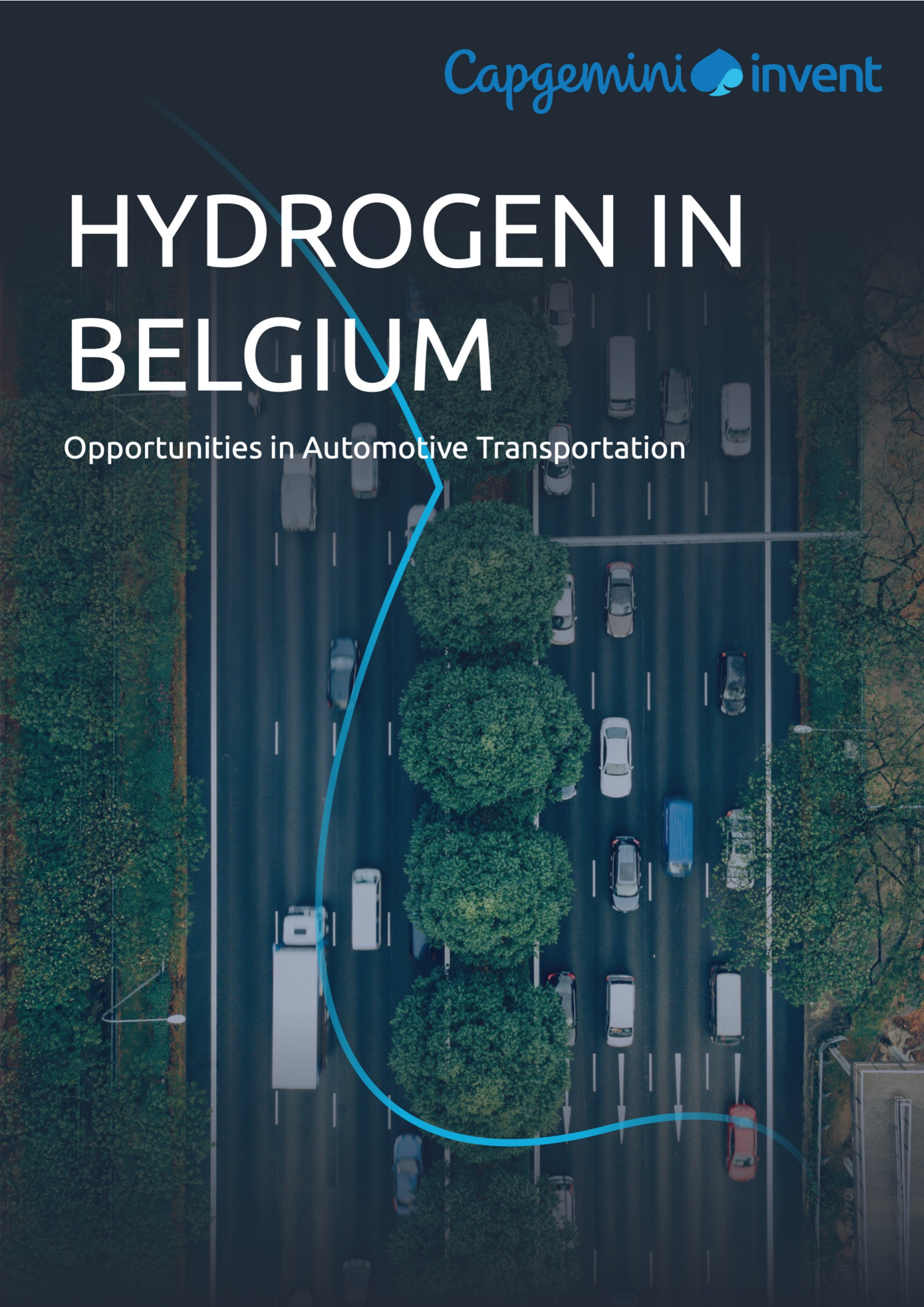
Capgemini invent

# HYDROGEN IN BELGIUM

## Opportunities in Automotive Transportation



# EXECUTIVE SUMMARY

**Introduction**

This study provides a clear overview of the Hydrogen ecosystem in Belgium while comparing it to initiatives in other European countries. Furthermore, barriers that are slowing down Hydrogen adoption are identified. This report will rely on our research and market data insights, interviews with industry experts, as well as observations from Capgemini Invent's industry consulting experience.

**Hydrogen in Belgium**

Compared to other parts of the world, Belgium shows a lot of research initiatives and some local firms are firm believers of hydrogen technology. Yet, some industry leaders within the automotive space are hesitant. Nevertheless, an increasing amount of research and development money is poured into hydrogen research. It is not only private institutions that are investing money - the European Union has launched a creative proof of concept initiative with garbage trucks and other heavy modes of transportation.

**Challenges & Opportunities**

Belgium, with its ports and petroleum-gas industries, already has a good foundation to support a broader hydrogen network. Even though there are a lot of smaller initiatives by governmental and municipal agencies to aid the acceleration of Hydrogen adoption, a large-scale roll-out takes time. In the best case, they will facilitate installations by private enterprises to fuel their transition into a cleaner world. Another opportunity arises for companies with close ties to the government which will allow them to gain permits and additional funding more quickly.

Belgium has a unique financial incentive for cars, as the Belgian car fleet consists of the newest vehicles worldwide. Compared to other countries, this makes for a much cleaner and more efficient fleet. However, due to the considerable number of kilometers driven per inhabitant, the savings overall are minimal. These days, the emphasis is on Electric vehicles as a solution. However, the Belgian electricity grid cannot cope in its current state with a gigantic influx of electric vehicles. To keep this fleet green in Belgium the government could look towards hydrogen as a solution for passenger cars. Moreover, several OEMs are investigating this opportunity. However, in the short term, large trucks, and other large vehicles, capable of swapping their diesel engines more easily than regular vehicles, can benefit most from hydrogen adaptation.

Considering the limited support of the government, if hydrogen adoption is to accelerate in Belgium, the various players active in the hydrogen ecosystem need to devise a clear path forward and come together where possible to align on the way forward. To overcome the challenge of the missing infrastructure, OEMs should form partnerships with production and logistics operators with expertise in hydrogen. A combined offering that would allow for a clear process to install and operate hydrogen fuel stations in and around Belgium would go a long way in reassuring reluctant players in conservative industries.

To reach clean transportation governments, companies, research institutes and entrepreneurs alike would need to push forward alternative sources of energy storage. Customer adoption will follow suit as the technology and (mainly) infrastructure improves.

# HYDROGEN: AN INTRODUCTION

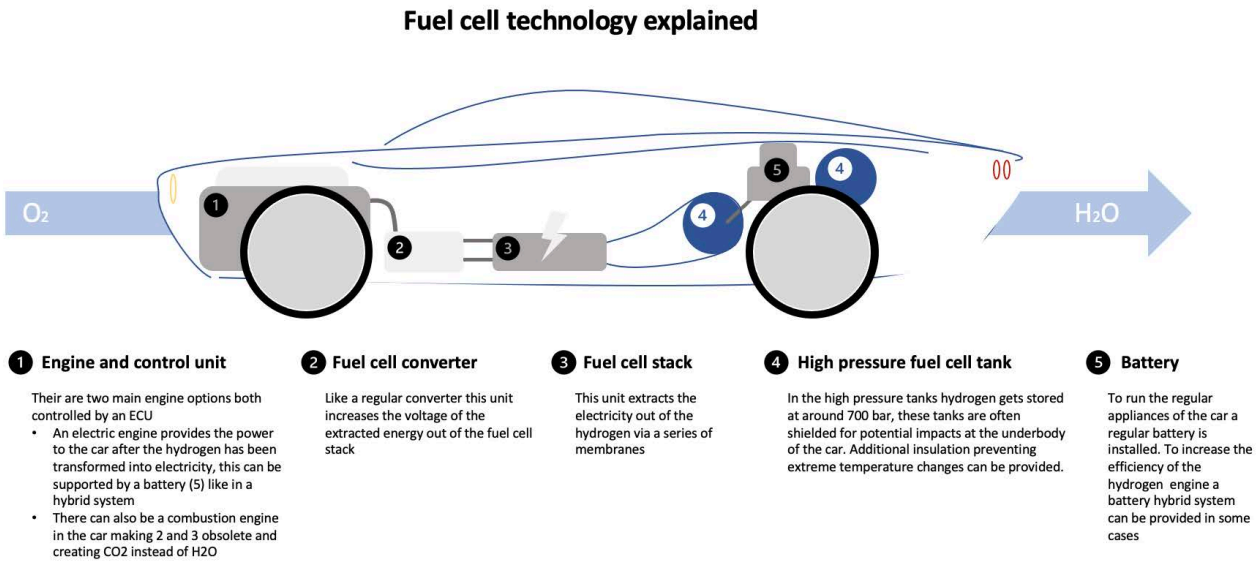
## What is hydrogen ?

Due to the small and stable molecular structure hydrogen is the most abundant element in the universe. Even though this molecule is rigid and stable, there is significant energy potential in its structure. This potential energy makes hydrogen great for storing energy - much how an apple stores energy for humans to break down and the use when we go about our daily lives. And like a human digestive system breaking down the apple to harness its nutrients, making sure we release the energy stored in hydrogen is a bit more complex yet not entirely difficult.

## Why is it green ?

That the only potential byproduct of hydrogen is water sounds almost utopian. So, the obvious question is, where is the catch? In production and in the energy conversion rate. To create hydrogen with our current technological understanding, it takes more energy than we can extract. Additionally, the energy density is not as great as conventional Diesel or Petrol fuels. Nevertheless, Battery technology scores even poorer. In essence, hydrogen is a clean form of energy storage. However, as with charging batteries, the energy to produce hydrogen must come from somewhere. This depends on the national grid of the given country where the production will take place.

**FIGURE 1:** Fuel cell technology explained




Source: Toyota, 2021

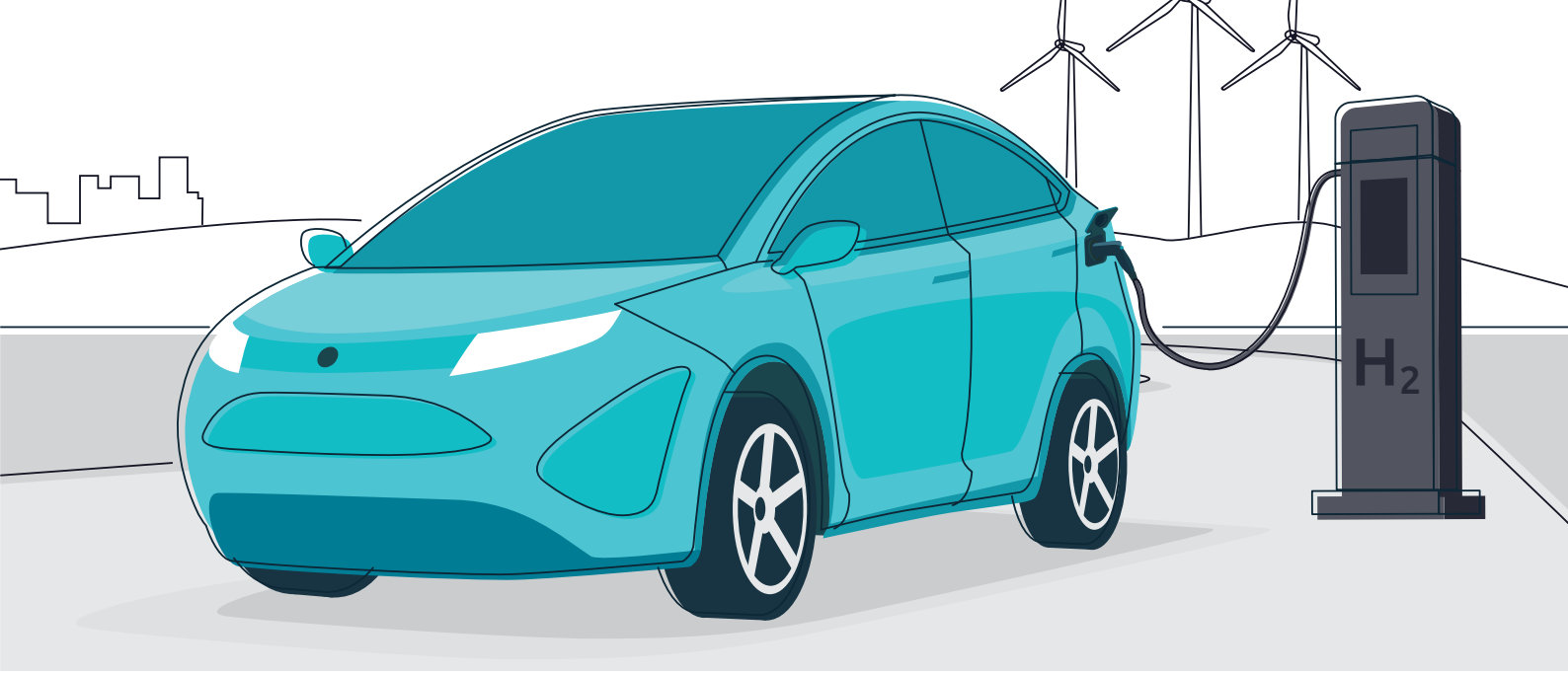
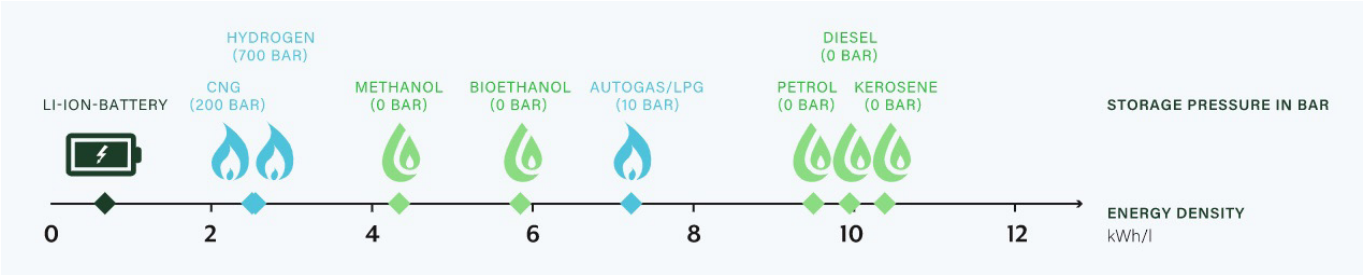



**FIGURE 2:** Energy density in relation to pressure (green=petroleum based; blue=other bases)




Source: Multiple sources, 2018

## Does it work?

Hydrogen is in its most stable gas form that floats around us all the time. However, it is most prevalent in the upper ranges of our atmosphere. To unlock the full potential of hydrogen fuel as an energy source, we need to create pure hydrogen and compress it to around 700 bar (700 times our atmospheric pressure).

With this compressed gas, we have the following options to release the energy potential: combust the gas or extract the energy like a battery. In the case of combustion, Hydrogen under the right conditions is flammable. Traditional internal combustion engines (ICEs) are capable to use hydrogen as a fuel with minimal adjustment to their internal workings. BMW produced a limited run of 100 hydrogen-powered models of the 760Li with this method. This experiment by BMW was in the early days of hydrogen combustion. Currently, brands like Formula One Group and DAF trucks want to introduce and create synthetic fuels based on hydrogen. These so-called E-fuels start with hydrogen made from renewable sources to then be enhanced with CO2 to create a "clean" fuel. Traditional ICEs can then run on these new carbon-neutral E-fuels. These E-fuels are "green" since they use CO2 to be created and do not generate excess CO2 since the energy used in their production originates from clean sources. Yet, these E-fuels fall in the same pitfall as regular fuels. They still need combustion, and there is significant energy loss due to heat and friction.

Let us return to pure hydrogen generated from clean energy sources. If we compress the gas, then we can use a similar process to batteries to extract energy. The hydrogen passes through several membranes, which break down the molecular bonds and in doing so releases the energy. The only byproduct? Water. The hydrogen breaks down, reacts with oxygen in the air, and creates freshwater. All the while, energy can be temporarily stored in a tiny battery or be sent directly to an electric engine and/or appliances.

# PROTOTYPING: PERSONAL CARS & COMMERCIAL VEHICLES

## Belgium's place in the world of personal car production

The main added value of car manufacturing in Belgium is its high quality, as well as the development and integration of the latest technologies, such as hybrid and electric vehicles. In 2020 alone, the employees of Audi Vorst and Volvo Gent managed to build around 270,000 cars, 40% of which had a plug on board (plug-in hybrids and fully electric models). While this represents half of the Belgian production of a decade ago, when Belgium produced more than 600,000 cars, it still represents a significant industry, with more than 15,000 people still employed in the assembly plants.[1]

While Toyota has no production facilities in Belgium, it has based its European headquarters in the Brussels region where it does research and development of new vehicles and technologies, specifically towards electric and hybrid vehicles (such as Fuel Cell Electric Vehicles).

## Agnostics

Several major leaders in the automotive world have expressed reservations regarding the use of hydrogen for passenger vehicles, even for the use of trucks.

Tesla boss Elon Musk famously dubbed Fuel Cells as "Fool Cells." Volkswagen CEO Herbert Diess said he believes in hydrogen, but only for industry and aircraft use, not for passenger cars.[2]

At the end of 2020, Honda announced that it is putting its hydrogen development on hold. Likewise, the Daimler Group announced that it will stop all investments in fuel cell technology for passenger cars. The German group had been working with Ford and Nissan on this technology since 2013 but has now decided to end this collaboration. Explaining their decision, a Daimler research leader said: "Fuel cells work excellently. We only have a cost problem and that is related to the scale. We need volume." [3]

## Believers

Hyundai and Toyota see the situation very differently. Both producers are at very advanced stages with hydrogen technology. BMW is considered one of the pioneers in the development of hydrogen-powered vehicles.

As an example, BMW was already able to commercialize hydrogen-powered vehicles in 2021 – chief among them the X5, which is now called Hydrogen Next. However, due to the Covid-19 crisis and the insufficiently mature charging infrastructure in Europe, BMW has decided to postpone commercialization for a year. From 2022, as a test, 200 BMWs X5 running on hydrogen fuel cells will be sold.

Since 2013, BMW has been working with Toyota on hydrogen technology for personal cars. For example, since 2015 the companies have been working on prototypes of 5-Series Gran Turismo cars equipped with Toyota fuel cells. BMW also made a hydrogen prototype of the i8, a hybrid version of the iconic BMW sports car.[4]

## Technical case-in-point: performance of BMW's FCEV 'Hydrogen Next'

BMW mentions in its press communications that its newly developed FCEV will sport a maximum power of 275 kW (or 374 hp). That power is achieved when drivers enable the performance buffer of a separate battery in the car. According to BMW, that corresponds well with the "most


powerful six-cylinder engines" that the company currently offers in its petrol car series. BMW mentions that this buffer can be used, for example, during short moments of acceleration, such as during the overtaking of another car. Without this performance buffer, the power would average around 125 kW (170 hp).[5]

However, it has not yet been determined in which regions BMW will commercialize these vehicles. Everything will depend on where Belgium stands in terms of hydrogen infrastructure, specifically charging points. Belgium is currently losing ground compared to the Netherlands, where initiatives to set up new Hydrogen Refueling Stations are emerging at a rapid pace.

**FIGURE 3:** Overview of hydrogen cars that can currently be ordered and delivered in Belgium (2021)

Hyundai Nexo
73.999€
666 km range

Toyota Mirai II
64.470€
650 km range

Source: Hyundai, Toyota websites (prices in Belgium, incl. VAT, ranges according to WLTP norms)

## Advantages & market segments

The big advantage of a hydrogen-powered vehicle is that it has the same advantages in terms of autonomy as a classic ICE vehicle. Driving a Hyundai Nexo, one has 660 km of autonomy and charging is just as fast as with a fossil fuel car (appr. 5 mins).[6] Regarding consumption, for 100 km, a personal vehicle needs 1kg of hydrogen, comparable with approximately 6 liters of gasoline.

Hydrogen is sold in kilograms rather than volume (such as liters), and current prices are around €11,5 to € 17,5 per kg. As an example, let us look at Toyota's FCEV, the Mirai. Its tank can hold approximately 5 kg and as such a full hydrogen refill would cost between €60 and €88. This means that hydrogen FCEVs are more expensive per distance traveled than both internal combustion vehicles and BEVs. With increased hydrogen use, a decrease of hydrogen technology (such as fuel cells and electrolysers), costs are expected to come down soon.

The rest of the car's running costs again bear a close resemblance to BEVs: servicing costs are significantly less than an internal combustion car because of the reduced numbers of moving parts, while consumables such as brake pads are used less because of brake energy recuperation.

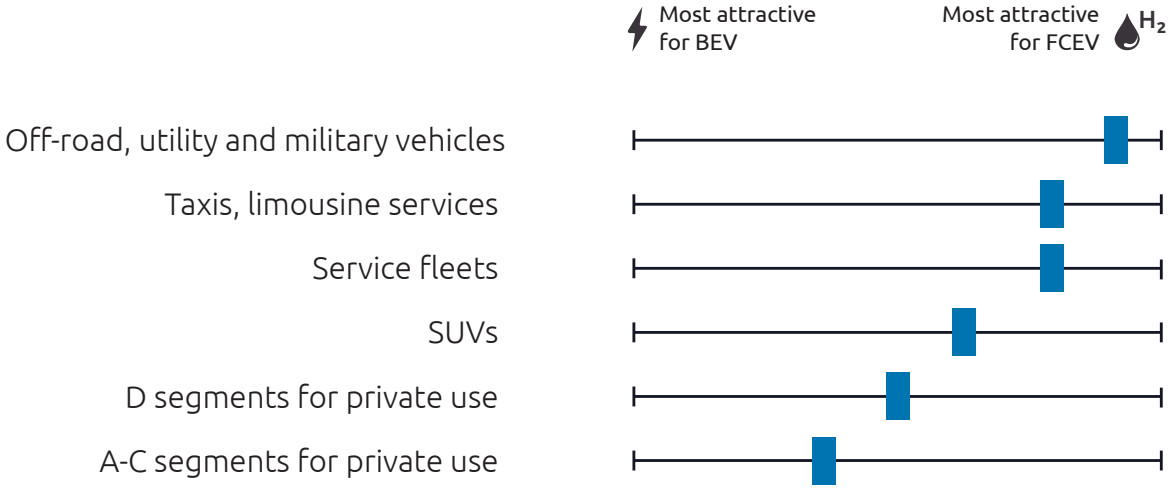
Toyota has a sharp vision towards hydrogen for passenger vehicles. For them, hydrogen-powered vehicles are complementary to electrically powered ones. In the medium term, a new market segmentation split appears to be forming for passenger vehicles: those used for short and medium distances (up to 500 km per day) and for long distances (above 500 km).

Equally, JLR (Jaguar Land Rover) announced that they are developing a prototype of the Defender based on a FCEV powertrain (a Fuel Cell Electric Vehicle Powertrain - FVEC for short - is like a traditional EV driven by electric motors, with the power sent to these motors stored as hydrogen rather than in the batteries). The tests on the road of the prototype are planned for the end of 2021.[7]

Vehicles with hydrogen powertrains are most interesting for professional usage, typically used with mid-sized and large vehicles. Consequently, this means that for smaller cars (up to medium sized cars, meant for shorter distances), it makes more sense to go for an EV.

Another oft-forgotten market segment are users who do not have the possibility to charge an electric vehicle. This potential was also noticed by BMW in their press release:

**FIGURE 4:** Medium- and large- car segments, by attractiveness




Source: Europa.eu

"The technology could become an attractive alternative to battery-electric drive trains – especially for customers who do not have their own access to electric charging infrastructure or who frequently drive long distances. It's hoped the tests will lead to the production of a small-series model in 2022".[8]

— BMW via CNBC, 2021

In terms of growth ambitions for the number of hydrogen vehicles, the Netherlands has sky-high ambitions in the total number of vehicles for the coming decade. In total, the Dutch government foresees that around 300,000 vehicles will run on hydrogen in 2030 in the Netherlands.[9] Japan predicts that there will be more than 800,000 hydrogen-powered vehicles driving on their roads.[10] Compared to today's entire passenger car fleet, this would be 3.4% in the Netherlands and 1.3% in Japan, respectively.[11] [12]

As a much larger market, China, too, has set extremely ambitious targets, and this at a relative short term. They predict around 1 million FCEV vehicles by 2030.[13]

## Sports & hydrogen can go together

It is a fact that hydrogen mobility is not only sustainable, but also holds potential for top sporting performance. In 2024, the "MissionH24" wants to bring 100% hydrogen-powered racing car prototypes to the starting line at Le Mans.[14] Additionally, Toyota already developed a motorsport prototype based on their GR Yaris model. Engineers of Toyota converted the 1.6- liter, three-cylinder combustion engine to run on hydrogen. The car performed similarly to the traditional ICE variant.[15] It also provides for interesting challenges for development teams, such as the space increase that is required for storing the hydrogen fuel, as well as making sure the engine runs smoothly. Indeed, motorsport is proving to be a successful test area to provide new key findings into new engine technology and can provide nifty insights on how to overcome challenges.

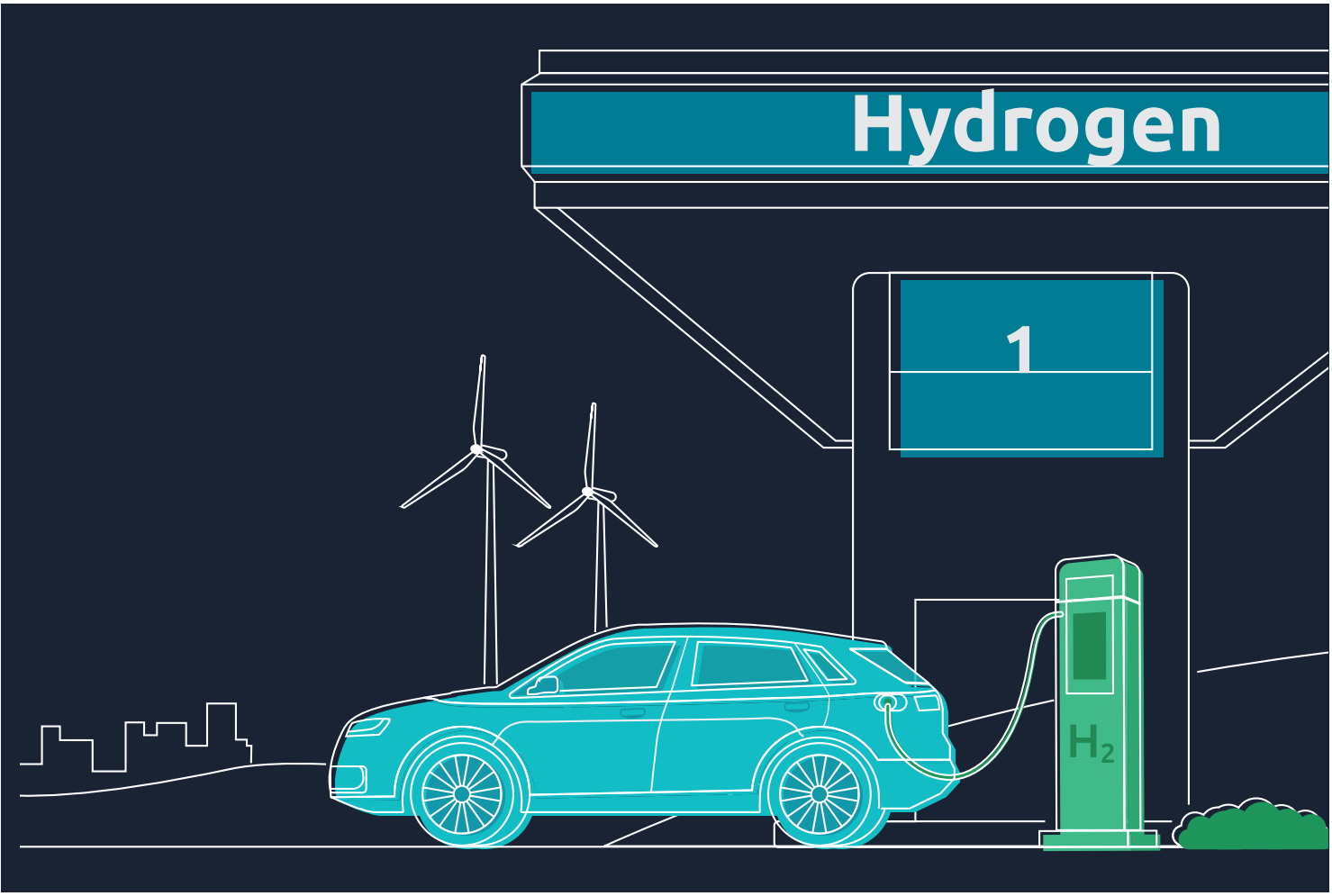


**FIGURE 5:** Key mobility targets in national hydrogen strategies

| | Number of FCEVs (2025) | Number of hydrogen trucks (2025) | Number of hydrogen refueling stations (2025) | Number of hydrogen refueling stations (2030) |
|---|---|---|---|---|
| France | 5,000[a] | 200[a] | 100[a] | 400 - 1,000[b] |
| Netherlands | 15,000[a] | 3,000 | 50 | / |
| Portugal | / | / | / | 50 - 100 |
| Spain | / | / | / | 100 - 150 |
| South Korea | 100,000 | / | / | 310 - 1,200 |
| Japan | 200,000 | / | / | 900 |

a: in 2023 b: in 2028

Source: Hydrogeneurope.eu, 2020

## Expectations in Belgium

When looking at the perspective of the rollout of hydrogen vehicles, we note that Asian countries have lofty expectations which in turn will impact the mid-term development in our region. Looking more closely, we see the Netherlands as the front-runner in the shift towards a diverse mobility landscape where hydrogen driven vehicles are expected to grow, in combination with the investment in a vast network of hydrogen refueling stations planned in the Netherlands. The federal government of Belgium has ambitious plans with regards to hydrogen and has stated it wants to become the hub for the import of hydrogen for the whole of Europe. The focus of the approved strategy is to make the heavy industry, heavy traffic, and marine shipping in Belgium more sustainable with the use of green hydrogen. As for vehicles on hydrogen (FCEV), Belgium has not made any stated ambitions with clear regard to its development. However, the Belgian government has stipulated that all company cars must be 'zero-emission' by 2026, which includes hydrogen-electric and battery-electric vehicles. Here above, we see the crucial differences between countries, which have already announced their intentions.[16]

# HEAVY TRANSPORTATION ON HYDROGEN: A WORTHY ALTERNATIVE

## Introduction

While passenger vehicles that drive on fossil fuels are gradually being phased out and new EV and PHEV models are increasingly available in the market, there are still challenges to decarbonize heavy road transportation.[17] In 2018, heavy road transportation was responsible for 27% of road transportation carbon dioxide emissions and almost 5% of total carbon dioxide emissions in the EU (European Union). The annual registrations of new trucks in the EU have been increasing since 1990 and are estimated to further increase by 46% by 2030 - compared to 2016.[18] With this in mind, keeping in mind the climate goals and challenges, it is required that heavy road transportation be decarbonized as well.

## Why hydrogen is interesting for heavy transportation

One of the solutions that is often suggested is to electrify the heavy transportation fleet, more specifically to transform the fleet into battery electric trucks. Having said that, manufacturers of trucks and light commercial vehicles who produce BEVs are facing several challenges. Currently, trucks and LCVs (light commercial vehicles) only have a range of 80-280 km and require a charging time of 3-8 hours. For many industries, this is an important hurdle which prevents them from investing in battery electric trucks. Some of these battery electric trucks can have a range extender, which is a small combustion engine that charges the battery while driving. Incidentally, as they are very silent and are not heard clearly by bikers and cars, these trucks are also something of a security hassle. This can be solved by adding artificial sound by way of speakers on the outside of the truck.[19]

**FIGURE 6:** Long distance comparison of FCE and BE trucks

| PARAMETERS |  Fuel cell electric truck |  Battery electric truck |
|---|---|---|
| **Total cost of ownership** 5-year user period (based on France) | **€ 329 k** € 139 k (vehicle purchase costs) € 38 k (annual renewable fuel costs) | **€ 277 k** € 167 k (vehicle purchase costs)€ 22 k (annual renewable fuel costs) |
| **Refueling / recharging time** (full) | **10-20 minutes** | **8 hours** (overnight) **60 minutes** (opportunity) |
| **Max range** without refuelling / recharging | **1200 km** | **800 km** |
| **Cost parity with diesel** without subsidies | **Mid 2040s** | **Mid 2030s** |
| **Economies of scale with cars** | **Low** | **High** |
| **Net payload loss** (weight) | **None** | **None** |

Source: Transportenvironment.org, 2020


Considering all these issues, one solution that is often mentioned is trucks with hydrogen fuel cells, which are, for one, deemed to be more suitable for sustainable long-distance transportation compared to battery electric trucks. There are several reasons that back this claim.

The first reason hydrogen fuel cell trucks are more likely to be used is due to the charging time. As mentioned above, recharging an electric truck is a lengthy process that can take up to 8 hours. Even when charging with a fast charger (150 kWh), it still takes about 1 hour. In comparison, a hydrogen-based truck is refueled within 10 to 20 minutes. Hydrogen trucks have a significantly longer range and shorter dwell time compared to battery electric trucks.[20]

Moreover, another reason hydrogen fuel cell trucks are more attractive for use is based on the cargo capacity. Here, the weight discrepancy with battery electric trucks is large, as they require a battery of 1 MWh (megawatt hour). Considering that a battery mass is approximately 5kg per kWh, the battery back weight for an average battery electric truck is 5,000 kg. Adding the weight of the electric engine, the invertor, and the gearbox of 600 kg, the weight totals around 5,600 kg. In comparison, a diesel truck with its conventional drivetrain and fluids in the tank weigh approximately 3,000 kg (about the weight of an elephant). Consequently, battery electric trucks lose a cargo of more than 2,500 kg (or almost double its weight!) compared to diesel trucks. Enter the hydrogen fuel cell truck, which requires a much smaller battery - around 75 kWh -, and in total loses around 500 kg of cargo compared to diesel trucks.[21]

Further, hydrogen trucks can offer much more flexibility compared to battery electric trucks. As illustrated in Figure 6, hydrogen trucks have a longer range, meaning that they are suitable for regional as well as long-distance delivery.[22]

Finally, the reason hydrogen fuel cell trucks have an edge on battery electric vehicles is based on the Total Cost of Ownership (TCO). According to the report of the National Renewable Energy Laboratory (NREL) of 2021, the TCO of a hydrogen fuel cell trucks is 15% to 25% lower than the TCO of a battery electric truck.[23] The main benefit stems from the difference in weight and stop times. A truck driven by the current battery technology will be very heavy. The percentage dedicated to energy storage relative to the total weight of the truck is far greater with batteries compared to hydrogen. Additionally, the range of a truck powered by batteries is lower compared to hydrogen and unpractical compared to traditional diesel trucks. Yet, Hydrogen and diesel trucks can fuel up quickly, while batteries take longer to the distance driven.

## Initiatives in Europe and the Benelux

A project that aims to trigger a hydrogen-based trucks market is the 'Hy Trucks project,' which is a collaboration between the ports of Antwerp, Rotterdam, and Duisburg, in collaboration with Colruyt and Air Liquide and with several leading truck manufacturers. The project aims to deploy 1,000 FCEV trucks by 2025 combined with a network of 25 Hydrogen Recharging Stations (HRS) located in the main logistics centers.[24]

As part of this initiative, Belgium will be responsible for 300 FCEV trucks, together with the expansion to 6 refueling stations by 2026.

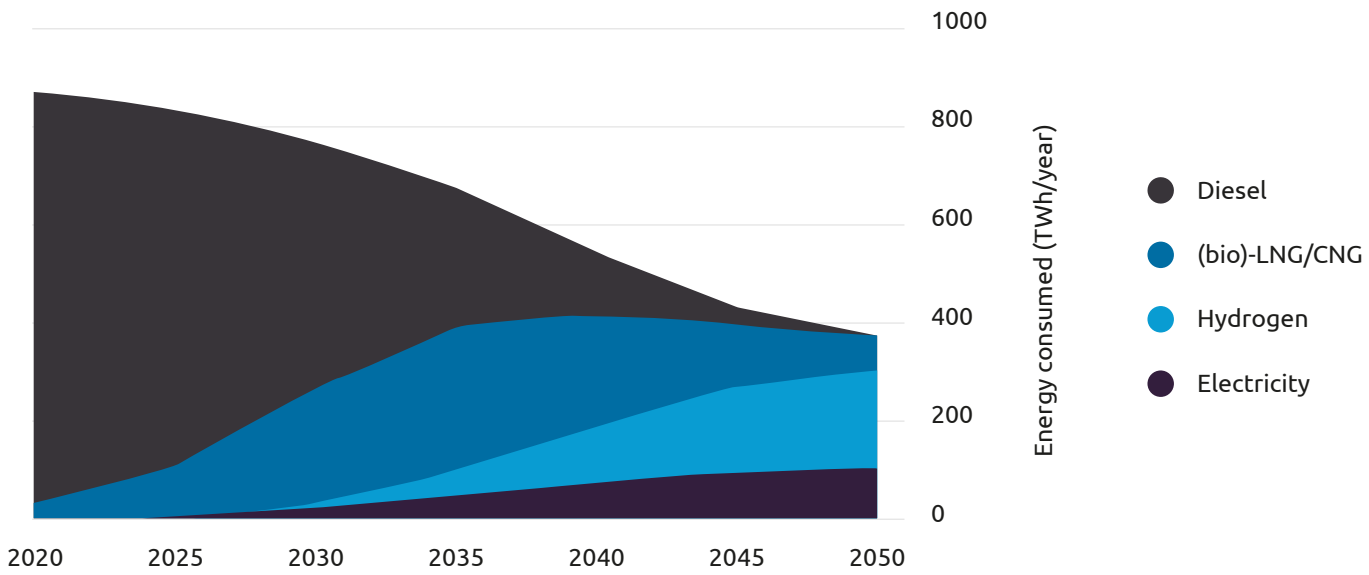
A new major project that helps raise the entire hydrogen truck market has just been set up. The objective of this initiative is to establish a European hydrogen logistic corridor, from North to South of Europe, facilitated by a partnership between Volvo-Daimler Trucks and Iveco.

At the same time, a major undertaking concerning hydrogen trucks is currently ongoing between the Scandinavian countries, Germany, and Italy. This project was triggered by two major automotive truck manufacturers, Volvo, and Daimler. They will work together in a joint venture for the development of hydrogen technology in trucks. The new joint venture is called 'Cell centric' and will start its commercial activity in 2025.[25]

The vision of Volvo and Daimler Trucks regarding electrification and hydrogen is like Toyota's vision:

"Purely battery-electric and hydrogen-based fuel-cell trucks will complement each other depending on the individual customer use case. Battery power will be rather used for lower cargo weights and for shorter distances, while fuel-cell power will tend to be the preferred option for heavier loads and longer distances."[26]

**FIGURE 7:** Pathway of European energy demand in heavy road transport from 2020-2050




Source: Gasforclimate2050.eu, 2021

Together with the Italian OEM Iveco, they will build a logistic corridor from the North until the south of Europe. This corridor traces 6,950 km of road and will allow the use of tens of thousands hydrogen trucks.[27] This goes hand in hand with a significant investment of approximately 400 hydrogen refueling stations planned along this route in Germany, Italy, and Austria with a cost of € 2,5 million per station. The total investment amounts to around € 1B.[28] [29] In order to enable this corridor to succeed, several European and Belgian firms are constantly developing ways to improve hydrogen (an overview of the most notable partners and projects can be found in the appendix).[30]

## Conclusion

As stated in the introduction, heavy road transportation is an essential segment of road transportation to be decarbonized in the current context of the climate crisis. Volvo Trucks and Daimler Group, large OEMs active in the truck sector, will create a new logistic corridor for hydrogen fuel cell trucks. They will invest heavily in the development of hydrogen fuel cell and electric trucks, as well as the infrastructure required for this logistic corridor.

In addition, some projects are initiated in Belgium to trigger the local hydrogen market for heavy transportation. Especially for heavy road transportation, numerous studies and reports identified hydrogen fuel cell trucks as a promising option to decarbonize this sector.

# INTO THE PUBLIC SECTOR: BUSES & GARBAGE TRUCKS

## Introduction

In recent years, various projects and initiatives have been started to accelerate the uptake of clean vehicles across Europe. The European Union demonstrated clear ambitions regarding clean vehicles, especially in the sector of heavy-duty vehicles and even more so in its plans for buses. The deployment of hydrogen fuel cell buses and garbage trucks might form a starting point for the overall transition to hydrogen fuel cell vehicles.

## European ambitions

In 2019, the European Commission revised and refined its Clean Vehicles Directive for clean and urban transportation. This directive promotes clean mobility solutions in public procurement tenders and applies to cars, vans, trucks, and buses. In their statement, a clean heavy-duty vehicle is defined as follows: any bus or truck using any of the following alternative fuels: hydrogen, battery electric (including plug-in hybrids), natural gas (both CNG and LNG, including biomethane), liquid biofuels, synthetic and paraffinic fuels, and LPG. This new, revised Directive also sets national targets for the public procurements of EU countries. Table 1 below, based on the European Commission's website, shows the targets set for each country in the EU.[31]

Of course, these targets are for clean buses in general (battery electric buses, plug-in hybrid buses, LPG, etc.), and not just for hydrogen fuel cell buses only. The Directive also states that at least half of the target needs to be fulfilled by procuring zero-emission buses. This last point is where hydrogen fuel cell might have an edge over other types of zero-emission buses.

"The new directive by the European Commission promotes clean mobility solutions in public procurement tenders and applies to cars, vans, trucks, and buses."

In addition to the published Directive, The European Commission also launched the Clean Bus Deployment Initiative. With this initiative, the European Commission publicly declares it will facilitate the creation of a dedicated initiative for clean buses. The European Commission has created a deployment platform where public authorities, public transportation operators, OEMs and financial organizations can exchange information, create better coalitions, and leverage potential investment opportunities.[32] Additionally, the Initiative pledged to create an expert group with actors from both the demand and supply side, to consolidate expertise on technological, financial, and organizational issues.[33]

**FIGURE 8:** Minimum percentage of clean buses in the aggregate public procurement across a Member State

| | 2021-2025 | 2026-2030 |
|---|---|---|
| **Portugal** | 35% | 51% |
| **Finland** | 41% | 59% |
| **France** | 43% | 61% |
| **Belgium, Austria, Germany, Sweden, Luxembourg, Italy, Spain, Netherlands, United Kingdom** | 45% | 65% |

Source: Europa.eu

## Business opportunity for hydrogen buses

There is a significant business opportunity when it comes to manufacturing hydrogen buses in Europe. Now, all the hydrogen buses which are funded by programs of the European Commission are produced in Europe. In this context, there is the opportunity to keep the supply chain and production of fuel cell buses within Europe. For example, if Europe would move more towards battery electric buses, then the supply chain and production of alternative energy vehicles would not be in Europe. The most important part of a battery electric bus is the battery itself, and that would be supplied from outside Europe. From this perspective, it is instrumental for the European Union to push for and shift towards hydrogen fuel cell buses to ensure a European production and supply chain, as well as the considerable number of jobs that this entails.[34]


## Projects of JIVE (EU backed projects)

The EU is committed to hydrogen buses through the Joint Initiative for hydrogen Vehicles across Europe (JIVE and JIVE2). Both initiatives are running for six years each, starting from January 2017 (JIVE) and January 2018 (JIVE2). The main objective of these initiatives is to accelerate and push hydrogen fuel cells to the fore. In fact, all the fuel cell buses which are currently operating in Europe were all funded and produced through projects such as those backed by the EU (JIVE and JIVE 2). By the end of 2021, an estimated 360 fuel cell buses should be on the road in Europe through these projects.[35] Bus manufacturer Van Hool makes up the largest part of this with 80 orders.[36]

Both Flanders and Wallonia have made clear their decision that the purchase of new buses, EV and/or hydrogen, are high on the agenda. Wallonia is very concrete in this regard in the roll-out of new HRS, with 20 HRS in 2025 and 30 in 2030. This would be a major step in the short term in the roll-out of hydrogen in the Walloon mobility ecosystem.[37] More specifically, in December 2020 the Walloon government published a tender in which it requests up to 430 new hybrid buses in the next four years. Manufacturer Solaris announced itself as one of the two candidates for the tender.[38]

## Garbage trucks

Concerning garbage trucks, there is increasingly the need for low or zero-emission vehicles to comply with the low-emission zones that are increasingly set up throughout cities in Europe. Also, garbage trucks have a significant impact on the emissions of a city, as these vehicles need to do many maneuvers and stops. These vehicles have an average fuel consumption of 65l/100km, which is significantly more than regular passenger vehicles.[39]

The European Union has set out their ambitions with the REVIVE project, whose main objective is to advance the development of fuel cell trucks by proving it to be a feasible alternative for zero-emission garbage trucks. This will be tested in an upcoming pilot, where 15 fuel cell garbage trucks will be deployed across 8 cities in Europe for the duration of two years. If this pilot turns out to be successful, it will not only have a significant impact on the progress of this technology but will also have an impact on the public authorities. The project will be able to support a broader roll-out of future hydrogen refueling stations, as there will be an increasing demand due to the hydrogen fuel cell garbage trucks.[40]

## Conclusion

The European Union and its projects are aiming to increase the understanding of both the benefits and business models for fuel cell buses and garbage trucks. With these projects, the European Union is currently playing a vital role by paving the way for OEMs and bringing them a step closer to mass-producing zero-emission fuel cell vehicles.

# HYDROGEN INFRASTRUCTURE

## Introduction

To scale-up hydrogen production and consumption, the development of a hydrogen infrastructure network to allow the transportation and use of hydrogen is crucial. Indeed, hydrogen infrastructure often provides the missing link between producers and end-users. Without this backbone, hydrogen deployment will never be able to reach its full potential and hydrogen business opportunities will never fully materialize.

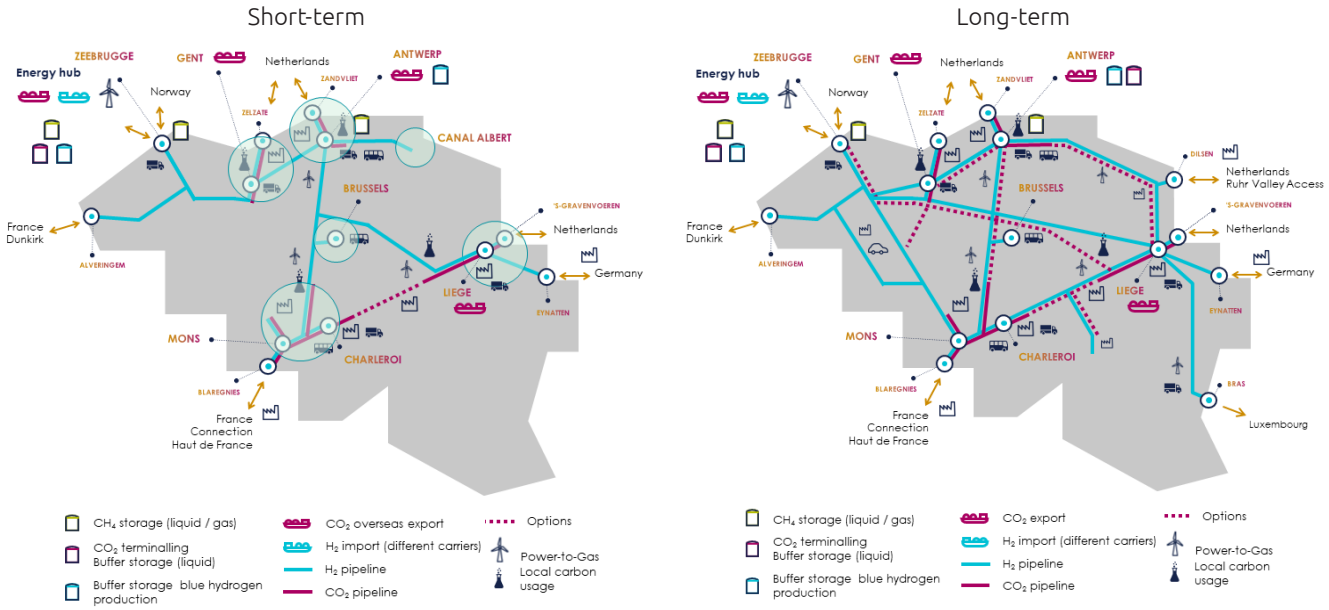
## Infrastructure in Belgium

In this context, the general view from Belgian Hydrogen stakeholders (e.g., Fluvius, Luminus) is that Belgium is very well placed to leverage its existing infrastructure and strategic (geographical) location to build a hydrogen economy. Case in point: the country's extensive network of terminals and gas pipelines represent valuable assets which it can build on to scale up hydrogen deployment. In addition, the Port of Antwerp, being one of the busiest ports in Europe and home to the continent's largest integrated chemical cluster, makes it an important link in the hydrogen import value chain.[41] Finally, being at the intersection of France, Netherlands, and Germany – countries with ambitious hydrogen plans and strategies of their own, Belgium is well placed to benefit from the expected domino effect of its neighbors' hydrogen investments.

Yet, the infrastructure needed to transport hydrogen and CO2 and to distribute these to end users is currently insufficient in Belgium: the country's current largest underground pipeline transport network of hydrogen, situated in Antwerp and owned and exploited by Air Liquide, is nevertheless limited in scale, and does not have an impact on the country at large. To enable a Hydrogen economy, there is a need for an interconnected network linking major Hydrogen production and consumption hubs. In this regard, the Federal government has vowed to build a hydrogen transportation infrastructure backbone in the context of the Recovery and Resilience Plan (RRP) which was submitted and approved by the European Commission recently.[42] According to the RRP, long-distance transportation infrastructure should not emerge immediately, and projects should initially be limited to a local scale. However, the long-term goal is to build a 100 to 160km long trajectory of transportation infrastructure, linking Belgium's key industrial hubs (i.e., Ghent, Antwerp, Brussels, and Charleroi). Although the focus will be on industry, it will also have spill-over effects on the infrastructure for hydrogen distribution for transportation (i.e., road, freight, air, and maritime). This, however, will require time (Horizon Europe) and investments (minimum € 1.4B to be invested in the next decade). Indeed, while current gas infrastructure (mentioned as an asset above) could be mobilized, there are nevertheless some adaptations that will need to be made to repurpose the existing infrastructure for hydrogen use (i.e., new compressors and engines needed to compress the hydrogen to the operating pressure of the pipeline and adapt to the density of hydrogen - which is three times more than dense natural gas and methane). Additionally, investments in new hydrogen pipelines will also be needed to complete the necessary transportation infrastructure. The gas network operator Fluxys will be tasked to lay out and build the aforementioned infrastructure. In a recent interview in De Tijd, Fluxys CEO Pascal De Buck called the next ten years 'crucial' for its development. Preparations for connections with other countries are also in full swing, primarily to the industrial area in Rotterdam and to the Ruhr area in Germany.[43]

The following illustrations, taken from Fluxys' website, show the planning for the years ahead. We can clearly see from the illustrations alone that that this infrastructure backbone

**FIGURE 9:** Short- and long-term projections of Hydrogen infrastructure in Belgium (projected by Fluxys)




Source: Fluxys.com

will be a key enabler for a series of Hydrogen applications and uses from Hydrogen use in industries, power to gas applications, to refueling stations for road transportation.

Looking specifically at hydrogen infrastructure for the automotive sector, the same observation can be made as above: without the sufficient availability of hydrogen refueling stations (HRS), the readiness and commercialization of hydrogen vehicles will not materialize. While the EU currently has close to 150 operational hydrogen refueling stations – of which 92 are in Germany alone – Belgium currently only has 4 operational HRS – including the latest addition of CMB's HRS in Antwerp that can serve ships, vehicles (750 bar), buses & trucks (350 bar).[44] HRS construction has in fact developed at a slower rate than hoped for when we look at old plans (e.g., Belgian's NECP & regional strategies) and previous objectives have not been met. Although several projects are in the pipeline (e.g., with Colruyt DATS24), Belgium is clearly lagging compared to its neighbors.

## The view of the industry

While interviewing various HRS providers and automotive companies, it was often defined as a "chicken or the egg" question: the automotive producers are reluctant to commercialize hydrogen cars because of the limited availability of HRS. At the same time, investors of HRS are reluctant to invest because there must be sufficient demand the make HRS viable. We must keep in mind that an investment of a (700 bar) HRS costs between €4M-6.5M. These investors must count, after investment, on a yearly increasing utilization of corporate or private end-customers (min. 20% yearly increasing utilization). Due to the limited number of vehicles that visit the first stations, these stations are not profitable.

Although throughout Europe (except for Germany) hydrogen cars are not significantly rolled out yet. Belgium, thanks to its young car fleet and favorable fiscal policy towards company cars, could be an ideal test market to see how consumers react to hydrogen vehicles.

The construction of an infrastructure backbone initiative from the Federal government (and Fluxys) clearly goes in that direction, but more needs to be done: a true roadmap is needed if Flanders, Brussels & Wallonia want to drive personal cars, buses, and heavy transportation with low emissions technologies, specifically on hydrogen.[45] The deployment of these stations are crucial to drive a hydrogen economy where not only industries but also EU-citizens will be significantly impacted.

# CONCLUSION

Belgium is a continually active country when it comes to hydrogen. The European Union developed several local initiatives and Belgium can truly become a testbed for creative innovative solutions. However, what we can see is that each industry has individual challenges. The core challenge is the lack of one uniform, cross-industry solution. That being said, the underlying infrastructure remains at the root of the solution.

A combined offering that would allow for a clear process to install and operate hydrogen fuel stations in and around Belgium would go a long way in reassuring reluctant players in conservative industries.

The infrastructure is in full development yet will take time. Some companies like Toyota are firm believers in hydrogen technology with investments reaching into the billions. Yet others remain skeptical. Nevertheless, an increasing amount of research and development money pours into hydrogen research, both from private and governmental investors.

Hydrogen technology has a lot of potential overall if the infrastructure is put in place. The development appears to be driven from larger B2B industries, especially trucking. In the short term, large trucks and other larger vehicles capable of accommodating a complete mobile fuel cell powertrain can benefit most from hydrogen adaptation.

Considering the limited support of the government, if hydrogen adoption is to accelerate in Belgium, the various players active in the hydrogen ecosystem need to come together and devise a clear path forward. To overcome the challenge of the missing infrastructure, OEMs should form partnerships with production and logistics operators with expertise in hydrogen. This way, customers can be made aware of the financial and environmental implications. This allows for other industries – those under pressure to deliver greener solutions, like automotive and people transportation - to pick up the pace and follow suit with their development.

A combined offering that would allow for a clear process to install and operate hydrogen fuel stations in and around Belgium would go a long way in reassuring reluctant players in conservative industries.

# APPENDIX

## 1. The electricity extraction process

### What are electrolysers & fuel cells?

The electrolyser produces hydrogen (H2) where the fuel cell produces electricity from hydrogen that drives the electric engine. The cost and the efficiency of both technologies are inherent to the success of future roll-out of hydrogen vehicles.

The electrolyser and fuel cells have similar technologies by which the processes are reversed. Where an electrolyser separates, with the use of electricity, hydrogen and oxygen, the fuel cell generates electricity by reaction of hydrogen and oxygen. As shown in the visual here below, the fuel cell, the anode is where hydrogen gas is consumed, and in an electrolyser, the hydrogen gas is produced at the cathode.[46]

## 2. Hydrogen advantages

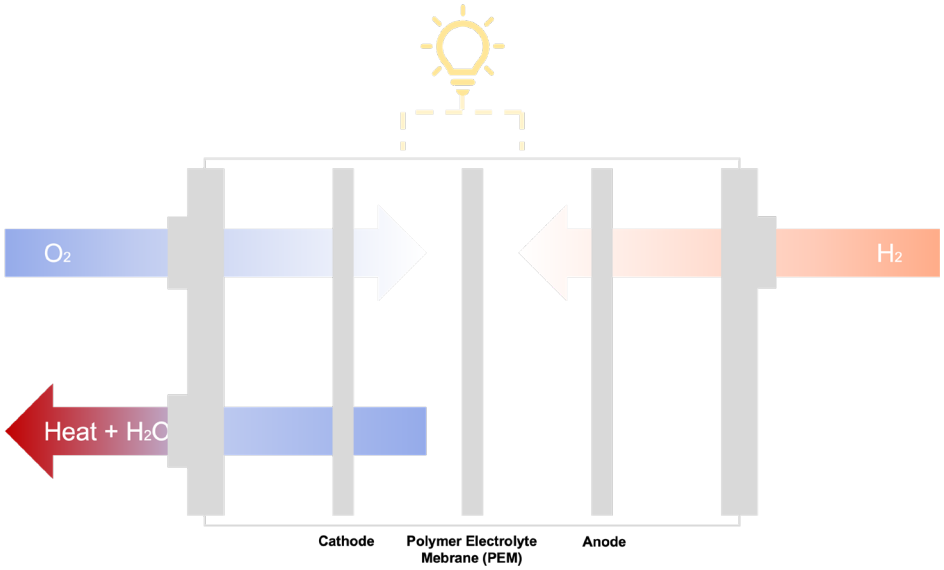
### Advantages

- Quicker to refuel for personal vehicles
- Higher energy density
- Lighter vehicles
- Less resource intensive
- New market opportunities
- Economics of scale are not at play yet
- Cross industry applications
- Industry driven innovation
- Lack of legislation
- Flexibility on how to extract energy

### Challenges

- Compression of hydrogen gas
- Slight loss due to leakage of hydrogen
- Immature technology
- Expensive and energy intense production method
- Lack of infrastructure
- Enormous investments in the technology
- Battery electric technology can be more useful for smaller vehicles
- Slow consumer adoption
- Lack of legislation
- Unique solutions per application

**FIGURE 10:** Fuel cell – H2 + O2 that generate electricity for the electric engine




Source: US Department of Energy, November 2015


21

## 3. Company overview list

| Company Name | Industry | Involvement with hydrogen | Location | Comment |
|---|---|---|---|---|
| Toyota | Automotive | Development and sales of hydrogen vehicles, promotion of hydrogen in motorsport, city of the future based on hydrogen | Japan | European HQ is in Belgium, partnership with BMW |
| BMW | Automotive | Development of hydrogen fuel cell vehicles, development of hydrogen technology | Germany | Tries gain funding through larger (more expensive) models in the range, partnership with Toyota |
| Jaguar Landrover Group | Automotive | Development of prototype for hydrogen fuel cell vehicles | United Kingdom | Uncertain commitment |
| Daimler Truck | Trucking | Development of hydrogen fuel cell vehicles, development of hydrogen technology | Germany | Benefit of north south corridor for hydrogen vehicles, joint venture with Volvo Truck |
| Volvo Group | Trucking, Buses | Development of hydrogen fuel cell vehicles, development of hydrogen technology | Sweden | Benefit of north south corridor for hydrogen vehicles, joint venture with Daimler Truck |
| Van Hool | Buses | Development and sales of hydrogen vehicles | Belgium | Sponsored by the European JIVE Project |
| REVIVE | Garbage trucks | Development of prototype garbage trucks | Europe | Sponsored by the European union |
| Fluvius | Energy | Expansion of hydrogen infrastructure and production facilities | Belgium | Build upon chemical infrastructure and gas lines running through Belgium |
| Luminus | Energy | Expansion of hydrogen infrastructure and production facilities | Belgium | Build upon chemical infrastructure and gas lines running through Belgium |
| Belgian government | Governance | Development of hydrogen capable pipelines | Belgium | Part of the recovery and resilience plan |
| Fluxys | Construction | Building of hydrogen infrastructure in Belgium | Belgium | Part of the recovery and resilience plan |
| Colruyt Group | Distribution | Building hydrogen fuel stations | Belgium | Under DATS24 brand |
| Bosch GmbH | Technology | Development of commercial hydrogen solutions | Germany | To later sell to the automotive market |
| Agfa Gevaert | Technology | Focus on hydrogen production and refinement of the technologies | Belgium | / |
| Hydrogenics | Technology | Production of pure hydrogen | Canada | Canadian-based |
| Borit | Technology | Development of hydrogen production technology | Belgium | Small-scale company |
| Atlas Copco | Technology | Specialisation in hydrogen compression technology | Belgium | / |
| Air Liquide | Distribution | Privatization of hydrogen network development | Belgium | Alternative to governmentally funded project |
| Plastic Omnium | Technology | Development of high-pressure tanks for hydrogen storage | Belgium | Small scale company |
| HydrogenPro | Technology | Development of hydrogen production technology | Norway | Backed by investment fund MHI |
| DAF | Trucking | Prototyping of hydrogen truck technology | The Netherlands | / |
| Caterpillar Int. | Large equipment | Development and production of hydrogen powered diggers and on sight power generators | United States | Large Belgian-based logistics hub |
| Panasonic | Technology | Small scale equipment manufacturing powered by hydrogen | Japan | / |
| Nouryon | Energy | Production of hydrogen | The Netherlands | In partnership with Gasunie, supported by the EU |
| Gasunie | Energy | Production of hydrogen | The Netherlands | In partnership with Nouryon, supported by the EU |
| Lateral | Yachtbuiliding | Ideation and technical mockup of hydrogen power super yacht | United Kingdom | Technical development in progress, so far only conceptual |

# REFERENCES


1: AUTOFANS, “Belgische autoproductie op 10 jaar tijd gehalveerd”, March 2021

2: AD, “Waterstof hoort niet in auto’s, vindt de hoogste baas van Volkswagen”, February 2021

3: Vroom, “Daimler stopt met waterstofautos”, April 2020

4: Tweakers, “BMW komt waarschijnlijk in 2022 met een X5-suv die op waterstof rijdt”, September 2019

5: Tweakers, “BMW test X5-suv die op waterstof rijdt op Europese wegen”, June 2021

6: Politico, “The range anxiety of driving a hydrogen car”, August 2019

7: CNBC, “Jaguar Land Rover is developing a hydrogen-powered vehicle and plans to test it out this year”, June 2021

8: CNBC, “BMW starts European road tests of hydrogen fuel cell cars”, June 2021

9: Rijksoverheid, “Overheid stimuleert de inzet van meer waterstof”, consulted in 2021

10: IEA, “Hydrogen report”, November 2021

11: Statista, “Number of passenger cars in use in Japan from 2012 to 2021”, consulted in 2021

12: Europa, “Passenger cars in the EU”, consulted in September 2021

13: Energypost, “Who will be the Hydrogen superpower? The EU or China”, August 2020

14: Michelin, “More than a mobility myth – the facts about hydrogen”, consulted in 2021

15: Topspeed, “Electric cars might still be the future, but hydrogen-burning engines could delay the inevitable”, April 2021

16: De Tijd, “Regering gaat voor grootschalige import van waterstof”, October 2021

17: EUROPEAN HYDROGEN BACKBONE, “Analysing future demand, supply, and transport of hydrogen”, June 2021

18: European Environment Agency, “Carbon dioxide emissions from Europe’s heavy-duty vehicles”, April 2018

19: Energie Transitie Nederland, “Elektrische vrachtwagen”, consulted in 2021

20: Greenbiz, “Why the future of long-haul heavy trucking probably includes lots of hydrogen”, June 2021

21: ICCT, “Zero-emission tractor-trailers in Canada”, April 2019

22: Transport Environment, “Comparison of hydrogen and battery electric trucks”, June 2020

23: NREL, “Spatial and Temporal Analysis of the Total Cost of Ownership for Class 8 Tractors and Class 4 Parcel Delivery Trucks”, September 2021

24: Waterstofnet, “1000 trucks en 25 tankstations op de as Vlaanderen, Nederland, West-Duitsland” consulted in 2021

25: Cellcentric, “Daimler Truck AG and Volvo Group fully committed to hydrogen-based fuel-cells – launch of new joint venture cellcentric”, April 2021

26: Cellcentric, “Daimler Truck AG and Volvo Group fully committed to hydrogen-based fuel-cells – launch of new joint venture cellcentric”, April 2021

27: European Commission, “Mobility and Transport”, consulted in 2021

28: Statista, “Projected number of hydrogen refueling station in Europe in 2025 and 2030, by main country”, August 2021

29: H2 Station Maps, “COSTS AND FINANCING”, consulted in 2021

30: European Commission, “CEF support to Scandinavian - Mediterranean Corridor”, May 2020

31: Eur-Lex, “DIRECTIVE (EU) 2019/1161 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL”, June 2019

32: European Commission, “Mobility and Transport”, consulted in 2021

33: Sustainable BUS, “Fuel cell bus projects in the spotlight: fleets, manufacturers, trends”, January 2021
34: Sustainable BUS, “«It’s time for large deployment of H2 buses in Europe». Interview with Bart Biebuyck (FCH JU)”, June 2020
35: Sustainable BUS, “Fuel cell bus projects in the spotlight: fleets, manufacturers, trends”, January 2021
36: Sustainable BUS, “Fuel cell bus projects in the spotlight: fleets, manufacturers, trends”, January 2021
37: FCH Belgium, “Opportunities for Hydrogen Energy Technologies Considering the National Energy & Climate Plans”, June 2020
38: Sustainable BUS, “Tender for 430 hybrid buses in Wallonie (Belgium). Solaris steps forward”, December 2020
39: VRT, “Vuilniswagens op waterstof in Antwerpen: “Eerste 2 van de 15 wagens in Europa”, November 2020
40: H2 Revive, “About Revive”, consulted in 2021
41: Euractiv, “Belgian port lays out plans for ‘massive’ imports of green hydrogen”, January 2021
42: De Tijd, “Waterstof zet de machtsverhoudingen op haar kop”, consulted in 2021
43: De Tijd, “De waterstofeconomie: wonder of waanzin?”, consulted in 2021
44: CMB, “Hydrogen Refuelling Station Antwerp”, consulted in 2021
45: Waterstofnet, “Overzicht waterstoftankstations Benelux”, September 2019
46: Fuelcellstore, “Introduction to Electrolyzers”, July 2017

# METHODOLOGY AND CONTACTS

## Methodology

This study aligns with previous studies by Capgemini Invent (notably, Capgemini Invent's 2019 'Automotive & Mobility' study and our 2020 'EV in Belgium' study) and adds timely research on the Belgian and European Hydrogen ecosystem. We leveraged unique market insights from our own industry consulting experience, held interviews with automotive and hydrogen experts, and capitalized on the latest research and trends.


## Acknowledgements

Special thanks Koen Vlaeminck (Engie), Roald Arkesteijn (Eneco), Sasa Marinic (TotalEnergies), Mariëlle Vande Lanotte (Luminus), Maarten Van Haute (Q8), Pieter Jacqmaer (Infrabel), Ben Cornelis (E-Trucks Europe), Michel Van den Brande (Fluxys), Vincent Vancaeyzeele (Fluvius), Nicolas Brahy (FiveT Hydrogen AG, Hydrogen Europe), and Jeroen Lissens (BMW Group) for their input to this study.

Much gratitude to Justine Vertommen and the IDEAN team, Kunal Adak, Prachi Manohar Jadhav, and Bart De Roeck for their contribution and efforts throughout the creation of this study.


## Contacts


**Robert van der Eijk**
Managing Director & Executive VP
Capgemini Invent Belux
robert.van.der.eijk@capgemini.com

**Jean-Michel Demoulin**
Head of Enterprise Transformation & Business Technology
Capgemini Invent Belux
jean.michel.demoulin@capgemini.com

**Guillaume Roudil**
Head of Manufacturing, Automotive & Life Sciences
Capgemini Invent Belux
guillaume.roudil@capgemini.com

**Carlos de Moura Cortes**
Head of Automotive
Capgemini Invent Belux
carlos.de.moura.cortes@capgemini.com

**Jonathan Schick**
Head of Mobility
Capgemini Invent Belux
jonathan.schick@capgemini.com

**Victor Donck**
Mobility Consultant
Capgemini Invent Belux
victor.donck@capgemini.com

**Pieter-Jan De Coninck**
Automotive Consultant
Capgemini Invent Belux
pieter.jan.de.coninck@capgemini.com

**Alexandre Smars**
Automotive/Energy Consultant
Capgemini Invent Belux
alexandre.smars@capgemini.com

## About

## Capgemini Invent

As the digital innovation, design and transformation brand of the Capgemini Group, Capgemini Invent enables CxOs to envision and shape the future of their businesses. Located in more than 36 offices and 37 creative studios around the world, it comprises a 10,000+ strong team of strategists, data scientists, product and experience designers, brand experts and technologists who develop new digital services, products, experiences and business models for sustainable growth.

Capgemini Invent is an integral part of Capgemini, a global leader in partnering with companies to transform and manage their business by harnessing the power of technology. The Group is guided everyday by its purpose of unleashing human energy through technology for an inclusive and sustainable future. It is a responsible and diverse organization of over 325,000 team members more than 50 countries. With its strong 55-year heritage and deep industry expertise, Capgemini is trusted by its clients to address the entire breadth of their business needs, from strategy and design to operations, fueled by the fast evolving and innovative world of cloud, data, AI, connectivity, software, digital engineering and platforms. The Group reported in 2021 global revenues of €18 billion.

Get The Future You Want

**www.capgemini.com/invent**