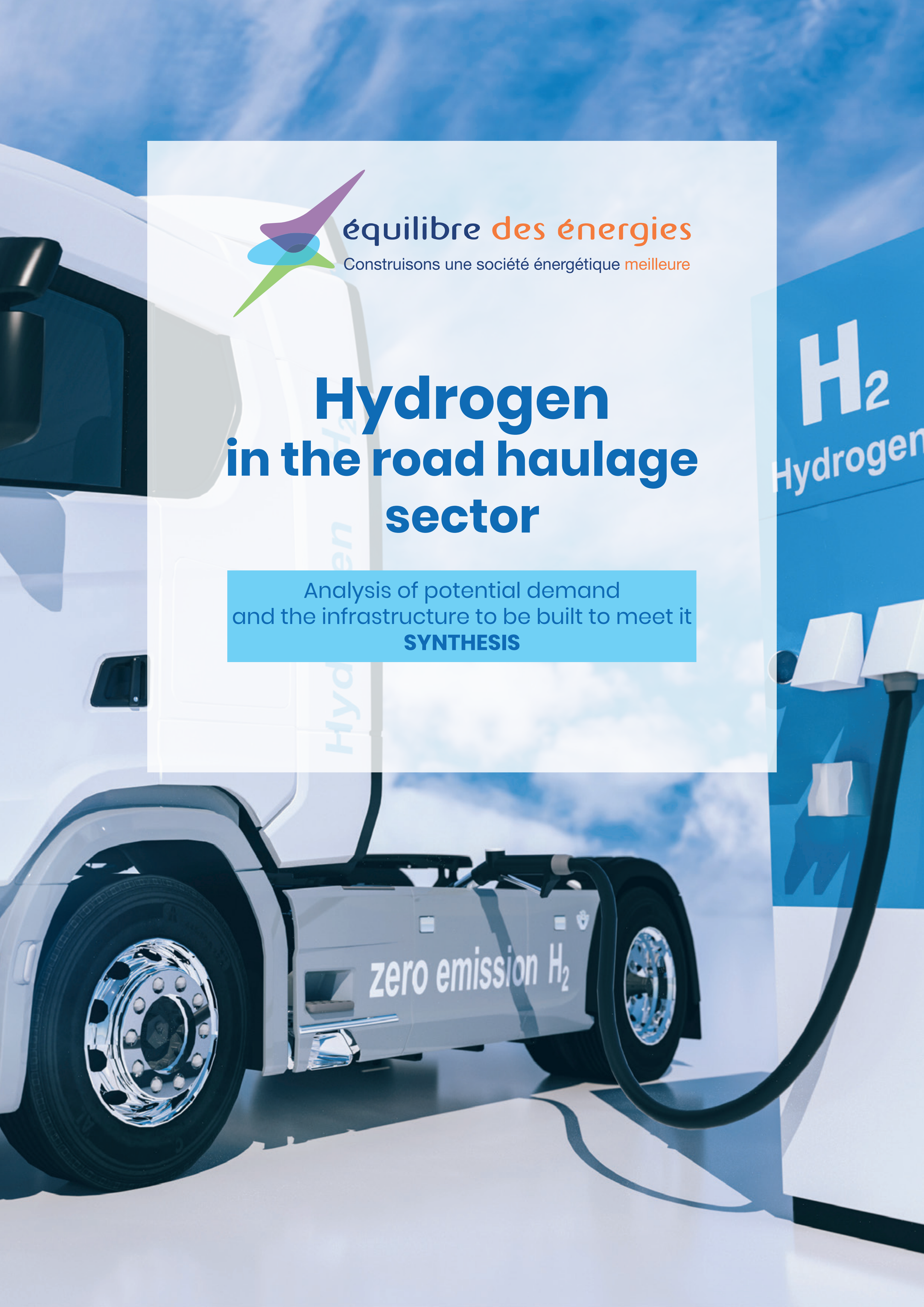

équilibre des énergies
Construisons une société énergétique meilleure

Hydrogen in the road haulage sector

Analysis of potential demand
and the infrastructure to be built to meet it
SYNTHESIS

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Analysis of potential demand and the infrastructure to be built to meet it

This report summarises a study by the association Equilibre des Energies
on the outlook and conditions to develop hydrogen mobility in the road haulage sector.

For any information about this study,
use the "Contact" form on the association's site or contact
Equilibre des Energies:
10 rue Jean Goujon 75008 Paris (France)
Tel: +33 153201370, info@equilibredesenergies.org

www.equilibredesenergies.org

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The authors

Jean-Pierre Hauet
Chief Scientist at Equilibre des Energies

Servan Lacire
Member of the Scientific Committee
of Equilibre des Energies
Head of R&D and Innovation for
Bouygues Energies & Services

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However, the conclusions of the study are the sole responsibility of the authors.

Summary

Introduction

In Europe, Germany, France and many other countries, hydrogen is now considered to be a likely contributor to the decarbonisation of the economy, alongside the direct use of electricity. A great deal of public funding is being used to develop hydrogen production from electrolytic sources and to promote a European and French hydrogen industry.

By 2030, France aims to invest **€7 billion in the sector**, including €2 billion in public support under the recovery plan. These €7 billion will be invested according to three priorities:
- decarbonisation of industry;
- the development of hydrogen-powered heavy transport;
- supporting outstanding research and developing training opportunities.

In particular, the French government has set a target of 6.5 GW of decarbonised hydrogen production capacity by 2030.

6.5 GW
electrolysers
by 2030

The industrial market for hydrogen is well established: it is largely a market to replace hydrogen of fossil origin – currently produced by reforming hydrocarbons, and therefore a major emitter of CO_2 - with hydrogen produced by electrolysis. As well as this replacement market, new markets could emerge, in particular steel production, using a process in which hydrogen acts as a reductant, and the generation of high temperature heat. Yet more than half of the 800,000 t of hydrogen currently consumed in industry is a by-product, without the hydrogen being the primary purpose of the production process. This is the case of the petroleum product refining industry, which is set to decline with the gradual phasing out of oil use.

In quantitative terms, a recent study by RTE[1] features a “reference” scenario suggesting **the potential industrial market**, excluding co-production of hydrogen, stands at 13 TWh H_2 in 2030 (i.e. 390,000 t) and at 18 TWh H_2 in 2050 (i.e. 545,000 t). In a Hydrogen + scenario, these forecasts would increase to 16 TWh H_2 (485,000 t) in 2030 and 40 TWh H_2 (1.21 Mt) in 2050. The forecast ranges are therefore very wide, and widen further as the timeframe lengthens.

For the second major market that hydrogen is expected to take over, i.e. heavy transport, forecasting is even more difficult. There is general agreement that hydrogen trucks, or rather fuel cell electric trucks, may be a suitable solution for long-haul heavy goods vehicles. Indeed, most alternative technologies to fossil fuels face technical challenges (range, charging time, weight, overhead line infrastructure) or inadequate environmental performance. Hydrogen trucks may be suitable for long-distance freight and offer significant reductions in CO_2 emissions.

However, there is currently no hydrogen market in road transport. Although there are a few experiments, notably in Switzerland with Hyundai trucks, there is still a great deal of uncertainty about where hydrogen fits within the goods transport field. The production, transport and distribution technologies adapted to road transport are not yet mature; the supply of vehicles is limited and their design is yet to be optimised.

The study carried out by Equilibre des Energies assesses the potential hydrogen needs of heavy road transport in two development scenarios and details the infrastructure ecosystem that would be required by 2030 and 2050 to meet these needs.

1. RTE is the French transmission system operator - Guidance document n°2 of the Prospective Commission WG n°4: Hydrogen development trajectories and coupling between electricity and heat networks.

The decarbonisation of heavy goods vehicles

Ending the sale of new heavy vehicles for the transport of people or goods that use mostly fossil fuels by 2040

Firstly, it examines the various possible solutions for decarbonising the heavy transport sector.

It is assumed that diesel trucks will be phased out well before 2050, either by regulation or by heavy taxation of CO_2 emissions. This is also the purpose of the August 2021 French law on combating climate change[2]. Article 103 sets the target of "*ending the sale of new heavy vehicles for the transport of people or goods that use mostly fossil fuels by 2040*".

Moreover, while the European climate law[3] has now established the goal of carbon neutrality by 2050, the *Fit for 55 package*, proposed by the Commission in July 2021, proposes to ban the sale of GHG-emitting thermal passenger cars from 2035. Specific measures for heavy goods vehicles should be announced in 2022.

As with the SNBC[4] forecasts, it is assumed that a shift to rail will take place, but rail currently accounts for only 8.9% of domestic inland freight transport in France, compared with 89.1% for road transport[5]. This all suggests that whatever the extent of the shift, road traffic is likely to remain dominant. The Equilibre des Energies study was based on the assumptions made in the AMS scenario[6] of the SNBC, by which traffic grows, in tonne-kilometres, by 5% by 2030 and 10% by 2050.

To decarbonise this road traffic, three sets of solutions are currently possible:

- **the use of gas; initially fossil and then gradually replaced by renewable gas**;
- **battery electrification:** "full battery" solutions or battery electrification with continuous recharging infrastructure;
- **the hydrogen sector**.

2. *Law n° 2021-1104 of 22 August 2021 on combating climate change and increasing resilience to its effects* https://www.legifrance.gouv.fr/dossierlegislatif/JORFDOLE000043113774/
3. *The European Climate Act, otherwise known as the Regulation of the European Parliament and of the Council establishing the framework for achieving climate neutrality and amending Regulation (EU) 2018/1999, OJEU 9 July 2021,* https://eur-lex.europa.eu/legal-content/FR/TXT/?uri=uriserv*:OJ.L_.2021.243.01.0001.01.FRA*
4. *SNBC: Stratégie Nationale Bas Carbone: French National Low Carbon Strategy.*
5. *Key transport figures - 2020 edition - Commissariat général au développement durable.*
6. *The "with additional measures" scenario, known as "AMS", aims to meet France's short, medium and long-term energy and climate objectives as closely as possible. It outlines a possible trajectory for reducing greenhouse gas emissions to carbon neutrality by 2050, which is the overarching objective of the scenario.* https://www.ecologie.gouv.fr/sites/default/files/Synth%C3%A8se%20sc%C3%A9nario%20de%20r%C3%A9f%C3%A9rence%20SNBC-PPE.pdf

The gas sector is mature

Many trucks run on NGV but natural gas only reduces CO_2 emissions by 10-15%[7]. Renewable gas (bioNGV) could replace it, but it costs a lot to produce, resources are limited and the uses of biogas in road transport will compete with those of industry, peak electricity production and even domestic heating for consumers that continue to use gas. In addition, agricultural biomass, especially from intermediate crops, may have to be used primarily to produce sustainable aviation fuels (SAF) rather than biogas. Gas will therefore play a role in the decarbonisation of transport, but is unlikely to predominate[8].

The electric truck sector is developing

It leverages the very significant advances in Li-ion batteries for light vehicles and battery-electric trucks are already available. All have relatively similar characteristics:

- a laden weight of 16 to 26 tonnes;
- one or two engines with a total power of between 100 and 250 kW;
- one or more battery packs with a total capacity of between 100 and 200 kWh;
- a range of 80 to 250 km;
- recharging times of around 1 to 2 hours at European standard Combo CCS 2 charging stations.

These battery-electric vehicles are well suited to local and regional transport returning to base at the end of the day. They will become increasingly competitive as the price of batteries is expected to fall. It was assumed in the study that the cost of battery packs for trucks could catch up with the cost of batteries for passenger cars (not currently the case) and would fall from €205/kWh in 2020 to €82/kWh by 2030 and €50 /kWh by 2050[9].

However, extrapolating battery solutions to larger tonnages (44 t) and very long journeys (with one or two drivers) is being debated. There are various issues.

The tonnage of batteries to be installed in electric trucks to ensure a range of several hundred kilometres and the associated recharging time may compromise the profitability of the operation. Nevertheless, the weight of the parts removed from the combustion vehicle will partially compensate for the weight of the batteries and the recharging time could match the mandatory 45-minute break after 4.5 hours of driving, especially if chargers of 600 kW and more are developed.

7. *AFGNV (Association française du GNV): NGV key figures.*
8. *Carbone 4 (Transport routier, quelles motorisations alternatives pour le climat? November 2020) estimates that even applying an optimistic assumption, biomethane will only be able to meet 24% of heavy transport demand by 2050.*
9. *The heavy vehicle battery market benefits directly from the volume of the battery market for individual EVs.*

The trickiest issue is to deploy charging stations that can recharge about 75% of the battery in 45 minutes at a competitive price, without shortening its life expectancy. It is also important to consider the power that recharging stations, whether or not they are equipped with buffer batteries, could draw from the grid if they are used by a large number of HGVs. The hydrogen solution, by offering storage capacities in the filling stations, can smooth out the load over the 24-hour day and the electrolysers can be switched off in case of stress on the grid.

Lastly, the launch of long-distance electric trucks, announced several times by Tesla, has been repeatedly delayed.

Some manufacturers have devised electric solutions that combine batteries with continuous recharging along specific tracks using suitable infrastructure, such as catenaries or rail. These solutions are being tested. Technically, these solutions are viable, but they are difficult to scale up gradually and in sync with the development of the vehicle fleet, and they can only be useful if the infrastructure is installed over sufficiently long distances. This difficulty in managing the transitional phase suggests that expansion will be challenging, but it should not be ruled out.

The trickiest issue is to deploy charging stations that can recharge about 75% of the battery in 45 minutes at a competitive price, without shortening its life expectancy

Hydrogen can solve the range problem

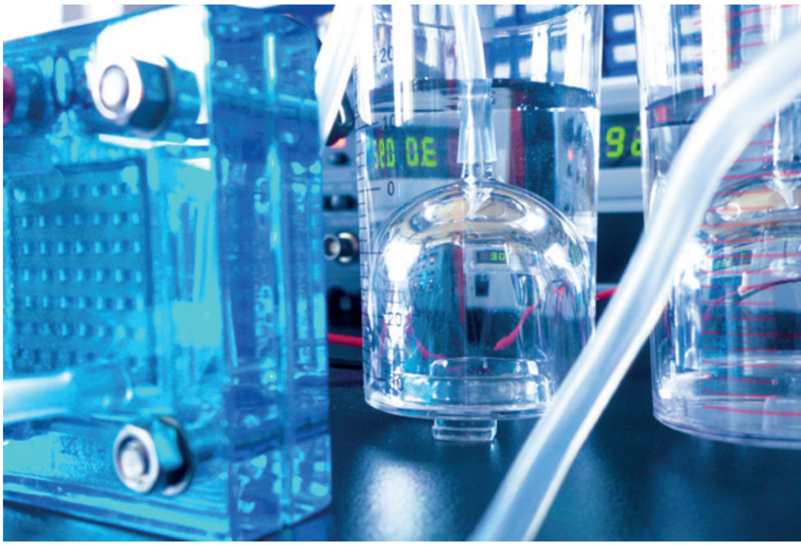
Hydrogen is a low-carbon energy carrier that can be stored and emits only water vapour when oxidised in a fuel cell. However, its use as an energy carrier for heavy transport is far less advanced than that of the battery sector. It is estimated that it will take at least ten years for the progress expected throughout the hydrogen chain to materialise[10].

It is assumed that the prices of high-capacity electrolysers (with the hydrogen purity required by fuel cells) will fall from €1000/kW in 2020 to €750 in 2030 and €375/kW in 2050. The price of fuel cells could fall from €205/kW in 2020 to €123/kW in 2050 and €82/kW in 2050.

Efficiency should improve from 50% in 2020 to 55% in 2030 and 60% in 2050 for both electrolysis and fuel cells. Hydrogen storage at 700 bars will become widespread before 2030 (instead of 350 bars at present) and tank prices will fall from €630/kg of H_2 in 2020 to €324/kg in 2030 and €250/kg in 2050. Trucks designed to transport hydrogen will have their load capacity increased from 450 kg to 1,200 kg by 2030.

By increasing the pressure from 350 to 700 bars[11] and optimising the storage configuration, long-distance freight trucks will be able to carry 72 kg of hydrogen from 2030 instead of the current 34.5 kg, giving them a range of around 850 km.

However, it is not certain that these very significant advances, if they materialise, will be enough to convince hauliers to switch to hydrogen.



Indeed, there are still disadvantages to hydrogen that may prove to be prohibitive:

- **the relatively low energy efficiency of the sector**, linked to the combination of electrolysis and the fuel cell, which has a significant impact on its competitiveness compared to the direct use of electricity;
- **the storage volume** which, even at 700 bars, remains eight times higher than that of diesel and is, more than the weight, detrimental to fleet operation;
- **too short a fuel cell life**: PEM fuel cells using metal plates in electric vehicles have a life of only 5,000 hours[12]. Their efficiency, which can be as high as 50% at start-up, also deteriorates over time[13];
- rules required for **safety and which may limit the use of the vehicles**.

10. The CRE Prospective Committee's June 2021 report, "The hydrogen vector", lists the preconditions for the emergence of a business model by 2030 in the field of heavy transport. CRE is the French regulation body.
11. It is possible that in buses, where volume constraints are less of an issue, the hydrogen used remains at a pressure of 350 bars.
12. Those using graphite have a significantly longer service life, but are at the same time significantly heavier and more cumbersome, making them more suitable for stationary use;
13. Hemmer, S., Walters, M. & Tinz, S. Skalierbare Brennstoffzellensysteme für Nutzfahrzeuge. MTZ Motortech Z 80, 72–79 (2019). See in particular chart 7.

The potential hydrogen market: two starkly contrasting development scenarios

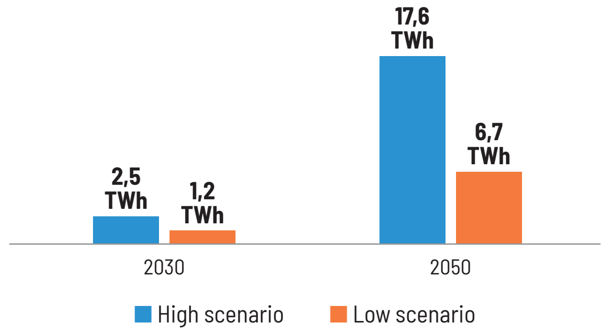
In a first so-called High scenario, it is assumed that hydrogen will prevail in the market segment for which it seems best suited, that of long-distance freight transport, especially in trans-European transport.
In this scenario, hydrogen captures 65% of the market for goods transport over 500 km by 2050, both in France and abroad. The balance is shared between bioCNG and electric batteries.

In addition, hydrogen captures 10% market share in transport of less than 150 km and 30% in transport of 150 to 500 km.

In a second and so-called Low scenario, hydrogen does not achieve a majority share. Its market share in transport over 500 km is capped at 25% and in the other two market segments at 5% and 10%.
In both cases, growth is not linear and by 2030 the penetration of hydrogen will remain limited, given the time needed to build infrastructure and migrate truck fleets to hydrogen.

Hydrogen needs for the two 2030 and 2050 timeframes have been estimated and point to hydrogen consumption of 17.6 million TWh H_2 in 2050 in the High scenario and of 6.7 TWh H_2 in the Low scenario.

Hydrogen consumption projections for road haulage in the High and Low scenarios (TWh of hydrogen).



This results in electricity consumption and an installed capacity requirement for electrolysers that develops as follows:

	High scenario		Low scenario	
	2030	2050	2030	2050
Hydrogen needs (TWh H_2)	2.5	17.6	1.2	6.7
Electricity consumption for electrolysis (TWh)	5.7	36.8	2.8	13.9
Installed capacity of electrolysers required (MW)	575 MW	3,850 MW	270 MW	1,400 MW

The hydrogen ecosystem problem

Having assessed the potential demand for hydrogen in the road haulage sector, the next question is how this demand can be met.

Many studies confine themselves to considering hydrogen as a production problem, which would result in the need to develop a national electrolyser industry.

The issue is much more complex. Hydrogen must first be produced, and there are several possible ways of doing this. It can also be imported. **In all cases, the degree of purity required for its use in fuel cells must be respected.**

The hydrogen must then possibly be transported, either by truck or by hydrogen pipelines.

Finally, it must be distributed at the right pressure for filling truck tanks. This entails storage and distribution facilities, and possibly compression, which have a significant impact on efficiency and costs.

An essential aspect, taken into account in the study, is the ramping up of the facilities. There is clearly a “chicken and egg” dilemma: hauliers will only switch to hydrogen if the appropriate infrastructure is in place, but this infrastructure will only be commissioned if the hydrogen market exists.

The study identifies three refuelling circuits for trucks

- **high capacity regional hubs** (from one to several hundred MWe) serving various markets (industry, public transport, freight transport, possibly injection into the natural gas network);

- **decentralised stations accessible to the public**, with much smaller capacities (typically 5 to 20 MWe) and corresponding to:
  - › or multi-use production stations (public transport, service vehicles, taxis, etc.) often developed by local authorities[14]. We could call these “mini-hubs”;
  - › or stations for mobile refuelling, located along or near major traffic routes. These stations could be supplied from the hubs or equipped with their own production facilities;

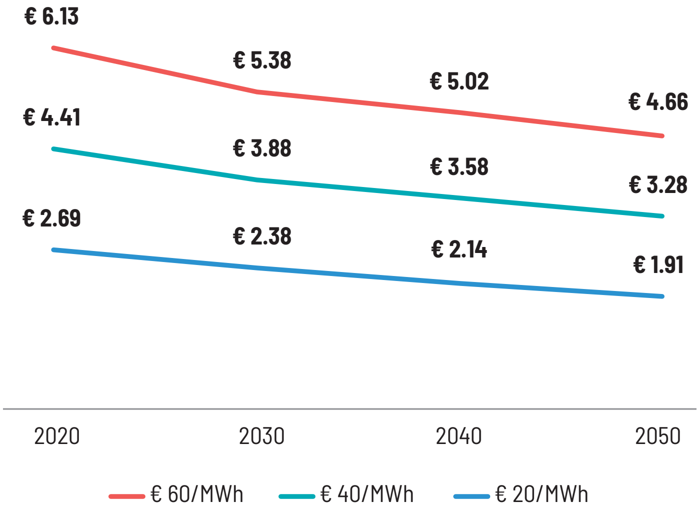
- **stations set up in the hauliers’ designated areas**, where the trucks return in the evening, with power facilities comparable to those of the decentralised stations mentioned above.

A typical fuelling station architecture is proposed, which could result from the conversion or development of existing service stations.

14. *The above-mentioned report by the CRE’s Prospective Committee recommends:* “Encouraging the creation of multi-use regional hubs near industrial and port areas and major European heavy transport routes, and coordinating the various local initiatives to avoid wasting public money*”.*

Assumptions are made about the lifespan of the various facilities and about price trends. The key factors are the price of the electrolysers and more importantly the price of electricity. It is assumed that the hubs can be supplied with electricity at an average price of €60/MWh (excl. VAT)[15], with the hubs operating on a base load basis, but able to be switched off in the event of grid stress, with an average availability rate of 90%; however, the decentralised stations will have to accept a higher price, estimated at €75/MWh (excl. VAT).
These prices are not expected to change throughout the period of the study. At the same time, it was assumed that electricity was supplied to electric trucks at €100/MWh for normal charging at company premises and €350/MWh for fast charging along motorways, to incorporate the investment and operating costs of the charging infrastructure.

Cost price of hydrogen from the hub (in €/kg) under different electricity price assumptions.



Transportation and distribution of hydrogen are important factors that add to the cost of production.

Transport will change significantly. The hubs may be connected by major routes and pipelines may be developed in their catchment areas. However, it is likely that decentralised distribution stations without their own production facilities will be supplied by trucks from the hubs. After a certain distance, local production in decentralised stations becomes more competitive. This breakeven distance, currently around 50 to 100 km, will increase to 150 km with the arrival of new lorries capable of delivering up to 1,200 kg of hydrogen.

Fuel stations should have enough lanes to avoid truck queues. Each will be equipped with a dispenser, a rather complex and expensive piece of equipment, but the cost is expected to fall. Refuelling by lorry will quickly reach its limits, given the capacity of the tanks, which, even when increased to 1,200 kg, will be unable to cope with very heavy traffic. It has been assumed that a station can only reasonably be resupplied[16] once a day, which leads to the development of local production as soon as the needs to be met exceed the equivalent production of a 3.3 MWe electrolyser.

15. This assumes that electrolysis remains exempt from the excise tax on the final consumption of electricity (TICFE) - which in 2021 was €22.5/MW - or benefits from a very reduced rate, in application of the European directive 2003/96, currently under review, on the taxation of energy products and electricity.
16. Refilling a hydrogen station involves swapping the empty tank and the full tank and presumably suspending distribution during this time. Doing so on average more than once a day seems unrealistic in the long term.

Ultimately, the cost price of the hydrogen delivered to the tank, excluding VAT, could develop as follows:

Cost price of hydrogen delivered to the tank in different distribution schemes. The green shaded boxes correspond to cases where supply by truck is cheaper than local production.

In €/kg H_2	Transp. distance (km)	2020				2030				2050			
		Produc.	Transp.	Distrib.	Total	Produc.	Transp.	Distrib.	Total	Produc.	Transp.	Distrib.	Total
Production Hub and delivery Hub	-	€ 6.13	- €	€ 0.93	**€ 7.06**	€ 5.38		€ 0.39	**€ 5.77**	€ 4.66		€ 0.25	**€ 4.91**
Hub generation and transport in decentralised distribution stations without generation facilities	50	€ 6.13	€ 0.76	€ 1.79	**€ 8.68**	€ 5.38	€ 0.35	€ 0.73	**€ 6.46**	€ 4.66	€ 0.30	€ 0.60	**€ 5.56**
	100	€ 6.13	€ 1.32	€ 1.79	**€ 9.24**	€ 5.38	€ 0.62	€ 0.73	**€ 6.73**	€ 4.66	€ 0.53	€ 0.60	**€ 5.79**
	150	€ 6.13	€ 1.89	€ 1.79	**€ 9.81**	€ 5.38	€ 0.90	€ 0.73	**€ 7.01**	€ 4.66	€ 0.76	€ 0.60	**€ 6.02**
	200	€ 6.13	€ 2.45	€ 1.79	**€ 10.38**	€ 5.38	€ 1.18	€ 0.73	**€ 7.29**	€ 4.66	€ 0.99	€ 0.60	**€ 6.25**
	250	€ 6.13	€ 3.02	€ 1.79	**€ 10.94**	€ 5.38	€1.45	€ 0.73	**€ 7.56**	€ 4.66	€ 1.22	€ 0.60	**€ 6.48**
	300	€ 6.13	€ 3.59	€ 1.79	**€ 11.51**	€ 5.38	€ 1.73	€ 0.73	**€ 7.84**	€ 4.66	€1.45	€ 0.60	**€ 6.71**
Production and distribution in decentralised stations	-	€ 8.13	- €	€ 0.75	**€ 8.89**	€ 6.55	- €	€ 059	**€ 7.14**	€ 5.69	- €	€ 0.50	**€ 6.19**

Today, this cost price can be estimated at between €10 and €12/kg. It can be expected to fall to around €6-7 by 2030 and €5-6 by 2050[17]. These evaluations assume that no other taxes (excluding VAT) than those currently affecting the price of electricity[18] for electrolysis will be added to the cost price of hydrogen. In addition, the cost price calculations included a coefficient of 25% to cover the overheads and the commercial margin of the companies in the production/distribution chain. This estimate seems correct if the operator is a public body. It is likely to be higher if the operator is a private company.

To put the orders of magnitude into perspective, a hydrogen price of €10/kg corresponds to a MWh Net Heating Value price of €300. By way of comparison, the cost price of diesel for hauliers, which is currently around €1/litre, corresponds to a Net Heating Value cost price of around €100/MWh[19].

17. These calculations assume public subsidies of 50% for investments up to 2030 and 30% from 2031 to 2035. These subsidies will be essential to get the industry off the ground, but their impact will diminish as the prices of electrolysers and distribution equipment become lower in relation to the price of electricity.
18. This includes the assumption that a special tax regime will be maintained for "electrolysis" use.
19. This rough comparison is only indicative, as the performance of each channel in use should be taken into account. The efficiency of the hydrogen chain, which combines the efficiency of the electrolyser and the efficiency of the fuel cell, will stabilise at around 30 to 35%. The efficiency of diesel engines on trucks rises to 40%.

The economic equation

The hydrogen solution can hardly claim to be competitive with the diesel solution. Note that it was assumed in this study that the phasing out of the diesel sector would be the result of regulatory measures or very large increases in taxes on CO_2 emissions.

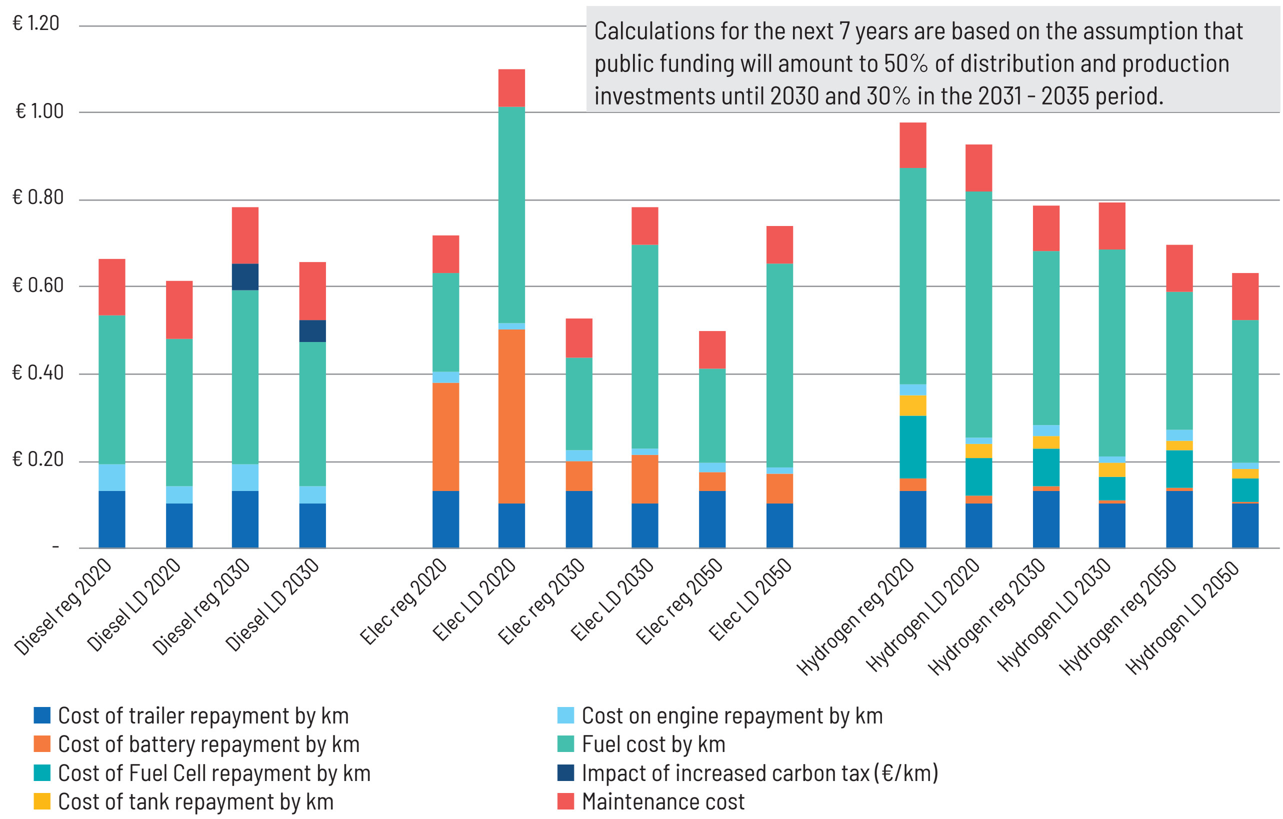
Conversely, in economic terms, it is essential to position the hydrogen sector in relation to the electric battery sector, chiefly to verify the development scenarios that have been chosen. A calculation of the total cost of ownership was made for 2020, 2030 and 2050, taking into account the expected technical and economic progress and modelling the distribution of traffic between the different production and distribution channels. The dialogue with transport companies showed that they were generally keen to safeguard their independence in terms of supplying their fleets, but they will, at least initially, be dependent on the hubs that will be developed with the support of the public or local authorities. At a later stage, production/distribution stations will be developed in companies and distribution stations will be set up along the motorways.

Based on these assumptions, the total cost of ownership would develop as follows:

Trend in total cost of ownership in €/km for the different engines. In each column, the most economical solution has been shaded in green.

In €/km	Regional traffic			Long distance traffic		
	2020	2030	250	2020	2030	2050
Diesel trucks	€0.666	€0.784	-	€ 0.614	€0.657	-
Battery electric trucks	€0.719	€0.527	€0.499	€1.101	€0.783	€0.740
Hydrogen truck	€0.978	€0.787	€0.696	€0.926	€0.793	€0.631

Component breakdown of ownership costs for the different types of engine: TCO in €/km of a diesel, electric or hydrogen truck in 2020/2030/2050, regional or long distance over 7 years



These results show that, for regional transport (less than 500 km), battery electric technology would remain the most competitive whatever the time frame, except for use cases where hydrogen would have a marked competitive advantage, such as 24-hour use. This sector will benefit from the decline in batteries and the introduction of recharging infrastructures associated with the development of electric mobility for light vehicles.

For long distances, compared to an electric truck equipped with a 1,050 kWh battery and carrying out rapid mobile refuelling at €350 /MWh, the hydrogen truck may be the best choice if the installation of electrolysers and the first distribution facilities are subsidised and if the cost of the electricity used to produce the hydrogen is moderate (60 €/kWh in the hubs), but the difference may not be decisive: both battery and hydrogen technologies have advantages and disadvantages and depending on public policies and technological breakthroughs, one or the other solution may prevail. In retrospect, this justifies the choice of the two High and Low scenarios, although it is not yet possible to say which one will prevail.

Three plausible game changers illustrate this point:

- the US Department of Energy has set a goal of **producing decarbonised hydrogen at €1/kg by 2030**[20];

- the emergence of **solid-state batteries** could lead to rapid recharging in less than twenty minutes. Depending on the price, this would give a clear advantage to electricity;

- the roll-out of charging stations corresponding to the CharIN consortium's proposal for a **very high power charging standard**, the Megawatt Charging System (MCS), at powers in excess of 1 MW and at a voltage of up to 1,500 V, would allow the development of electric heavy goods vehicles with a high range, subject of course to the price of charging.

20. https://www.energy.gov/eere/fuelcells/hydrogen-production

Conditions for development:
Hydrogen master plans and transport routes

Hydrogen still has a long way to go before it becomes a mature solution for powering heavy goods vehicles.

Many of these markets are the responsibility of industry, which will have to develop more efficient equipment than is currently available for the electrolytic production of hydrogen, fuel cells, storage, compression, transport and distribution of hydrogen.

However, other responsibilities lie with governments:

- hydrogen delivered to trucks should not be affected by taxes other than those currently levied on electricity for electrolysis to remain within acceptable electricity price limits. This requirement will have to be raised to the European level as part of the ongoing revision of the energy and electricity tax directive;

- For a good dozen years, investments in hydrogen production and distribution will have to be supported by the state, up to 50% in the 2020s and 30% in the 2030s. **The corresponding effort, spread over the period, has been calculated at €990M in the High scenario and €415M in the Low scenario**, which are relatively modest amounts given what is at stake.

- The hydrogen production and distribution ecosystem must be designed rationally from the beginning. The analysis in the study showed that it should be based on three areas:
  - › high-capacity hubs;
  - › decentralised stations, either multi-purpose and built by local authorities (mini-hubs), or service stations located along or near motorways:
  - › installations on company premises.

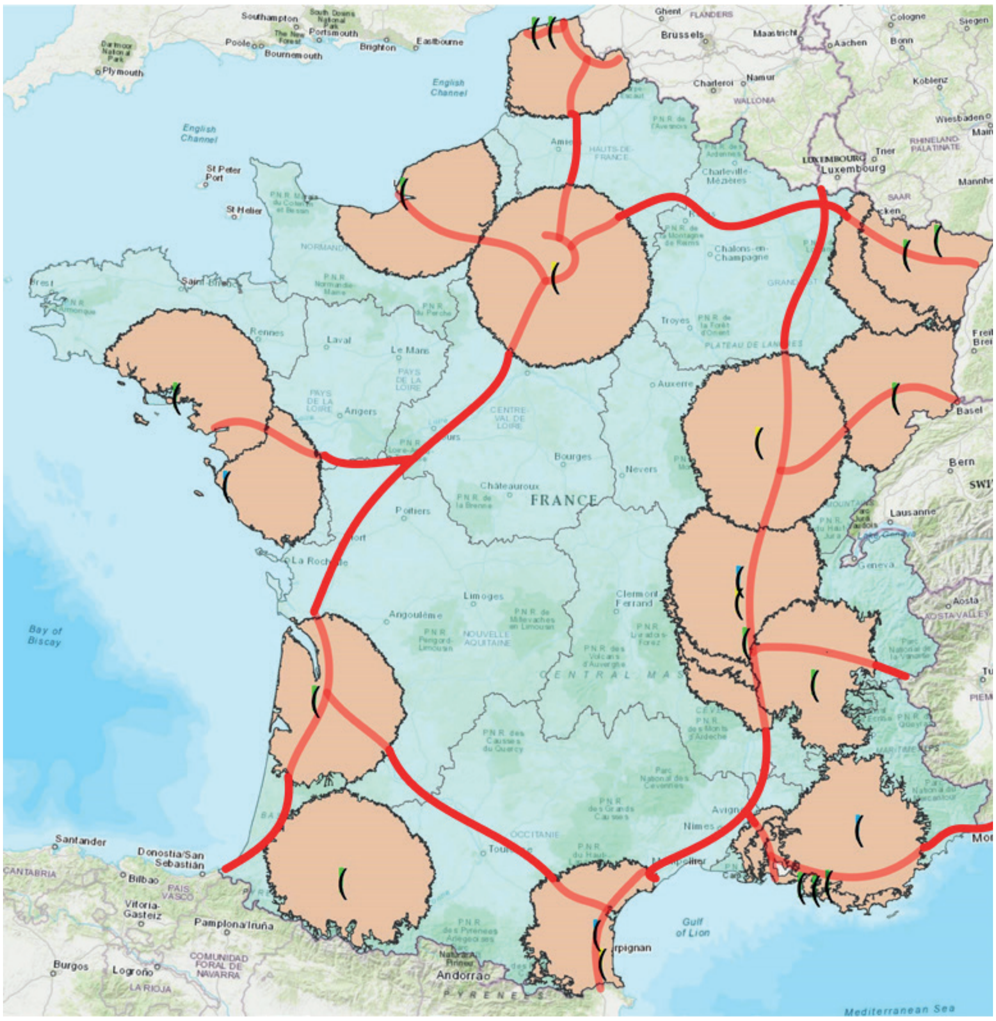
The hubs will be the most competitive in terms of cost price and – depending on the traffic considered – could therefore handle c.30 to 40% of HGV refuelling[21]. There will probably be about twenty of them, perhaps more, depending on the development of hydrogen uses.

Transport companies will have to equip themselves as the sector develops. Their own facilities would account for 25% in 2030 and 40% in 2050.

The rest should be provided by regional mini-hubs or by stations along or near motorways and expressways. By 2050, there should be between 30 and 100 stations. If the High scenario is adopted, dedicated hydrogen filling stations will become widespread along or near all motorways and will be able to provide a refuelling point every 100 km at most. If the Low scenario applies, these stations will be located only along the busiest roads.

21. However, it is likely that large international trucks will not make the diversions to the hub and will prefer to refuel on the motorway or very nearby.

Potential service areas for hydrogen hubs and highway segments to be supplied by decentralised stations.



But it is vital that these investments are coordinated and planned, more so than is the case with the fast-charging EV stations along the motorways.

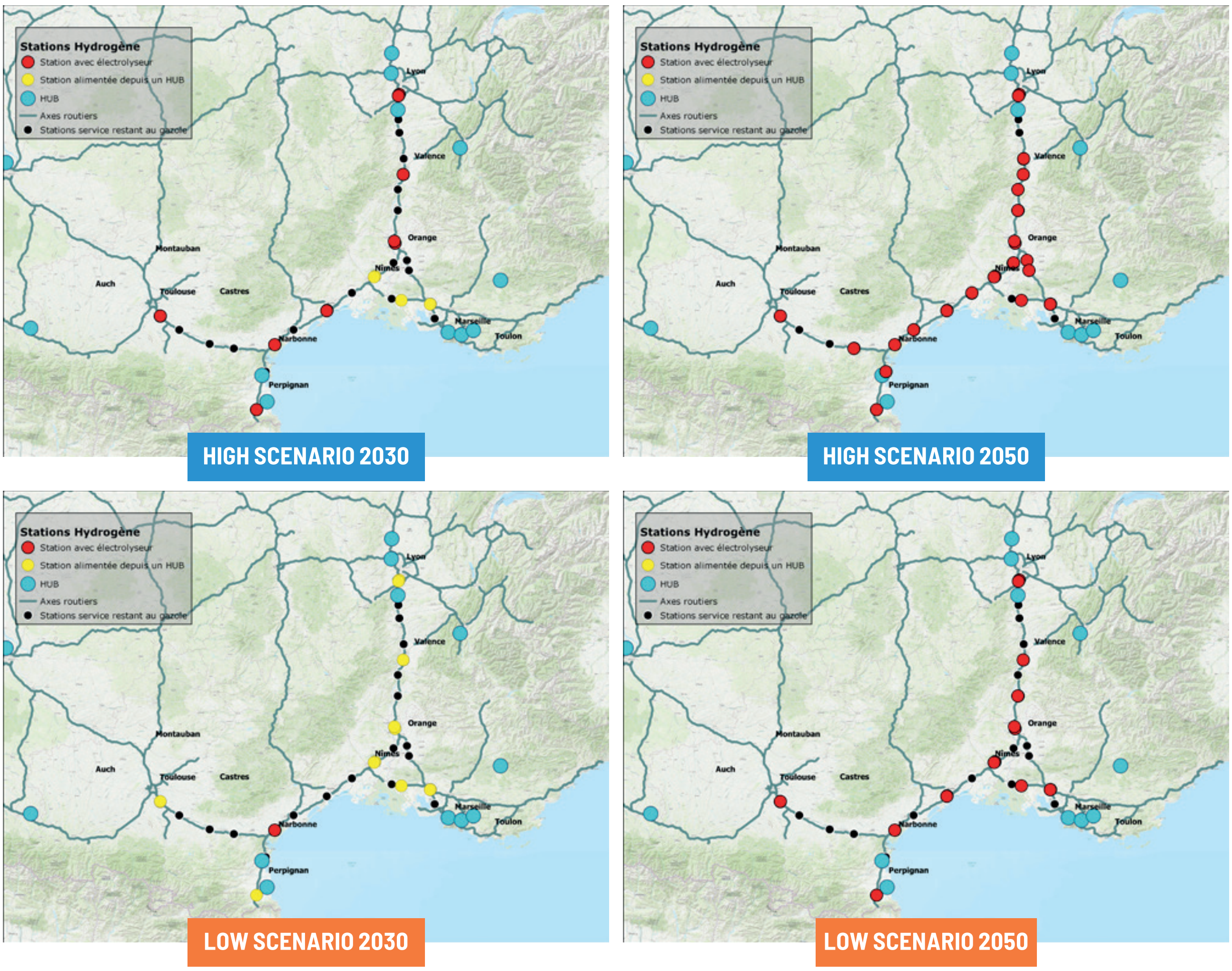
It is therefore proposed that master plans for the siting of hydrogen production and distribution facilities for heavy goods vehicles be undertaken immediately. Concession or public-private partnership arrangements will have to be devised as private investment is unlikely to be keen to pre-empt a demand that will take several years to develop.

It is therefore proposed that master plans for the siting of hydrogen production and distribution facilities for heavy goods vehicles be undertaken immediately.

A case study was carried out on the Autoroutes du Sud de la France (ASF) for which precise, albeit relatively old (2001), data on HGV traffic and its breakdown into starting points and destinations are available . This study focuses on a motorway triangle with a high volume of heavy goods traffic on 750 km of motorways. It led to a distinction being made between several types of traffic and to a methodology being developed to assess the needs to be met in terms of hydrogen-powered heavy goods vehicles along the various sections. In short, this approach defines the number of stations needed and their approximate location, in addition to other sources of supply and taking into account the current fleet of diesel stations.

It leads to the layouts shown in the figures below (High and Low scenarios). For the 2030 and 2050 timeframes, we identify the distribution stations required assuming that beyond a distributed volume of 1,200 t of hydrogen per day - corresponding to a daily resupply of the station - the stations will have to equip themselves with their own means of hydrogen production in a range from 5 MW to 20 MW.

Hydrogen stations in 2030 and 2050 in high and low scenario.



22. Better knowledge of heavy goods vehicle traffic on the A7-A9 axis - Origin/destination survey (DRE - ASF - CETE Méditerranée) - Contribution to the public debate: https://cpdp.debatpublic.fr/cpdp-vral/docs/pdf/etudes/5._les_etudes_routieres/Meilleure_connaissance_des_trafics_PL_sur_A7_A9.PDF

We see that the stations supplied from the hubs will play a start-up role, but that fairly quickly in both the High and Low scenarios, decentralised production resources will have to be planned in these stations with capacities ranging from 5 to 20 MWe.

This type of master plan can be designed at the regional level, but more effectively at the European level, as the target market is largely that of large international transport. **With this in mind, we propose that the idea of hydrogen corridors be raised to the European level, equipping the main routes used by major European transport as a priority.** This discussion should be part of the work on the trans-European TEN-T network with a view to enabling transport companies to invest in hydrogen trucks as soon as they are available on the market and thereby begin the migration of heavy transport to the hydrogen solution.

The European Commission's proposal for a regulation on recharging infrastructure for alternative fuels[23], published on 14 July 2021, is a step in this direction, as it specifies that the Member States must equip the trans-European transport network with hydrogen distribution stations spaced at a maximum of 150 km apart, with a capacity of 2 t/day for gaseous hydrogen at 700 bars, and 450 km for liquid hydrogen[24]. It also intends to provide each urban node with a hydrogen filling station.

However, this proposal should focus more on the core TEN-T network, whose hydrogen infrastructure could then have a knock-on effect on the global TEN network, and then on the other main routes and potential market segments (light vehicles).

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23. Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the deployment of alternative fuels infrastructure, and repealing Directive 2014/94/EU of the European Parliament and of the Council, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021PC0559.

24. The case of liquid hydrogen has not been considered in this report. It raises specific problems. It was not considered that this solution would facilitate the development of the sector and care will have to be taken not to dilute the investment effort. This solution is nevertheless being studied by a number of OEMs, Daimler Truck AG in particular. For tanks of a comparable size, it almost doubles the vehicle's range compared with compressed hydrogen at 700 bars, but at the cost of consuming about 20% more energy than hydrogen at 700 bars.

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Construisons une société énergétique meilleure

Association loi de 1901 Équilibre des Énergies
10, rue Jean Goujon - 75008 Paris - France
T. +33 (0)1 53 20 13 70
info@equilibredesernergies.org

equilibredesenergies.org