarbonation of heavy transports**	Decarbonation in the transport sector with green hydrogen	Decarbonation in the transport sector

Sources: European Commission; Monitor Deloitte Analysis

FCEV, a credible technological pathway for long-haul trucks

Most alternative technologies to internal combustion engines (ICE) for long haul trucks face technical challenges:

- **Battery electric trucks** have limited autonomy (ca. 200 km) and require long charging times (ca. 8h), often overnight, while EU road freight is primarily long-distance (ca. 40% of total EU road freight - in km or t.km). Furthermore, the heavy battery weight reduces the available truck load (up to 20%, i.e. ~ 7 tons), another major drawback for long haul freighters[11].
- **Catenary or induction systems** require / necessitate large-scale infrastructure across the EU, whose upfront deployment in the short-term is unlikely[12].
- **Compressed and Liquified Natural Gas trucks ("CNG" / "LNG")** are considered as the way forward by certain manufacturers, given their high technological maturity (8 to 9 Technology Readiness Levels).

However, the case for natural gas as a credible green energy source is still questioned:

- **GHG emissions reduction potential remains modest:** Manufacturers have estimated a 10-20% emissions cut compared to diesel vehicles. For example, Iveco claims that LNG-powered vehicles emit 10% less carbon.

  According to Scania, LNG trucks would reduce CO_2 emissions up to 20% vs. diesel vehicles. Volvo states that the new LNG model delivers a 20% CO_2 decrease on a tank-to-wheel basis.[13]
- Recent independent studies[14] demonstrated that **NOx and SOx emissions are higher than diesel**, contrary to truck manufacturers' claims.

Figure 4.

Truck engine technologies

Fuel cell hydrogen is the most appropriate technology for green long-haul road freight, offering high autonomy and fast-charging time

Summary of current key truck engine technologies

		Internal Combustion Engine trucks (ICE)	Battery Electric trucks (BEV)	Fuel Cell Electric Trucks (FCEV)	CNG / LNG trucks	Catenary trucks / Induction charging
Costs (as of 2020)	Capex (k€)	65	175-195	**330**	135-150	n.a.
	Maintenance costs (€/km)	0.15	0.3	**0.3**	0.2	n.a.
Energy	Energy consumption	33 L / 100 km	1.2-1.4 kWh / km	**7,5 kg H2 / 100 km**	30 kg / 100 km	n.a.
	Autonomy (km)	~700-1000	~350	**~400 (Hyundai)-1200 (Nikola)**	~700-1000	Dependent on the catenary length
	Power (kW)	300	200-400	**250-750**	300-400	100-400
	Charging time	10 min	8 hours	**10-20 min**	8 hours	n.a.
Technology	Readiness Level	Level 9	Level 6-7	**Level 6-7**	Level 8-9	n.a.
Product range	Current models	• Daimler • Volvo • Iveco • MAN • Scania	• Daimler E-Fusio Vision One • MAN eTGM	• **Hyundai Xcient** • **Toyota Class 8 Fuel Cell** • **Nikola, Esoro, Kenworth**	• Volvo FH GNL • Scania GNL G340 • Iveco GNL Stralis	• Siemens eHighway truck route system (*Excluded given the large network infrastructure investment required)*

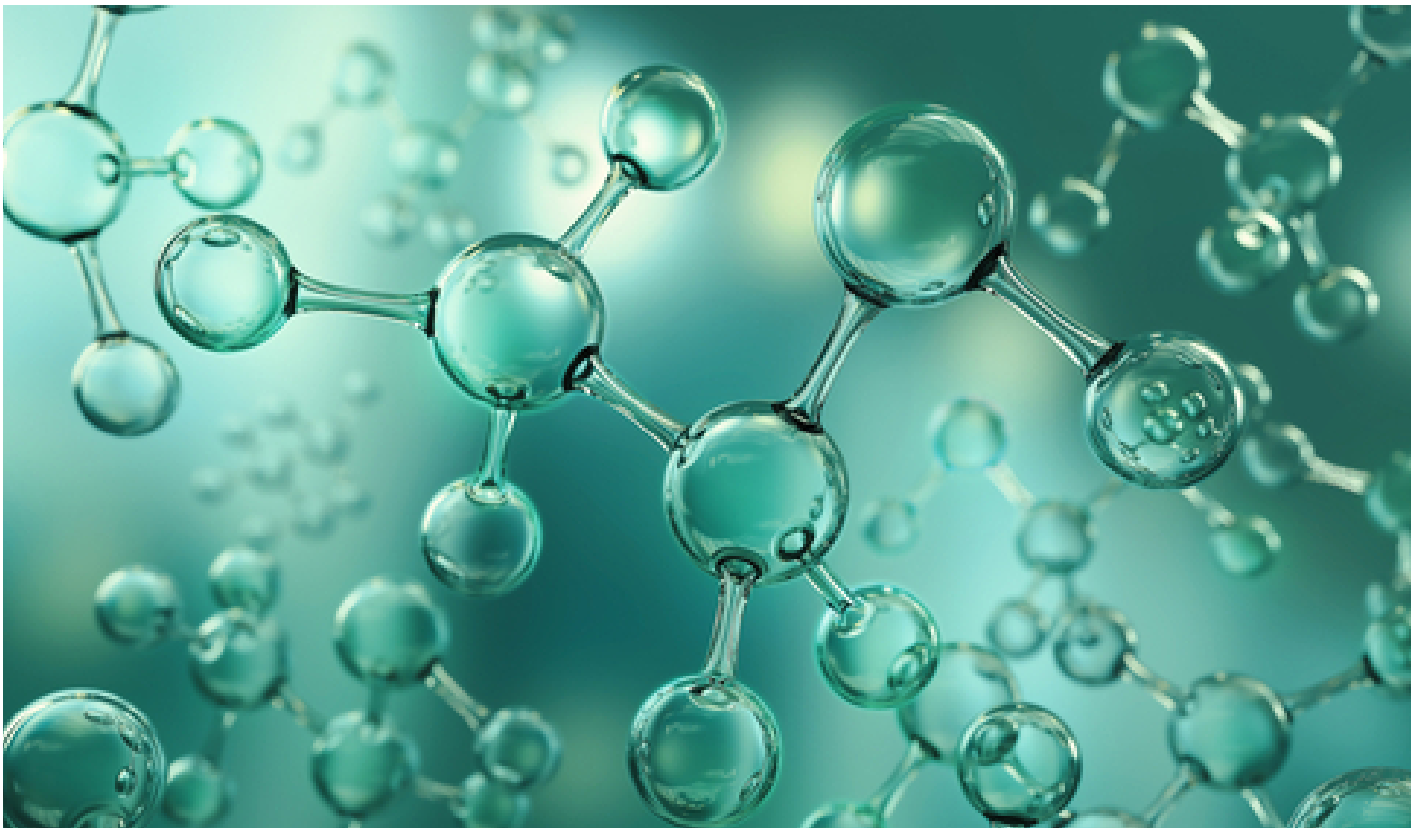
Sources: FCH; Transport & Environment; Monitor Deloitte Analysis

From a technical standpoint, FCEV trucks can cope with long-haul freight constraints, leverage a set of mature technologies, and allow potentially significant GHG emissions reduction:

- **Hydrogen-powered trucks have been brought to the market that fulfill long haul freight needs and meet productivity constraints**, with an autonomy above 400 km and a short refueling time of ca. 15 min. For example, Hyundai shipped the first 10 Xcient Fuel Cell trucks to Switzerland.

The manufacturer plans to deliver 50 vehicles by the end of 2020 and roll-out 1600 Xcient trucks in total by 2025 globally.[15] Hyundai is also developing a 1,000 km-autonomy truck on a single hydrogen fill-up[16]. Furthermore, Nikola and Iveco are working on the "Nikola Tre" truck concept for European markets, with a target range up to 1,200km.[17]

- **Steam Methane Reforming ("SMR") combined with carbon capture and storage technologies ("CCS") can drastically reduce the GHG footprint of hydrogen production, capturing up to 89% of CO_2 produced.**[18 19]
  - In the short-term, this method can be used to capitalize on existing SMR capacities and scale-up hydrogen production. The only major drawback in the mid-term will be the non-renewable nature of SMR-produced hydrogen, though.
  - In the longer term, production process will shift from SMR to "green hydrogen", as electrolysis reaches an industrial scale and becomes cost-effective (estimates below €2 / kg by 2025-2030), supported by European countries' energy mix tilted towards renewables.



A forseeable future

Pan-European freight relies primarily on long haul transport and is concentrated along key routes (Trans-European Transport Network called "TEN-T") **and logistics hubs**. Furthermore, many existing hydrogen production sites are situated in close proximity.

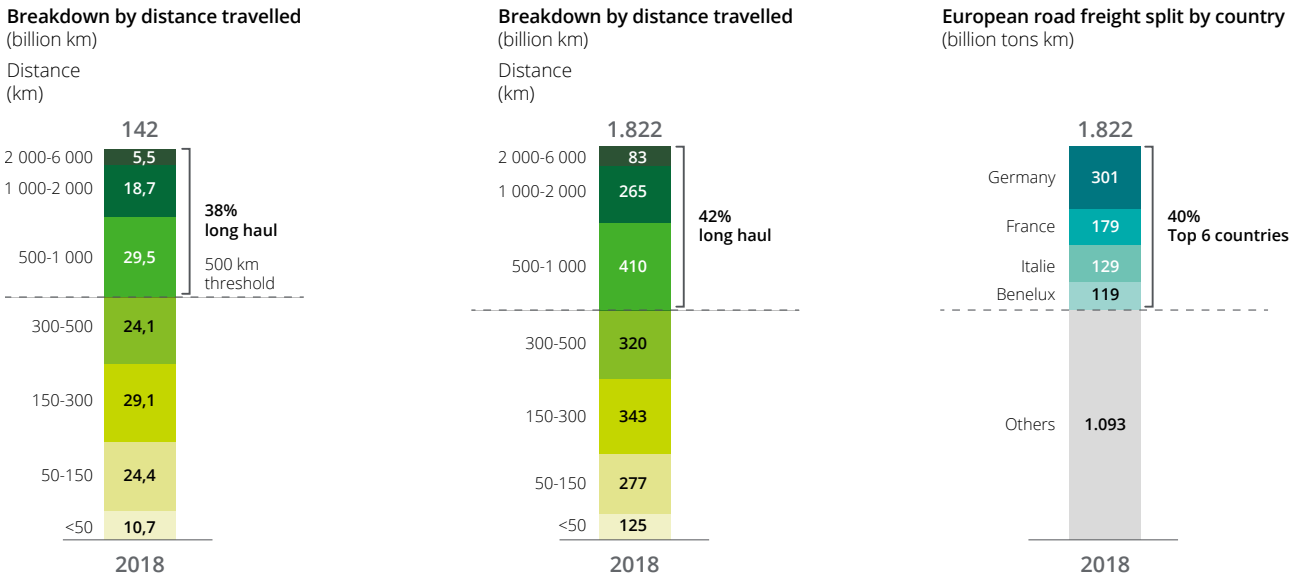
Figure 5[20].

European road freight

A significant part of EU road freight is on long distance (~ 40%)
6 key countries (Fr, Ger, Benelux, It) represent 40% of this traffic

European road freight relies primarily on long haul transport...

...driven by Germany and France



Sources: Eurostat; Monitor Deloitte Analysis

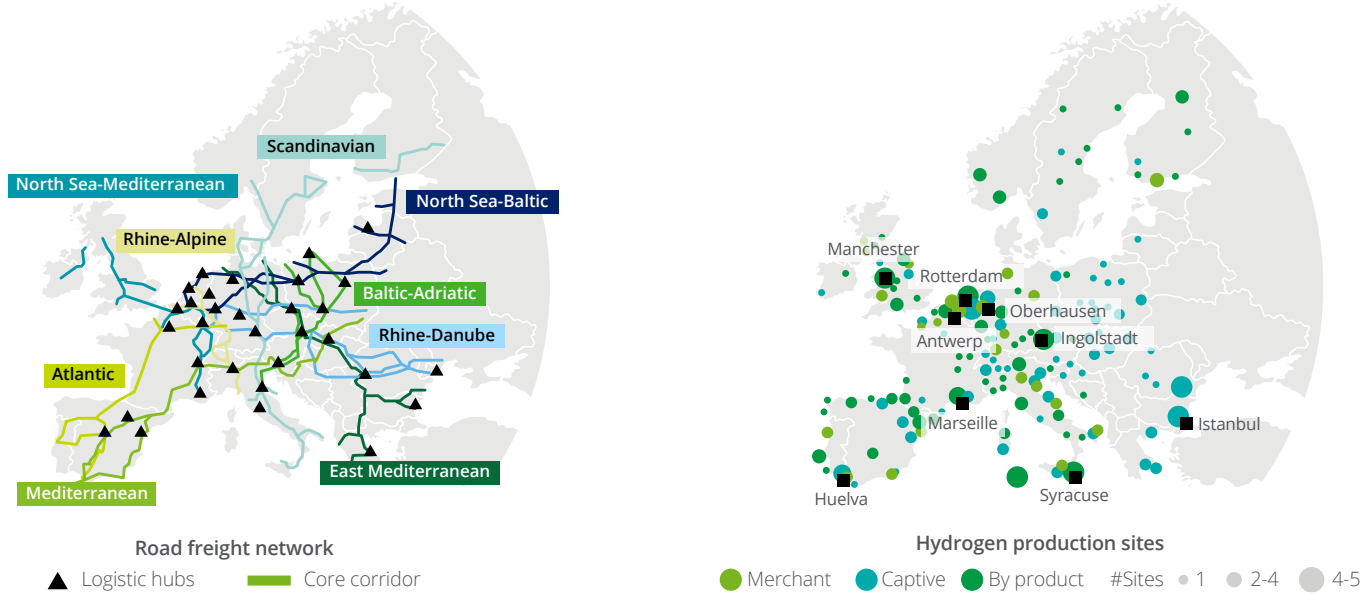
Figure 6[21 22 23].

European road freight and H_2 production facilities

In 6 key countries (Fr, Ger, Benelux, It) major traffic corridors (TEN-T) match with H_2 production locations

European road freight is concentrated on key traffic corridors and hubs...
Trans-European Transport Network (TEN-T) core corridors and logistic hubs

...along which hydrogen production
Hydrogen production sites in Europe



Sources: EU regulation; CertifHy; Monitor Deloitte Analysis

Therefore, the integration of existing assets into an "end-to-end" hydrogen value chain should be assessed for short-term deployment, beyond the sole technical feasibility:

- **Hydrogen production** – especially merchant one – already exists in EU:
  - Industrial-scale SMR hydrogen production sites are already located close to the main European highways (TEN-T) and logistics hubs (particularly in France, Germany, Benelux and Italy, accounting for 40% of European long-distance traffic).
  - These facilities, if not directly supplying hydrogen to trucks because of market conditions and capacity constraints, can be a good foundation for further brownfield development and / or installation of CCS technologies.
  - Although alkaline and PEM electrolysis are mature technologies, required investments to scale-up capacities are currently still high and will only bring results in the long term.
- **Transport and storage technologies**, in either liquid or compressed gaseous (up to 700 bars) forms, are well-known as of today:
  - **Liquid hydrogen trailers** offer a much larger load carrying capacity than **tube or container** trailers with compressed H_2 (ca. 4,3t H_2 batches vs. 700kg of H_2 in a 500-bar trailer), which makes them an attractive transport option. Liquefying hydrogen for transport is more expensive, has lower conversion yields and requires long truck loading and unloading times (up to 3h – 3h30). Therefore, this option should be preferred only when production sites are not in proximity to refueling station[24].
  - **Hydrogen pipeline networks** are still at a nascent stage in Europe, with ca. 1600 km, led by Belgium (615 km), Germany (380 km) and France (300 km)[25]. Ongoing projects to blend H_2 with natural gas networks or to develop a dedicated hydrogen European backbone will foster its distribution scalability but are expected to be a credible Europe-wide option only by the 2030s'.[26]
  - **Tanks** are the most common hydrogen storage methods and should be the preferred option for an agile supply chain, as they are easy to implement with limited volumes, compared to underground geological caverns and reservoirs.
- **Distribution:** As a first step, a few refueling stations could be installed in key logistics hubs – truck refueling only takes 15-20 minutes and can be easily coordinated with loading and unloading operations.

Figure 7.[27 28 29 30 31 32 33 34]

Hydrogen value chain

The "End-to-end" value chain must be activated in the short-term to initiate the transition towards FCEV long-haul heavy-duty vehicles

Hydrogen technologies along the value chain

Production	Conversion	Transportation	Storage and reconversion	Distribution	Hydrogen long haul road transport
Thermochemical conversion (◉) · Steam Methane Reforming (SMR) + CCS ● · Coal Gasification + CCS ● · Concentration of Solar Fuels ● · Chemical looping (metal oxidation and reduction)	**Gas compression** (◉) · Compressed Gaseous H_2 (15°, 350/700 bar) ● · Cryo-compressed H2 (-235°, 300 bar)	**Compressed gas (CH_2)** ● · Pipelines (◉) · Tube trailers ● · Container trailers ● · Trains	**Pressurized tanks** (◉) · Compressed or liquified hydrogen	**H_2 refueling stations** (◉) · Compressed or liquified hydrogen	· Hyundai XCient · Toyota and Hino Class 8 Fuel Cell Electric Truck · Nikola · Kenworth / Toyota T680
Electrolysis ● · Alkaline ● · Proton Exchange Membrane (PEM)	**Liquefaction** (◉) · Liquid Hydrogen (-253°, 1 bar)	**Liquid gas (LH_2)** (◉) · Liquid trailers ● · Vessels	**Geological storage** ● · Underground salt caverns ● · Depleted oil and gas reservoirs ● · Water aquifers		
Microbial reaction ● · Microbial electrolysis ● · Dark fermentation	**Solidification** ● · Slush Hydrogen (-259°, 1 bar)		**Cans** ● · For hydrides		
	Chemical combination ● · Liquified Organic Hydrogen Carrier (LOHC) ● · Ammonia ● · Hydrides (e.g., bonding with metals)				

(◉) H_2 technologies to leverage to initiate hydrogen long haul transport deployment

Technology Readiness Levels : ● 1-2 (Ideation ● 3-4 (Lab / Demo) ● 5-6 (Prototypes) ● ≥7 (Industrialization)

Sources: IEA; CSIRO; Shell hydrogen study; Monitor Deloitte Analysis

A reasonable economic bet

In the mid-term outlook, cost savings driven by scale effects and technology improvements are expected to make FCEV trucks competitive vs. ICE counterparts.

In 2020, the TCO of FCEV trucks is estimated to be twice as high as conventional diesel trucks. This gap can be explained by two key factors:

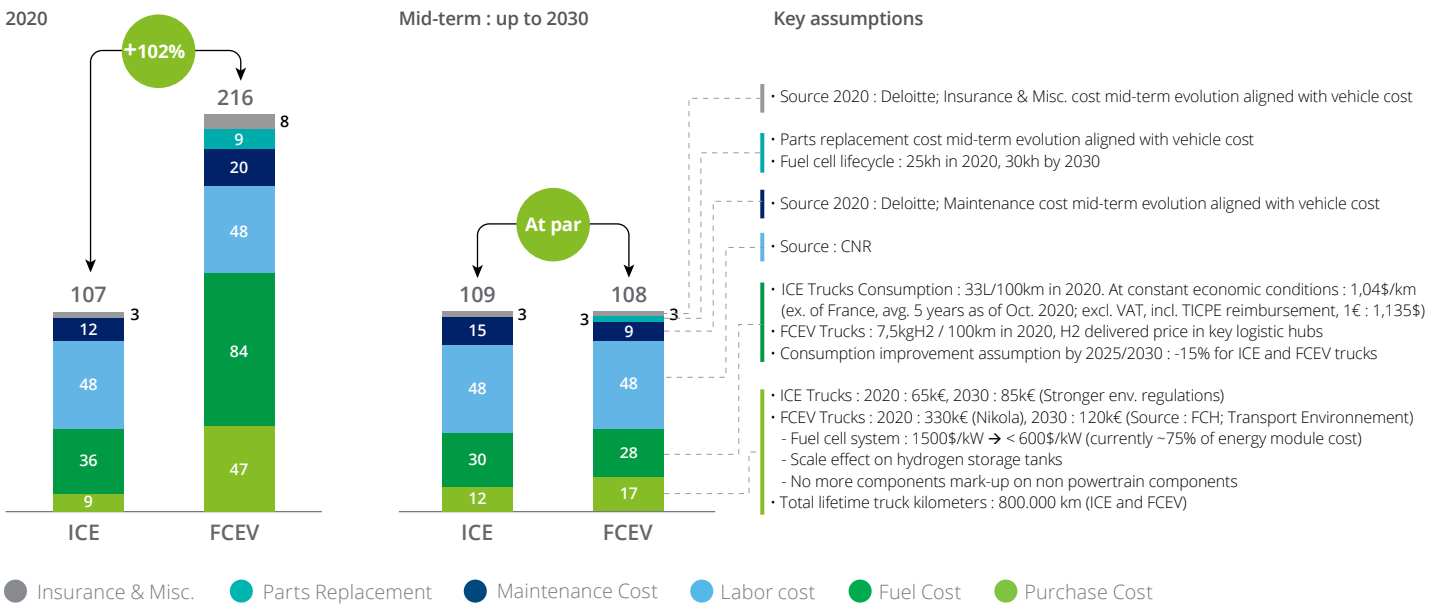
- The CAPEX for a FCEV truck is currently estimated to be four times higher than that of a conventional ICE truck (ca. 300k€[37] vs. 65k€), mainly due to **energy components' small-scale production** (fuel cell, truck H_2 storage tank) and **significant mark-ups on non-energy and powertrain components**. Over 300,000 trucks[38] with a load capacity above 16t are sold in Europe each year, while Hyundai plans to deliver its 50 first FCEV trucks in Switzerland by the end of 2020. The small-scale production of components also impacts part replacement and maintenance costs.
- **Current high fuel costs** (above $10 / kg H_2), driven by high refueling station costs, also hamper FCEV trucks' TCO:
  - **SMR-based hydrogen production** is a well-known and widely deployed process, incurring a standard Levelized Cost of Hydrogen ("LCOH") of ca. $1.7 / kg of H_2, with **limited cost improvement potential**.
  - **Hydrogen transport costs** are expensive due to the **limited dedicated pipeline networks** and the need for **trailers** (tube, container or liquid) to ship low-density hydrogen.
  - **Distribution costs** account for the largest share of delivered costs (> $6 / kg H_2), driven by the expected small scale and low utilization of hydrogen refueling stations in the short-term.

Figure 8.[35 36]

FCEV VS. ICE long haul truck face-offs : TCO

FCEV trucks TCO expected to drop significantly and establish itself at par with ICE trucks by 2030

FCEV vs. ICE trucks TCO ($/100 km), at constant economic conditions*



* 5 years average economic conditions as of Oct. 2020 (Diesel Price and € / $ exchange rate) Excl. Tolls & Taxe

Sources: IEA, CNR, FCH, Nikola, Transport & Environnement, ADEME, Volvo Trucks, Deloitte China / Ballard, Monitor Deloitte Analysis

By 2030, the TCO of FCEV long haul trucks will fall, in terms of both CAPEX and OPEX, to become at par with ICE trucks' TCO (around $1.1+ / 100 km).

- **On the one hand, CAPEX decrease will be driven by FCEV truck construction technology scale-up and standardization, lowering purchasing costs down to €120k in 2030:**
  - **A continuous decline of fuel cells systems costs** is expected by 2030, from $1,500 / kW in 2020, down to $600 / kW in 2030. The fuel cell costs are primarily driven by high manufacturing costs, due to technological expertise requirements. This leaves significant room for future cost improvement and economies of scale. Some material costs are also expected to decline, with a reduced platinum demand from a current 0.4 – 0.5g / kW ratio to below 0.2g / kW in 2030.
  - Similarly, **carbon fiber hydrogen storage tanks'** costs are expected to decline.
  - The mark-up on propulsion agnostic components, due to lower economies of scale of FCEV production compared to ICE vehicles, is also expected to fall by 2030, as the production of FCEV trucks gains from enhanced scale and standardization.
- **On the other hand, OPEX drop will be driven by hydrogen-delivered cost reductions and result in a 60% cost saving "at the pump" to less than $5 / kg of H_2 by 2030:**
  - Although limited production cost improvements are expected, **"blue hydrogen" costs** (i.e., produced with the SMR process and carbon capture facilities) should decline and close the gap with "brown" sources.
  - The **expansion of pipeline networks**, either leveraging dedicated hydrogen networks or blending hydrogen into natural gas, will bring significant economies of scale vs. trailers and avoid expensive liquefaction.
  - **Scaled-up demand will trigger an increase in refueling stations' size and utilization rate**, driving hydrogen delivered cost reductions (up to 70% decrease). Further industrialization in manufacturing of station equipment could also bring incremental cost savings, although more significantly so for passenger cars than for long haul trucks.
  - **Maintenance and parts replacement costs will decrease** in line with the increase of fuel cell system lifecycle, reaching 30,000 hours by 2026 vs. 25,000 hours currently.

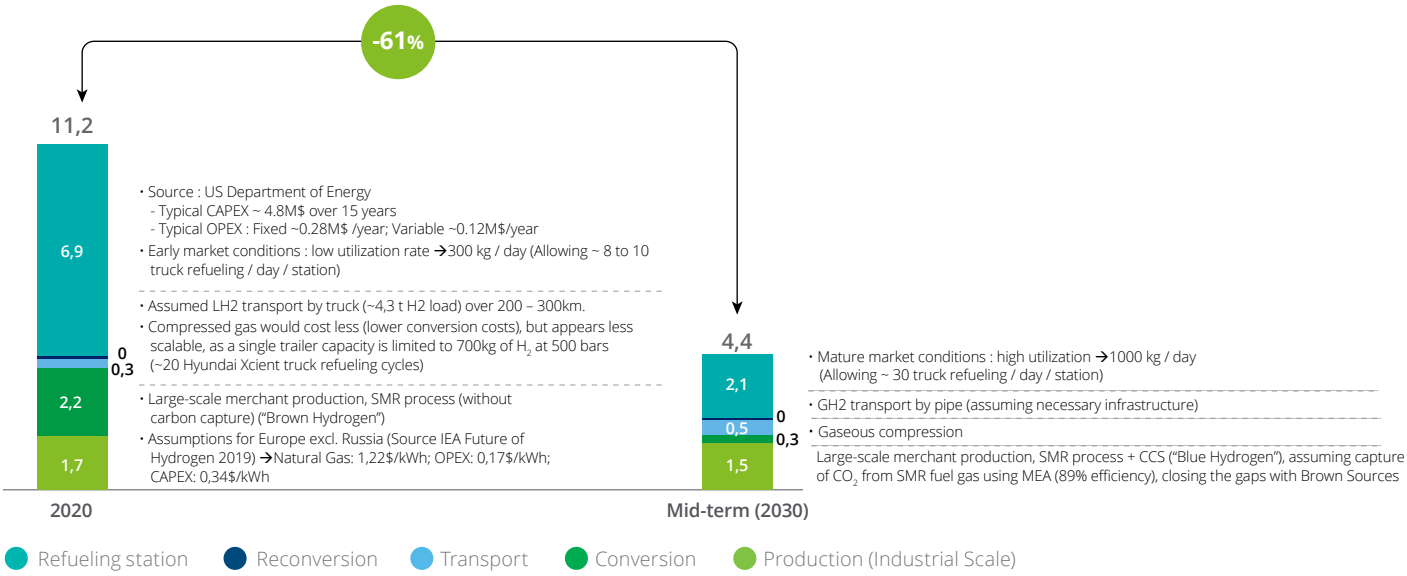
In this document, our assessment is mainly technical. Indeed, the impact of potential public subsidies or taxes (e.g., CO_2 tax establishment in road transport, ban or specific tolls for ICE trucks, ...), as well as the variation in economic conditions (e.g., cost of hydrocarbons and diesel fuel[44 45 46]), on either FCEV or diesel vehicles, have not been quantified.

Figure 9.[39 40 41 42 43]

FCEV VS. ICE long haul truck face-offs : H_2 delivered cost

Increase in stations utilization rates and deployment of pipe transport infrastructure will strongly decrease H2 delivered costs

Hydrogen delivered costs up to trucks' tank; 2020 – 2030 ($/kg)*



*Assuming no cost of CO_2

Sources: IEA; US Department of Energy; Monitor Deloitte Analysis

A sizeable impact on GHG emissions

FCEV long haul trucks will significantly contribute to the CO_2 emissions reduction effort, while not providing a significant edge on the NOx front.

CO_2 emissions

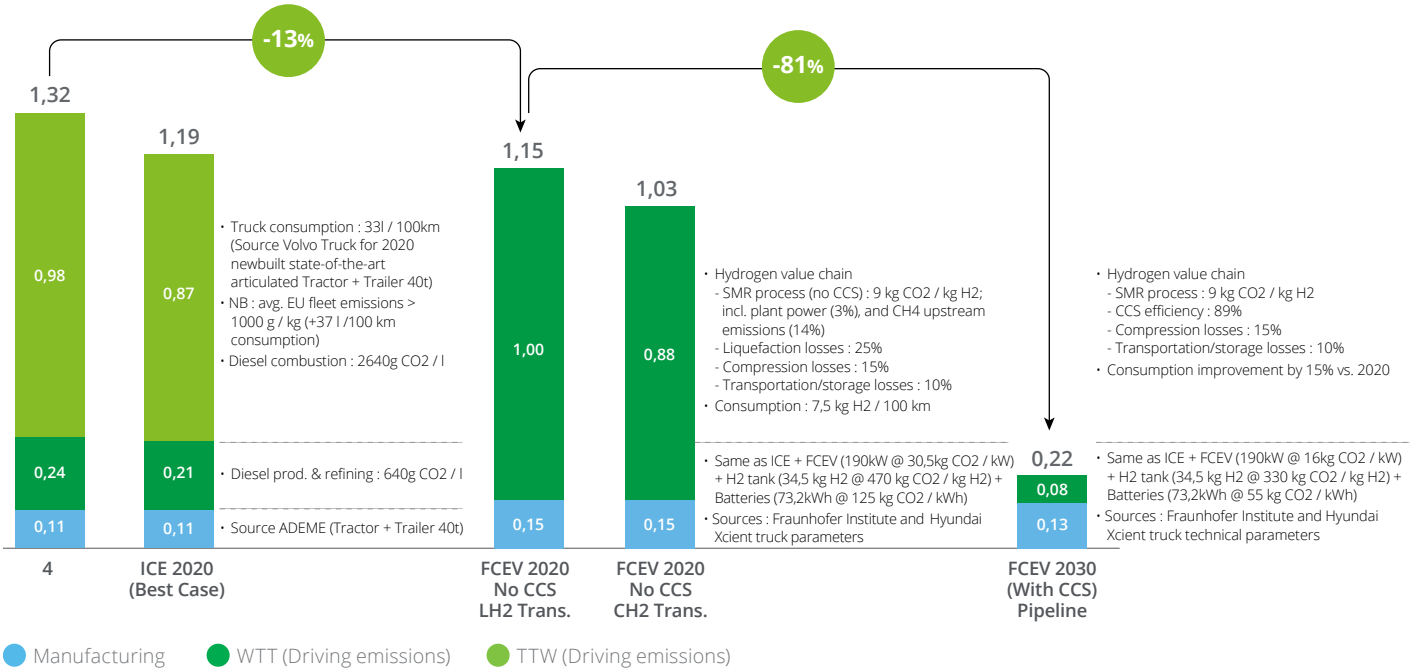
- **In the short term, and before combining SMR and CCS for production, the replacement of ICE vehicles by FCEV trucks fueled by "brown" hydrogen can cut CO_2 emissions by approx. 10% to 15%:**
  - On the one hand, production-related emissions for FCEV trucks are slightly higher than for ICE trucks (150g / km for FCEV vs. 110g / km for a diesel articulated tractor with trailer system), due to **additional carbon intensive components** (i.e., fuel cell, carbon fiber hydrogen storage tanks and batteries)
  - On the other hand, **real driving CO_2 emissions** are lower, up to 20% depending on hydrogen distribution technology. The liquid hydrogen ("LH_2") supply chain is hampered by lower conversion yields (max. 70-75%) in comparison with yields (up to 85-90%) of compressed gaseous hydrogen ("CH_2").[51]
- **By 2030, CO_2 emissions of FCEV long haul freight transport are expected to significantly reduce (up to 80% vs. current "brown" hydrogen), driven by several factors:**
  - **The emergence of carbon capture and storage capacities (CCS) combined with SMR**, is the most significant factor, as the CO_2 capture rate is estimated at 85-90%, with – in the long term – only modest "blue" hydrogen production costs increase vs. current "brown" processes.
  - The **reduction of energy consumption in FCEV trucks** is expected to reach **15%**. Diesel trucks should experience a similar trend, as best-in-class lorries' diesel consumption is expected to drop from 33 L / km, currently, to 28 L / km, under the same operating conditions.[52]
  - **Technology improvements in FCEV trucks manufacturing** for all key components, such as batteries, platinum (e.g., mining footprint, platinum recycling, etc.) and carbon fiber used in storage tanks, could bring additional emissions cuts.
  - In the longer term, the **development of H_2 pipeline networks** (either a dedicated H_2 backbone at EU scale, or by blending H_2 within natural gas networks) will reduce the need for LH_2 road distribution and related poor conversion yields.

Figure 10.[47 48 49 50]

FCEV VS. ICE long haul truck face-offs : CO_2 emissions over lifecycle

Leveraging CCS technology could help reduce FCEV vehicles emissions by > 80% over lifecycle vs. ICE

CO_2 emissions by technology over truck lifecycle; 2020 – 2030 (kg CO_2/km)* - Assuming hydrocarbon sourced H_2 only



*Assuming no cost of CO_2

Sources: IEA; US Department of Energy; Fraunhofer Institute, Hyundai, Volvo Trucks, Linde Kryotechnik, Monitor Deloitte Analysis

NOx emissions

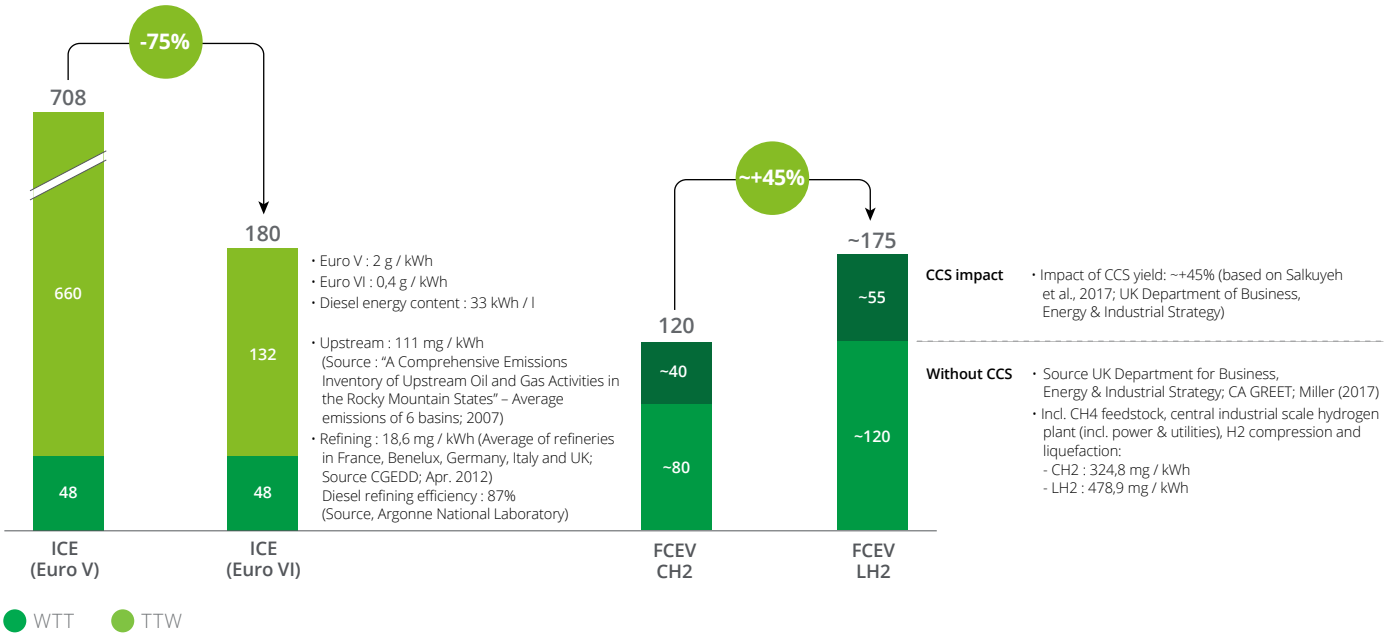
Even if there are no specific EU reduction targets for NOx, these emissions are closely monitored by truck manufacturers towards a green fleet transition. European Euro VI norms, endorsed in 2015, have set a maximum threshold for diesel NOx emissions at 180g / 100km. FCEV trucks, regardless of the hydrogen form used, are approximately at par with these emission levels.

Figure 11.[53 54]

FCEV VS. ICE long haul truck face-offs : NOx emissions over lifecycle

NOx emissions of FCEV vehicles (LH_2 SMR + CCS) at par with Euro VI trucksCCS has a negative impact (~ + 45-50%) on NOx emissions

NOx emissions by technology over truck lifecycle; (g NOx/ 100 km)* - Assuming hydrocarbon sourced H_2 only



Sources: CGEDD, UK Department of Business, Energy & Industrial Strategy, Miller, Argonne National Lab, Monitor Deloitte Analysis

There is no such thing as a free lunch

By 2030, a 10% "blue" hydrogen FCEV penetration rate for long haul freight transport in 6 key EU countries (France, Germany, Benelux, Italy), well-covered by both TEN-T corridors and industrial scale hydrogen production facilities, **is technically achievable, although challenging:**

- By 2030, assuming a +1.6% p.a. traffic growth[55], **20 000 FCEV trucks** would be required to match with this ambition. This pre-requisite should be evaluated in the context of the following:
  - **Yearly heavy-duty trucks market in EU:** Each year, 300 000+ heavy duty trucks are sold in Europe. This would result in a ~7% average yearly market share for FCEV trucks over the period.
  - **Country-by-country FCEV trucks penetration objectives:** France announced an up to 2 000 heavy duty vehicles target, while Netherlands aims to have up to 3 000 heavy duty trucks on its roads in 2030.
  - **Truck manufacturers ramp-up production capabilities:** Hyundai aims at deploying 1600 Xcient trucks by 2025 (starting from 50 in 2020). Most of major heavy-duty truck manufactures such as Toyota, IVECO / Nikola, MAN / Esoro, Scania / Renova and Asko also have projects, yet only under prototype development stage.[56]
- **The distribution infrastructure** will also have to be developed Europe-wide:
  - If well-positioned on key logistic hubs and TEN-T corridors, approx. **600+ dedicated refueling stations will be necessary.**

This can be compared to existing service stations networks: ESSO, Shell and Avia operate together ~ 800 stations[57] on motorways in Europe, AS24, a fueling stations network dedicated to trucks operates ~ 1000 stations in Europe[58]. France is the country with the most motorways stations (operated by all brands), i.e., approx. 440 stations.[59]

  - **Assuming LH_2 distribution by trucks** (as pipe networks would not reach adequate scale and maturity by 2030), a fleet of **140 trucks + trailers** will be necessary to feed refueling stations.
- The 20 000 FCEV trucks would use **190kt of H_2**, which would make necessary to produce up to **280kt out of plants because of liquefaction and distribution yields** (3% of 9.8Mt EU-28 yearly H_2 production). Assuming there will be not much spare H_2 production capacity, this would require the equivalent of an additional **~ 10 production facilities**, average industrial scale production facilities currently ranging usually between 50 and 200 tons / day. However, this should be assumed a conservative assumption, as some spare capacity could be leveraged to initiate the transition towards hydrogen-powered mobility.

By 2030, a 10% blue hydrogen FCEV penetration rate for long-haul trucks, would result in 20 000 FCEV fuel trucks, 600+ refueling stations, 140 trailers for logistics and 280kt production capacity.

However, there is no such thing as a free lunch: ca. €5b to €6b investments will be required to deploy the hydrogen infrastructure necessary for long-haul traffic and strive towards GHG reduction ambitions.

- Approximately half of the CAPEX (€2.7b) will be dedicated to deploying the network of refueling stations, as well as the necessary LH_2 transportation trucks.
- The other half will be dedicated to production facilities, with a very significant part of it for liquefaction plants and loading terminals (€1.6b over €2.9b industrial CAPEX). This is assumed to be an upper boundary, as either compression technology and / or pipelines could be leveraged in relevant areas.
- Such figures represent ~20 – 25% of total investments announced by the 6 priority countries (Fr, Ger, It, Benelux). Therefore, private investments from gas industry and energy incumbent competitors should be leveraged to fully grasp the available funds for deployment.

As a matter of comparison, €600M p.a. of CAPEX would represent ~10% of combined yearly CAPEX of Air Liquide and Linde, the leading merchant H_2 producers in EU (In 2019: €3.2b. resp. $2.6b)[60 61]. Other mobility players, such as vehicle manufacturers, highway operators, oil & gas players and power & gas utilities are also expected to engage into bold moves.

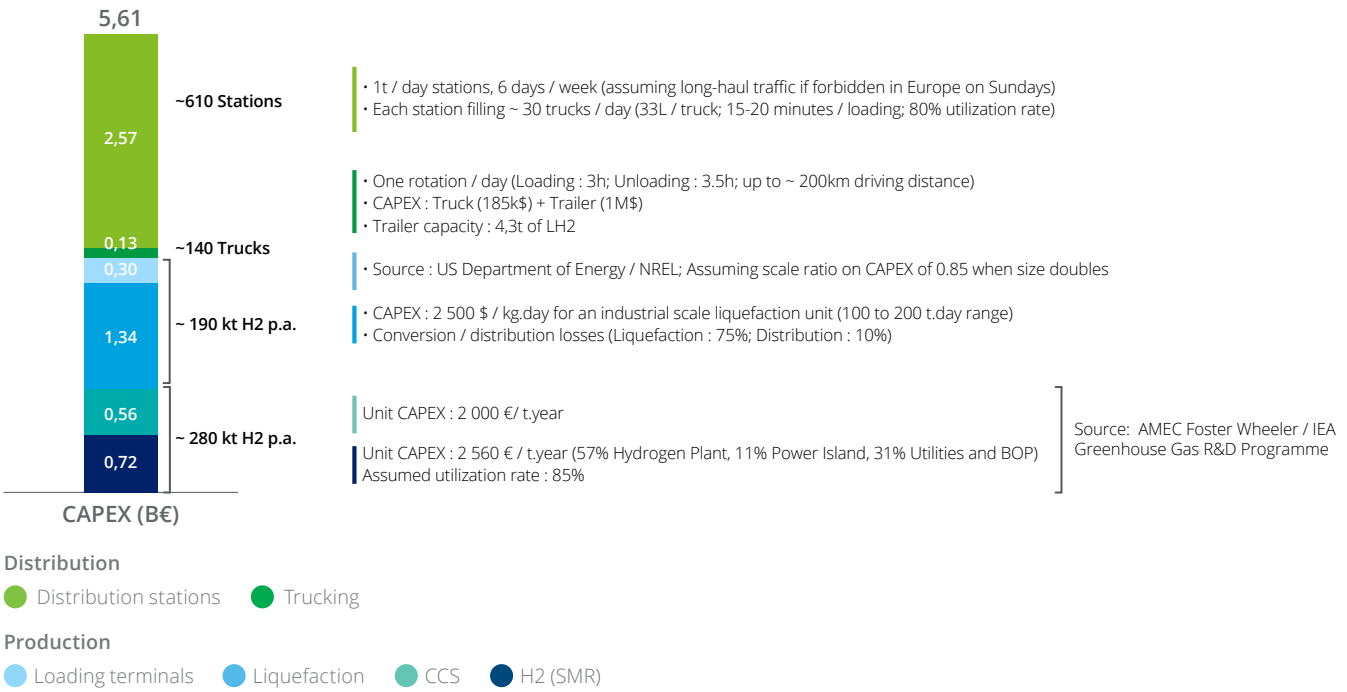
In terms of CO_2 emissions, 10% "blue" hydrogen FCEV penetration rate for long haul freight transport in 6 key EU countries would allow to switch 2.5b km distance covered by ICE trucks to FCEV vehicles. This would result in **2.5M tons of avoided CO_2 p.a.**, i.e., approximately 4 - 5% of the total heavy-duty vehicles GHG emissions target. Assuming CAPEX depreciation over 15 years, and operating costs at par with ICE vehicles, this would imply a rather high CO_2 **avoidance expense of ~ 150 € / ton**.

However, there is no such thing as a free lunch: ca. €5b to €6b investments will be required to deploy the hydrogen infrastructure necessary for long-haul traffic and strive towards GHG.

Figure 12.[62]
Necessary investments by 2023

A total of ~ 5B€ CAPEX will be necessary to deploy the H_2 infrastructure necessary to fuel 10% of long-haul traffic in Top 6 EU areas*

Infrastructure CAPEX necessary to shift 10% of long-haul traffic ; (B€ over 2020 - 2030) – Assuming a SMR + CCS + LH_2 value chain



*Germany, Benelux, France, Italy
Sources: AMEC Foster Wheeler; IEA Greenhouse Gas R&D Programme; US Department of Energy / NREL; University of California (Institute of Transportation Studies); Monitor Deloitte Analysis

The way ahead

In this document, we have demonstrated how FCEV can address the GHG emissions reduction challenge for long-haul trucks in Europe by 2030.

Nevertheless, several major uncertainties persist:

- Despite being a credible technological solution – allowing production of H_2 at competitive costs with drastically reduced GHG emissions thanks to CCS – "blue" hydrogen is still a non-renewable energy resource, as it relies on CH4 feedstock.
- Therefore, only the deployment of "green" processes (e.g electrolysis) will provide fuel to trucks with a sustainable path, in the future. This option is however subject to many questions:
  - What is the likelihood of deploying electrolysis at large scale with competitive costs in the near future?
  - Which operating models will be most suitable (industrial scale vs. distributed electrolysis)?
  - How to integrate electrolysis with countries' electrical mix strategies to leverage low-cost renewable power?
- Value chain activation strategies will require both public and private stakeholders to coordinate in order to fund and operate end-to-end value chains, emphasizing the need for building winning business models.

Value chain activation strategies will require both public and private stakeholders to coordinate in order to fund and operate end-to-end value chains, emphasizing the need for building winning business models.

Glossary

CCS: Carbon Capture and Storage

CH_2: Compressed Hydrogen

CNG: Compressed Natural Gas

FCEV: Fuel Cell Electric Vehicle

GHG: Green House Gas

ICE: Internal Combustion Engine

LCOH: Levelized Cost of Hydrogen

LH_2: Liquid Hydrogen

LNG: Liquid Natural Gas

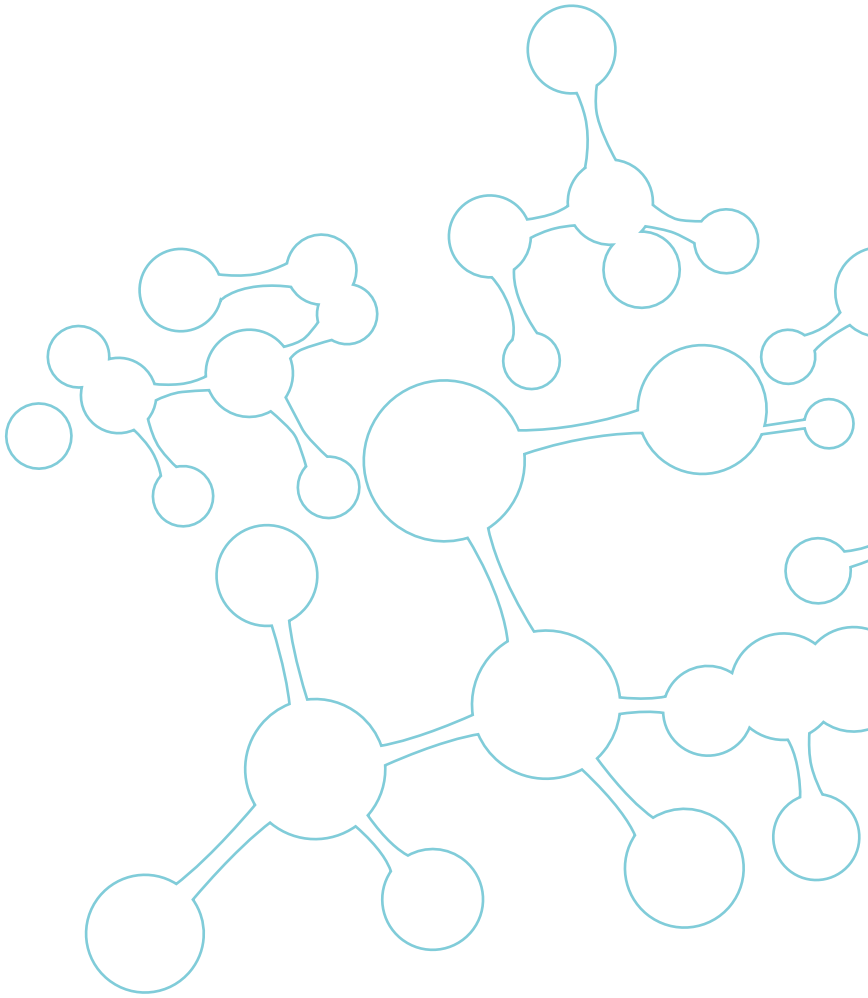
PEM: Proton Exchange Membrane

SMR: Steam Methane Reforming

TCO: Total Cost of Ownership

TTW: Tank to Wheel

WTT: Well to Tank



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