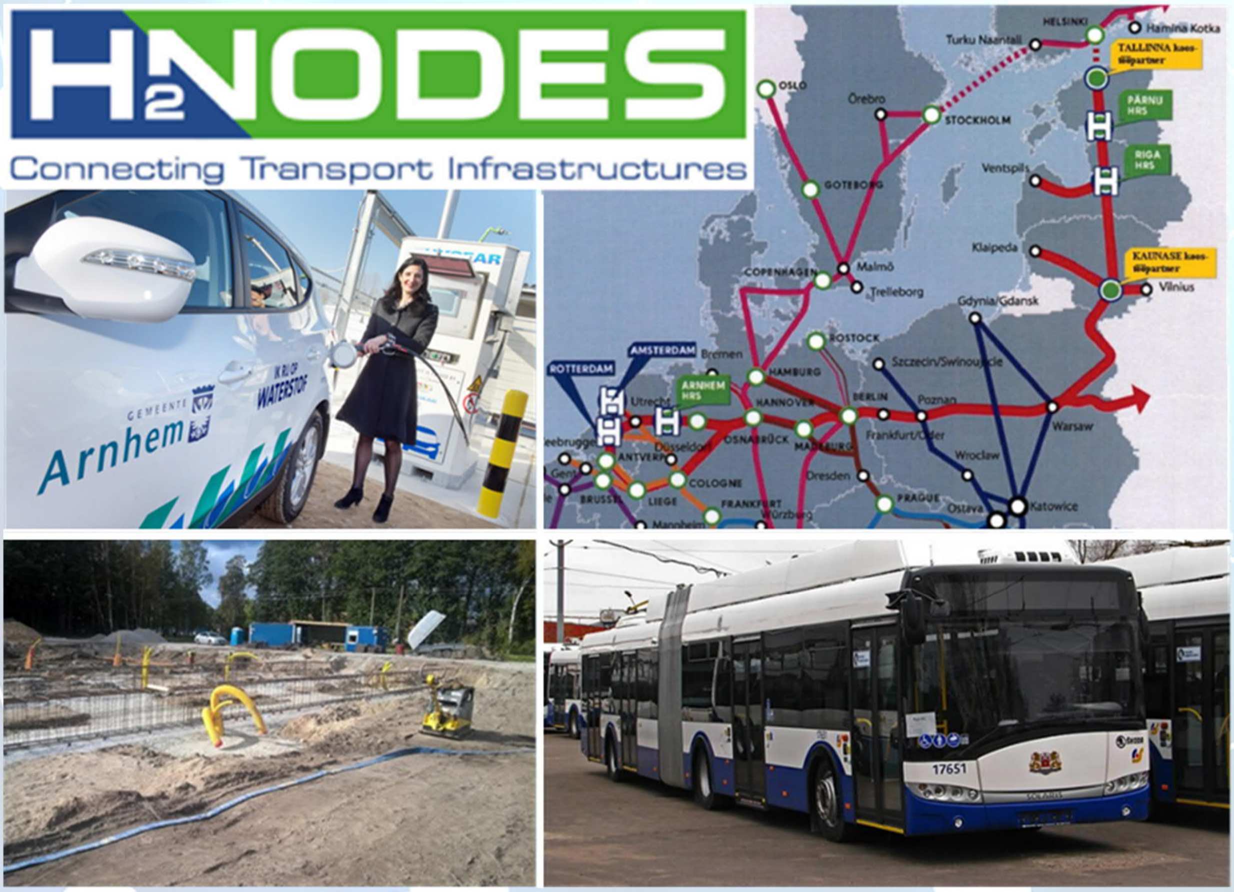
Milestones H2Nodes

Milestone 11

Hydrogen refuelling station upscaling



Milestone 11 Report

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1. Introduction

This report describes the upscaling potential, strategy and plans for the Arnhem HRS for the coming years. The starting point for regional upscaling is the reference hydrogen refuelling demand based on Sub-Activities 3.1 and 3.2 of the Action as described in the H2Nodes Grant Agreement.

Sub-Activity 3.1 includes one FCEV (Fuel Cell Electric Vehicle) car and two FCEV buses that serve the objective of real-life trials, making it possible to monitor and evaluate the use of FCEVs.

Sub-Activity 3.2 includes the mobilisation of local actors and users. In the case of HRS (Hydrogen Refuelling Station) Arnhem this will be achieved through the active mobilisation of an initial group of FCEV drivers in the Arnhem region demonstrating the specific merits of FCEVs.

Chapter 2 explains this reference situation in more detail.

Upscaling of regional HRS capacity is related to hydrogen refuelling demand for the coming years in addition to this reference demand currently serviced by HRS Arnhem. This additional demand originates from policy goals and actions set at two levels: the national level and the regional level. The characteristics and scope of these two levels are illustrated below on the basis of the pattern of the market penetration of innovative products over time, as described by prof. E.M. Rogers[1].

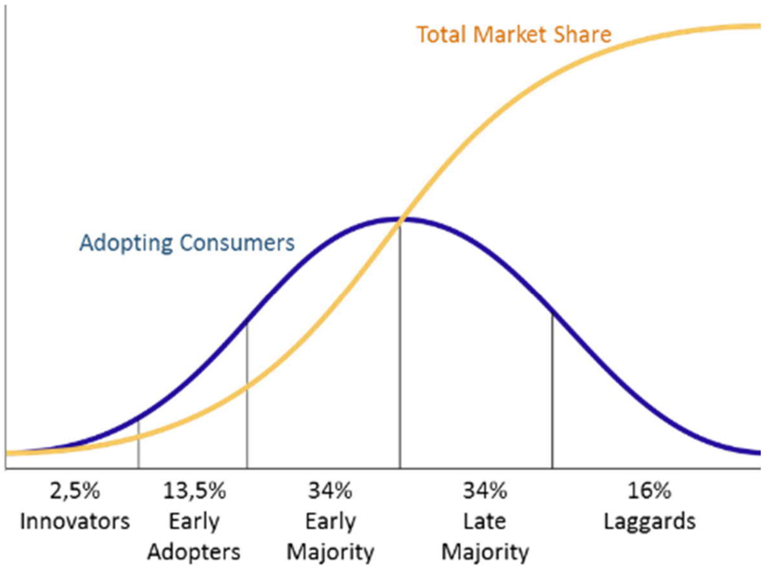

Figure 1. The S-curve showing the acceptance of innovation in 5 phases.

This orange S-curve in figure 1 showing the overall market penetration of innovative products. In relation to the energy transition this S-curve is also referred to as the transition curve, showing the overall market penetration of sustainable energy sources, at the expense of non-sustainable energy sources. In relation to the mobility-related transition this S-curve indicates the total market

[1] Diffusion of Innovations, E.M. Rogers

penetration level of zero-emission vehicles in general or fuel cell electric vehicles in specific. In this report this will also be referred to as the upscaling curve.

This upscaling results from customer groups who decide over time to replace their fossil fuelled vehicle with a zero-emission alternative or, more specifically, an FCEV. The blue line in figure 1 shapes five consecutive customer groups with each group having its specific characteristics:

- Innovators are people who want to be the first to try the innovation. They are venturesome, interested in new ideas and willing to take risks.
- Early Adopters are people who represent opinion leaders. They are already aware of the need to change and very comfortable adopting new ideas.
- The Early Majority consists of people who are rarely leaders, but they do adopt new ideas before the average person. They typically need to see evidence that the innovation works.
- The Late Majority consists of people who are sceptical of change, and will only adopt an innovation after it has been tried by the majority.
- Laggards are people are bound by tradition and very conservative. They are very sceptical of change and are the hardest group to bring on board.

The upscaling curve is for the most part shaped at a national level with the national Climate Agreement[2] as a guideline in terms of targets as well as regulatory and supportive policy instruments to meet those targets. Consequently, the upscaling or regional HRS capacity is the regional reflection of the transition targets and instruments that are mostly set at the national level, leading to the deployment of more FCEVs.

In addition to incentives set at the national level, the initial development or upscaling of regional HRS capacity can also result from activities initiated or executed at this regional level, including:

- the launching of demonstration projects where the supply of hydrogen refuelling facilities is combined with the creation of early regional demand as a means to anticipate future larger growth units as a result of policies and instruments set at the national level.
- the tendering of public transport concessions which in The Netherlands is the responsibility of regional public authorities. In the case of the Arnhem region, the Province of Gelderland is such a public transport authority.

One of the required elements of this milestone report is to anticipate growing demand for hydrogen, taking the reference situation as a starting point. As explained above, this growing demand is determined by developments and actions at the national level as well as the regional level.

Chapter 3 drafts FCEV upscaling initiated at the national level.

Chapter 4 drafts FCEV upscaling initiated at the (Arnhem) regional level.

Chapter 5 describes how FCEV upscaling is translated in to hydrogen demand.

Chapter 6 concludes this milestone report with a strategic framework for upscaling as well as the explanation of the existing upscaling plans.

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[2] Klimaatakkoord, The Hague, June 28th, 2019, www.klimaatakkoord.nl

2. Reference Hydrogen Refuelling Demand

The reference hydrogen refuelling demand is the demand that created within Activities 3.1 (2 FCEV buses and 1 FCEV car) and 3.2 (mobilisation of local actors and users) of the Action and is known or expected to be continued after the end date.

2.1 FCEV buses

The two FCEV buses operated by the Gelderland public transport company Syntus in the Veluwe public transport concession area will not be deployed in the period after the Action has ended.

In 2019 the Veluwe public transport concession was re-tendered by the provinces of Gelderland, Overijssel and Flevoland as part of a larger new public transport concession that covers significant parts of all three provinces. This concession was granted to Keolis, a merger of various regional Syntus public transport companies, including Syntus Gelderland. This public transport concession contract was tendered as a zero-emission contract, leaving the decisions about the composition of the bus fleet to the bidders. Keolis included a 100% BEV bus fleet in its bid. The new concession period will start in mid-December 2020. The two FCEV buses will be taken out of service as the specific connections will be operated by BEV buses that also provide zero-emission transport.

2.2 FCEV cars

The FCEV car that is used to produce test results (as part of Activity 3.1, used by the city of Arnhem) will remain in service. Furthermore Activity 3.2, the mobilisation of local actors and users, is specifically focused on the recruitment of a group of FCEV drivers in the Arnhem region.

The activity mobilisation of local actors and users is described in the Milestone 17 report. The most relevant aspects in relation to the determination of the reference demand are:

- the fact that multiple public events were organised to demonstrate FCEVs and to advertise HRS Arnhem as a nearby refuelling location for local and regional users;
- the availability of a special deal for a first group of motorists deciding to drive an FCEV car, including a 50% discount on the hydrogen fuel price, and extra services such as free assistance at the roadside if required.

but despite the impact of the corona virus and technical problems at the refueling station it is expected that a that a group of about 40 extra drivers will be the result at the end of July. The original target of 90 FCEVs as a direct result of demand aggregation activities (including 90 contracts) will not be reached. With respect to the market projections as a basis for the forecast of future hydrogen demand, we assume that as an indirect result of demand aggregation activities the remaining 50 cars can be added to the current group of approximately 40, not by the end of 2020, but in the years after. Currently the 700 bar facility does not function as it should. As soon as the 700 bar facility has an (almost) 100% performance level, some market pull effects can be expected, as it seems that the current lower performance level comes with a wait-and-see approach from potential users.

2.3 Reference demand versus capacity

Not all first movers are on the road yet, so the available refuelling data for this group are limited and also expected to be distorted as road traffic has significantly decreased as a consequence of COVID-19-related prevention actions.

The reference demand per day per vehicle is therefore estimated. This is done as follows:

number of kilometres per year / 100 × fuel consumption (kg per 100 km) / 365 × HRS loyalty

with:

- distance driven per vehicle: 13.000 km per year[3] or 35,6 km per day
- fuel consumption (0,01 1 kg per km)[4]
- HRS Loyalty[5]: 100%: it is assumed that 25% of all refuelling session are done elsewhere, but that this 25% “loss” is compensated by other FCEVs refuelling at HRS Arnhem.

The free capacity is the total technical capacity of HRS Arnhem minus the reference demand:

Technical Capacity	260 kg/day
Reference Demand: 35,6 km/day (distance per vehicle) × 0,01 kg H2 per km (fuel consumption) × 90 FCEVs	32 kg/day -/-
Free Capacity	228 kg/day

A free capacity of about 88% means that from a technical capacity point of view HRS Arnhem will be able to facilitate a significant part of the additional refuelling demand without having to expand. This is in line with the intention to have a future proof capacity in place at HRS Arnhem.

[3] This equals the average distance covered by a car in The Netherlands in 2018. Source: Central Bureau for Statistics (Statline Database).
[4] Based on Hyundai Nexo, source: Van der Linden Groep
[5] HRS loyalty expresses which part of the refuelling of the underlying fleet are done at a particular HRS.

3. FCEV upscaling initiated at the national level

3.1 Introduction

As explained in chapter 1 the regional upscaling of the FCEVs as one of the two zero-emission alternatives to ICE vehicles (BEVs are the other alternative) can be broken down into upscaling initiated at the national level and upscaling initiated at the regional level.

This chapter describes the FCEV upscaling initiated at the national level. Paragraph 3.2 describes the policy framework as the basis for upscaling. Paragraph 3.3 specifies the upscaling potential per vehicle type on a national level.

3.2 National Level Policy Framework For FCEV Upscaling

3.2.1 The National Ambition In Milestones

The National Climate Agreement[6] is the overall framework that includes the targets, rules & regulations and incentives for all paths of the overall energy transition. Mobility is one of these transition paths. This part of the Climate Agreement is the result of negotiations between public law makers, non-governmental organisations (such as environmental interest groups) and groups representing the mobility sector.

The Climate Agreement sets the path towards 100% zero-emission mobility in 2050. The upscaling potential is determined by various factors such as

- the availability and performance levels of zero-emission vehicles;
- the total cost of ownership of these vehicles;
- the emergence of a market for used zero-emission vehicles; and
- mobility innovations in the field of self-driving vehicles and mobility-as-a-service concepts.

This results in vehicle upscaling curves that for specific user groups or vehicle types are translated into user/vehicle specific agreements, such as the administrative agreement zero-emission bus, zero-emission target-groups transport , the covenant zero-emission cleaning vehicles and the green deal zero-emission city logistics.

The abovementioned path towards 100% zero-emission mobility is shaped by a milestone planning which ambition-levels quantified for the years 2025, 2030 and 2050. Table 1 contains an overview of these milestones for zero-emission vehicles in general and for FCEVs in particular.

[6] Klimaatakkoord, The Hague, June 28th, 2019, www.klimaatakkoord.nl

General milestones	FCEV-specific milestones
2025 • all newly added public transport buses are zero-emission; • 100% of all vehicles deployed for target-groups public transport are zero-emission; • 50% of all taxis are zero-emission; • 50.000 zero-emission vans; • environmental zones implemented in 30-40 larger municipalities; all cars, vans and medium trucks used for city logistics and entering environmental zones have to be zero-emission as well as all newly sold trucks and trailers.	• 15.000 FCEV cars • 3.000 FCEV heavy duty vehicles • 50 HRSs
2030 • all public transport buses are zero-emission; • all vehicles entering environmental zones are zero-emission; • 115.000 zero-emission vans; • all newly sold passenger cars are zero-emission; • overall 30% reduction of CO2-emissions by long-haul freight transport • 8 billion kilometres reduction of business-related mobility by car.	300.000 FCEV cars
2050 all mobility zero-emission.	

Table 1. Zero-emission milestone planning laid down in the Climate Agreement

3.2.2 Rules and Regulations

A framework of binding rules and regulations is currently being prepared. The exact outcome is determined by the zero-emission mobility ambitions and the availability of suitable zero-emission vehicles. The most significant first regulatory step is expected to become effective in 2025 on the level of zero-emission zones in 30-40 larger municipalities[7]. These rules will deny entry to zero-emission zones of all non-zero-emission cars, vans and medium trucks used for city logistics as well as all heavy-duty vehicles deployed for inner-city construction works. The entry of all other non-zero-emission heavy-duty trucks and trailers will be either totally denied, or only denied to newly sold vehicles with the possibility to grant temporary access to existing heavy-duty trucks that meet the Euro 6 environmental standards.

The set objectives for zero-emission bus transport and zero-emission special purpose taxis is secured through the tendering of public transport commissioned by regional transport authorities. The deployment of zero-emission vehicles is a knock-out criteria, meaning that only bids including zero-emission vehicles are eligible. The extent to which BEV-buses or FCEV-buses are operated within a public transport concession is at the discretion of the bidding public transport companies.

[77] https://www.greendealzes.nl/

3.2.3 Incentives

At this moment the upscaling of FCEVs is for the most part determined by various incentives, encouraging but not enforcing their deployment[8]. Almost all incentives are set on the level of zero-emission vehicles, not discriminating between BEVs and FCEVs. The most important incentives are:

- no annual road taxes for electric vehicles until the year 2025;
- no private motor vehicle tax unit the year 2025 for all zero-emission vehicles;
- until the year 2026 the taxation of the private use of an electric business vehicle is set at a lower level. This taxation is based on the catalogue price of the vehicle and applies to a maximum of EUR 50K for BEVs and has no maximum for FCEVs;
- from 1 July 2020 a subsidy for all privately owned or leased electric vehicles of EUR 4K for new cars and EUR 2K for used cars in 2020 and 2021 – this subsidy arrangement will be prolonged until the year 2025 but the exact amounts for the period after 2021 are yet to be determined;
- all zero-emission vehicles deployed for business purposes are eligible for fiscal incentives under the Environmental Investment Rebate provision and Arbitrary Depreciation of Environmental Investments provision – this means that the purchase of such vehicles comes with the option to lower the level of taxable net income.
- As from 2023 the Dutch government will introduce a heavy goods vehicle (HGV) charge. This is a charge on a per kilometer basis. The tariff is around EUR 0,15 per kilometer on average. Depending on the weight and euro class of the HGV: the lighter and cleaner the vehicle, the lower the charge[9]. The goal is to reinvest the income of this scheme in sustainability measures in the sector

3.3 FCEV Upscaling Per Vehicle Type

3.3.1 Overall Upscaling Potential

The total upscaling potential of FCEVs starts with the determination of the total theoretical upscaling potential of electric vehicles, BEVs and FCEVs. This theoretical upscaling potential consists of a forecast of the total number of vehicles per vehicle type through extrapolation[10] minus the total number of existing electric vehicles per vehicle type in May 2020.

Table 2 shows the total number of electric vehicles (BEVs and FCEVs) per vehicle type in May 2020.

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[8] https://www.rvo.nl/onderwerpen/duurzaam-ondernemen/energie-en-milieu-innovaties/elektrisch-rijden/beleid

[9] Source: Brochure “Introduction of Heavy Goods Vehicle Charge”, Ministry of Infrastructure and Water Management, September 2019

[10] This extrapolation is based on official number released by the Netherlands Central Bureau of Statistics. The base year is 2018 and the extrapolation is developed on historical growth rates per vehicle per fuel type in the period 2012-2018. Refer to Annex 1 for details.

	2020/5
cars	
- BEV	119.229
- FCEV	253
vans - BEV	4.944
medium trucks - BEV	147

Table 2. Number of BEVs and FCEVs per vehicle type in May 2020[11]

Table 3 shows the theoretical upscaling potential of electric vehicles as defined above.

	2020	2025	2030[12]
cars	8.554.367	9.029.419	9.537.953
vans	894.873	924.343	954.787
medium trucks <12t	68.797	62.314	56.441
heavy-duty trucks >12t	24.416	24.407	24.399
trailers	98.064	107.612	118.088
coaches	4.667	4.226	3.827
buses	6.384	6.109	5.846

Table 3. The total theoretical upscaling potential of electric vehicles based on the extrapolation of the number of non-zero-emission vehicles per vehicle type (Source: Central Bureau of the Statistics – Statline Verkeersprestaties)

The number of vehicles shown in table 3 are displayed as total upscaling potential for zero-emission vehicles up to the year 2050 (assuming than all vehicles will be zero-emission then). The actual course of the upscaling is vehicle type specific (explained in the following paragraphs) and within the upscaling per vehicle type the trade-off between BEVs and FCEVs will be set as car owners and users will make their choice for one of these technologies.

[11] Source: Netherlands Enterprise Agency https://www.rvo.nl/onderwerpen/duurzaam-ondernemen/energie-en-milieu-innovaties/elektrisch-rijden/beleid

[12] For the period after 2025, the actual number of vehicles is expected to deviate from the reference based on extrapolation of historical data, given the development of mobility as a service concepts with the objective to have mobility requirements serviced by fewer vehicles. However, within the context of this milestone report, the determination of the number of vehicles is not an objective in itself, but a component to determine the demand for hydrogen. This demand will be based on number of vehicles multiplied by the average distance travelled per vehicle. This number will have a smaller deviation as mobility as a service concepts will also lead to a larger average distance travelled per vehicle, as a consequence of the intended more efficient deployment of each vehicle.

Paragraphs 3.3.2 to 3.3.7 contain an estimate of the upscaling potential of FCEVs at the national level.

3.3.2 Cars

The ambition level of FCEV cars is set at 15.000 for the year 2025 and 300.000 for the year 2030. If we assume that the overall market potential for FCEVs equals the number of ICE-diesel cars[13][14] then the 2025 ambition level equals 1,2% of the potential and the 2030 level equals 24% of the potential.

However, the following factors explain why the ambition levels deviate from this ICE-diesel car reference:

- Diesel cars have a lower total cost of ownership when used for longer distances. This is mostly determined by the lower fuel price of diesel compared to petrol. FCEVs do not have a similar cost advantage.
- The availability of FCEV brands and models is limited compared to BEVs. Currently only Hyundai (Nexo) and Toyota (Mirai) sell FCEVs on the Dutch market. Both vehicles are positioned in the higher price segment with a purchasing price higher than EUR 80.000. Other brands that are expected to come with FCEVs are BMW (i Hydrogen NEXT) and Audi (H-tron), also positioned in the higher segment. A few years ago Mercedes-Benz introduced the Mercedes-Benz GLC F-Cell with a limited availability. Daimler announced that it will not continue the introduction of new FCEV models in the car segment. Its future FCEV activities will be focused on the truck vehicle segment[15].
- Hyundai experiences a demand for FCEVs that exceeds the current production capacity. This had led to delivery delays and price increases[16]. It is unknown when the delivery times are back on track.

This explains the 2030 ambition level of 300.000 FCEV cars in 2030. However, the ambition level of 15.000 in 2025 is not a realistic market expectation, given the fact that the current number of FCEV-cars is 253 and that OEMs (Original Equipment Manufacturers) other than Hyundai and Toyota still have not yet introduced their FCEV models.

[13] The reference number of diesel cars is 1,3 million (on a total car volume of 9,5 million).
[14] Diesel cars are currently mostly used by drivers that travel longer distances on an annual basis: about 24.000 km per year compared to 11.000 km for vehicles using other fuels (source: Netherlands Central Bureau for Statistics, 2018). Taking the number of diesel cars as a reference is based on the assumption that the competitive edge of FCEVs is a structurally longer driving range than BEVs and a shorter refuelling time than BEVs.
[15] “Mercedes gelooft niet meer in waterstof voor personenauto's”, Algemeen Dagblad, 20 April 2020
[16] Grote vraag naar Hyundai Nexo drijft Nederlandse prijs op”, Autoweek, 4 oktober 2019

3.3.3 Vans

The demand for zero-emission vans is expected to be mainly driven by the upcoming zero-emission zones and the 100% zero-emission target in 2025 for special purpose public transport (mainly operated by vans). The Climate Agreement assumes a total number of 50.000 zero emission vans in 2025 and 115.000 in 2030. This seems to be modest in relation to a total number of 845.000 existing vans in 2020, but ambitious in relation to a total of less than 5.000 zero emission vans (all BEVs) in May 2020.

FCEV-vans have the potential advantage of a longer driving range compared to BEVs, especially given the fact that one of the first models that have become available are converted BEVs, such as the Volkswagen Transporter FCEV, which is a Transporter BEV with an added fuel cell[17]. Furthermore, FCEV vans are suitable to tow a trailer up to 2.200 kg. Volkswagen has a similar FCEV-van available, the E-Crafter HyMotion. This OEM expects that this FCEV-van will become cost competitive by 2025.

Renault is introducing hydrogen fuel-cell Kangoo and Master vans in 2020. It will give them three times more range than the current battery-electric versions. Developed in partnership with Symbio, a Groupe Michelin subsidiary, the Kangoo ZE Hydrogen and Master ZE Hydrogen will boast ranges of over 350km, compared to 120km for the Master Z (BEV) and 230km for the Kangoo ZE (BEV), enabling their use for long-distance fleets[18].

As is the case with FCEV-cars, the number of available FCEV-vans is still limited compared to BEV-vans. However, Volkswagen and Renault are major vehicle suppliers in the van segment and Mercedes Benz is currently working on the introduction Sprinter F-Cell[19].

The FCEV-van potential is estimated at 24% of all current diesel vans – similar to the estimated number of FCEV-cars compared to the total number of diesel cars. This corresponds with a 23% FCEV share in all vans (this percentage is just a bit lower as most current vans have diesel engines). which equals 12.000 FCEV-vans in 2025 and 26.000 vans in 2030.

3.3.4 Medium Trucks

The medium truck segment is comparable to the van-segment in the sense that these vehicles are often deployed in urban areas for city distribution purposes. The plans to have a large number of zero-emission zones in place as from 2025 will be a significant incentive to deploy zero-emission vehicles in this segment[20].

This segment has more in common with the van-segment: the limited number of available FCEVs. BEV medium trucks are already available, FCEV-medium trucks are now at the beginning of their introduction. Most FCEV medium trucks are based on earlier released BEV-models, such as the Mitsubishi Vision F-Cell, built in co-operation with Mercedes Benz. a 7,5 tons medium truck, fueled by

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[17] Century Autogroup cells this vehicle, which is converted by Holthausen Clean Technology (source: century.nl)
[18] “Renault to add hydrogen fuel-cell vans in 2020”, ITT Hub, Media, 22 October 2019
[19] https://media.mercedes-benz.nl/diversificatie-van-lokaal-emissievrij-rijden-concept-f-cell-sprinter/
[20] https://www.greendealzes.nl/

both batteries and a fuel cell. This combination provides these vehicles with a larger driving range compared to BEVs. FCEV-medium trucks are also a solution to the potential problem of a shortage of charging points for BEVs.

The upscaling potential in the short term is limited by the fact that OEMs follow a strategy of first introducing their BEV-models to the market, followed by an FCEV-version of the same model. A possible solution for this shortage is the purchase of a BEV-medium truck and have it converted to an FCEV at vehicle conversion suppliers such as Holthausen or Ginaf. This however cannot be done at a large scale due to limited conversion capacity and given the significant costs of such a conversion.

An estimate can't be given at this point.

3.3.5 Heavy-duty Trucks

Heavy-duty trucks (including trailers) are not yet commercially available. In the van and medium truck segment most OEMS follow a strategy of introducing their BEV-models first, followed by FCEV-versions of these initial BEV models. BEV-technology is considered to be insufficient for a significant part of the heavy-duty truck market, especially the long haul segments and segments that require high performance, such as high-performance hydraulics. This is a major reason why Hyundai and Toyota are expected to be the first OEMS introducing FCEV heavy-duty trucks to the market. Toyota is currently developing a heavy duty-truck with a 600 km driving range. Hyundai is testing truck in Switzerland[21] and heavy-duty truck were also tested in the H2 Share project[22]. Nikola and Iveco are expecting to introduce a hydrogen truck with a 1.000km range to the market in 2021[23].

Upscaling of about 60.000 heavy duty trucks will probably not start before 2025, given the fact that the vehicles are still being developed and transport companies need time to extensively test new vehicles.

3.3.6 Coaches

The Climate Agreement does not mention any specific policy for coaches. The FCEV-technology for buses is available, but given the EU-wide policy stimulating the deployment of zero-emission public transport buses, we estimate that the upscaling of FCEV-coaches will for the most part take place after 2025.

3.3.7 Buses

The transition of the upscaling of zero-emission public transport buses is agreed in the Administrative Agreement Zero Emission Bus Transport and operationalised through a system of public tendering of public transport concessions. This tendering process is carried out by regional transport authorities. The fact that zero-emission for public transport can be “enforced” by this regional public tendering, means that all newly added buses in 2025 will be zero-emission and in 2030 the entire fleet of public

[21] https://imotion.hyundai.nl/hyundai-levert-1600-waterstoftrucks-h2-xcient-aan-zwitserland/
[22] https://rwsenvironment.eu/news/2018/rijkswaterstaat/
[23] https://www.iveco.com/en-us/press-room/release/Pages/CNH-Industrial-brands-IVECO-and-FPT-together-with-Nikola-Motor-Company.aspx

transport buses. The share of FCEV-buses is hard to predict as FCEV buses currently only operate in demonstration projects, such as the FCH-JU/CEF JIVE project.

4. FCEV Upscaling initiated at the regional level

4.1 Introduction

As explained in chapter 1 the regional upscaling of the FCEVs as one of the two zero-emission alternatives to ICE vehicles (BEVs are the other alternative) can be broken down into upscaling initiated at the national level and upscaling initiated at the regional level.

This chapter describes the FCEV upscaling initiated at the regional level. Upscaling in the Arnhem region originates from two main activities: the launchings of regional FCEV demonstration projects, described in paragraph 4.2 and the tendering of public transport, described in paragraph 4.3.

Paragraph 4.4 specifies the upscaling potential per vehicle type initiated by these regional level activities.

4.2 The launching of regional FCEV demonstration projects

Demonstration projects serve multiple regional goals:

- The creation of awareness about the fact that road transport is an essential part of the overall energy transition and requires the transition to zero emission vehicles.
- The creation of awareness about the characteristics of FCEVs as one of the two zero-emission alternatives to ICE vehicles (BEVs are the other zero-emission alternative).
- The establishment of a basic HRS network coverage to facilitate growing demand as a result of upscaling that originates at the national level. The active stimulation of early refuelling demand on a regional scale leads to a revenue stream that otherwise would not yet have existed. The combination of significant HRS capital expenditure (usually in the range of EUR 1 million to EUR 3 million) with low early market demand and insecurity about upscaling is the main reason that HRS operators and their investors are currently reluctant to build and operate totally private funded HRSs. This is referred to as the Valley of death: all funds are invested while lacking a clear forecast on when and to which extend these funds will be recovered[24].
- The branding of the region as an economic hydrogen region. The region already includes a wide range of highly innovative companies that are active in various segments of the hydrogen market. This is a growth market in terms of innovation, employment and regional earning capacity, as illustrated by a recently released hydrogen fact sheet[25].

Currently the Province of Gelderland is closely involved in two of such demonstration projects: The JIVE2 bus+ project and the H2 truck initiative.

[24] The Valley of Death is extensively described in the report “HIT-2 Corridors Activity 3, Strategic Corridor Analyses and Plans”, January 2015

[25] The broader importance of hydrogen for the province of Gelderland is summarised in the factsheet “Gelderland, Silicon Valley of hydrogen technologies”, Kiemt, https://www.kiemt.nl/wp-content/uploads/2019/10/KIEMT_FACTSHEET-EN_DIG-1.pdf

4.2.1 The JIVE2 Bus Initiative

JIVE is the Joint Initiative for hydrogen Vehicles across Europe project aiming at the deployment of a total of nearly 300 FCEV buses and associated refuelling facilities across Europe[26]. The main objectives of JIVE are:

- to demonstrate that fuel cell buses are commercially viable for bus operators to include in their fleets;
- to empower local and national governments to regulate for zero emission propulsion for their public transport systems.

This European demonstration project comes with funding from the FCH-JU (Fuel Cells and Hydrogen Joint Undertaking) for the deployment of the FCEV buses and funding from CEF (Connecting Europe Facility) for the associated hydrogen refuelling infrastructure. The JIVE project ends in late 2023. About 150 FCEV buses are already operational under the first tranche (JIVE1). The second tranche (JIVE2) aims at a total of 152 FCEV buses. This number has not been reached yet, due to the fact that some regional participants cancelled their participation.

The province of Gelderland has resolved to step into the released position as a result of this cancellation. The Gelderland proposal includes the deployment of 10 FCEV buses by the end of this year as the JIVE project end late 2023 and requires a minimum deployment period of 36 months for at least 50% of the involved fleet.

These FCEV buses can be deployed in the existing public transport concession Achterhoek-Rivierenland. This public transport concession is currently operated by Arriva and will last at least for about 4 years, enough to comply with the 36 months minimum period. From the regional point of view this offers the opportunity to continue having FCEV buses in service for a longer period, even now Keolis/Syntus has decided to operate the Veluwe concession area with a fleet of BEV buses only.

Furthermore, the deployment of 10 FCEV buses in the Achterhoek-Rivierenland concession area creates the opportunity to develop a second HRS in the region, as the refuelling demand of 10 FCEV buses creates a significant and constant revenue stream for the HRS operator. The province of Gelderland will demand that such an HRS is publicly accessible for other FCEVs as well, so that it can also support the upscaling within other vehicle segments. The location of this HRS will most likely be Zutphen, where the current operator of this concession has its main bus garage.

4.2.2 The H2 Truck Initiative

The H2 truck initiative refers to the ambition of the Province of Gelderland and the transport sector to initiate a demonstration project more specifically (but not exclusively) targeted at transport and logistics activities. As explained in paragraph 3.3.5 the characteristics of FCEV trucks and road tractors make them particularly suitable as zero-emission alternatives to diesel trucks and road tractors in the heavy-duty segment. Upscaling of zero emission trucks in general and FCEV-trucks and road tractors in particular will soon have to start in this segment.

The Province promotes a demonstration project concept that is similar to HRS Arnhem in the sense that it includes the development of an HRS in combination with a mixed FCEV fleet using it. In this

[26] https://www.fuelcellbuses.eu/projects/jive-2

case heavy duty trucks and road tractors are specifically targeted so that users of these vehicle types get the opportunity to experience the deployment of FCEV trucks in their specific transport operations.

Furthermore, the additional regional HRS capacity created as a part of this demonstration project can also be used to facilitate the future growths of refuelling demand originating from policy and incentives set at the national level. And finally, this demonstration project contributes to the wider goal of positioning hydrogen-related activities in terms of regional branding as the region has early refuelling facilities available for all vehicle segments (cars, vans, medium trucks, buses, heavy duty trucks and road tractors).

This demonstration project is now in the preparation phase. A definite scope and location have not yet been determined but a recent study[27] includes all feasibility aspects, such as specific private sector appetite to participate, specific transport vehicles and operations qualifying for FCEV-deployment, availability and characteristics of fuel cell trucks replacing ICE trucks and available funding.

It is expected that this demonstration project will include about 10 FCEV trucks, possibly in combination with the deployment of fuel cell forklifts[28]. 's-Heerenberg en Park 15 Heteren are on the top of suitable locations.

4.3 The tendering of public transport concessions

Public transport is organised through a system of regional concessions for two main types of transport: general public transport and special purpose public transport.
General public transport includes regional buses and trains available to the general public, mostly on a fixed timetable basis. General public transport for the Arnhem region used to be a commissioned by the Province of Gelderland. Recently the provinces of Gelderland, Overijssel and Flevoland implemented a system of joint general public transport commissioning with respect to a new concession area that covers parts of each province.
Special purpose public transport is available to specific groups with specific transport demands that can't be serviced by available general public transport, such as transport for people with a mobility handicap and school transport. Special purpose public transport used to be commissioned by each individual municipality. Recently 18 municipalities in the Arnhem-Nijmegen region agreed to a system of joint commissioning of special purpose public transport.
In the agreement zero emission bus transport and the agreement zero emission special purpose public transport provinces and municipalities agreed to create a situation where as from 2030 transport services commissioned by them is fully operated by zero emission vehicles. As from 2025 each newly added vehicle to these public transport fleets also is required to be a zero-emission vehicle. The implications for the general public transport commissioned by the Province of Gelderland and special purpose public transport commissioned by the joint municipalities in the Arnhem-Nijmegen region are explained below.

[27] Project H2 trucks Gelderland, Arnhem, May 2020 (draft version)
[28] A similar project including the deployment of fuel cell forklifts in combination with a public HRS was started in 2016 at a distribution centre of the Belgian supermarket retailer Colruyt. This project started with 15 fuel cell forklifts and now 75 forklifts are deployed.

4.3.1 General public transport

In the province of Gelderland, public transport is arranged through three public transport concessions that are visualised in figure 2.

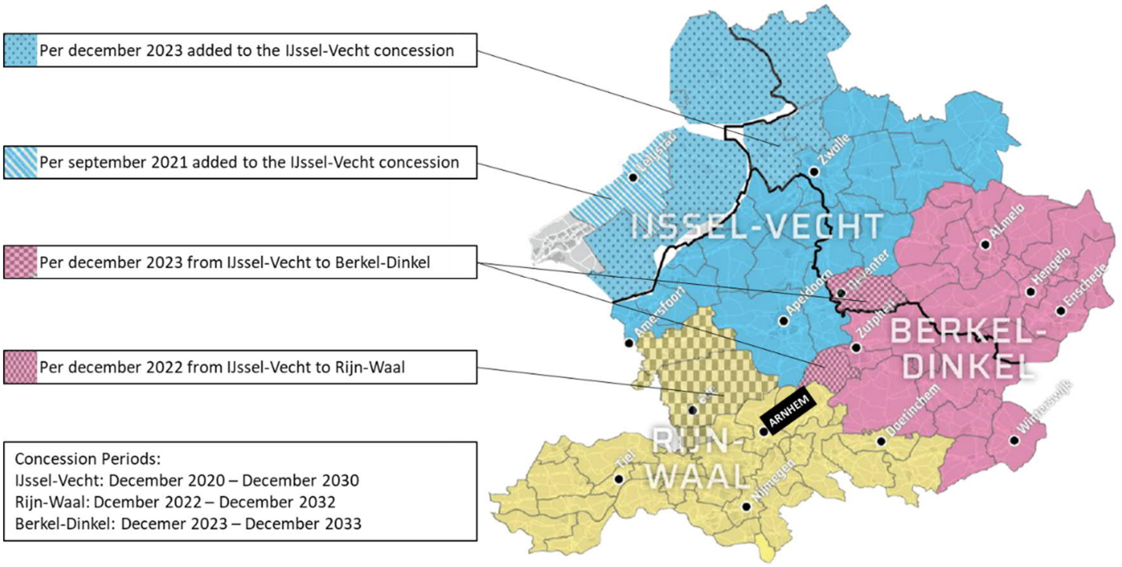

Figure 2. Public transport concessions issued by the provinces of Gelderland, Overijssel and Flevoland.

Concession IJssel-Vecht includes the current Veluwe concession where Syntus operates the two H2Nodes FCEV buses. This concession was recently tendered and awarded to Keolis. Keolis will operate a fleet of BEV-busses only within this concession which will last until December 2030. Due to the fact that the new three-concessions approach replaces a system of a multitude of concessions with various expiry dates, concession IJssel-Vecht will undergo some changes during the period September 2021 – December 2023, with some parts being added to the concession and other parts being transferred to other concessions, as indicated on the map in figure 2. This concession also includes parts of the provinces of Overijssel and Flevoland. It is jointly commissioned by the three provinces.

The tendering of concession Rijn-Waal is currently being prepared as its operations are supposed to become effective per December 2022. This means that the underlying tendering process has to be finished by December 2021. However, due to the effects of the corona virus on public transport, the tendering process for Rijn-Waal may be delayed.

Finally, the concession Berkel-Dinkel will become effective in December 2023. It is expected that the preparation of its tendering process will start at the end of next year. This concession also includes part of the province of Overijssel. It is jointly commissioned by the two provinces.

With respect to the regional upscaling potential from demand currently serviced by HRS Arnhem, two of the abovementioned concession contracts are of particular importance: the concession IJssel-Vecht as it includes the formerly Veluwe concession where Syntus operated the 2 FCEV buses as part of Activity 3 of the H2Nodes Act and the concession Rijn-Waal as it includes the HRS Arnhem location.

The IJssel-Vecht concession will not produce additional demand for hydrogen until at least the end of 2030. This concession was recently awarded to Keolis, based on a proposition including the deployment of BEV-buses only.

The Rijn-Waal concession is currently being prepared. According to the current time table the tendering process for this concession will have to produce a winning bid by the end of next year. The RfP (Request for Proposal) will demand the deployment of a zero-emission bus fleet, but leave it up to the tendering candidates to provide the practical implementation of this demand by proposing the deployment of BEV- and/or FCEV-buses.

4.3.2 Special Purpose Public Transport

Special purpose public transport in the Arnhem-Nijmegen region is was recently operationalised through two public tenders of a total of 13 lots for the period mid-2020 to mid-2030.

The first tender includes scheduled special purpose public transport on a (daily or weekly) timetable basis. This tender includes 9 lots, visualised by figure 3.

Figure 3. Lots for scheduled special purpose public transport in the Arnhem-Nijmegen region.

The second tender includes demand-specific special purpose public transport This tender includes 4 lots, visualised by figure 4.

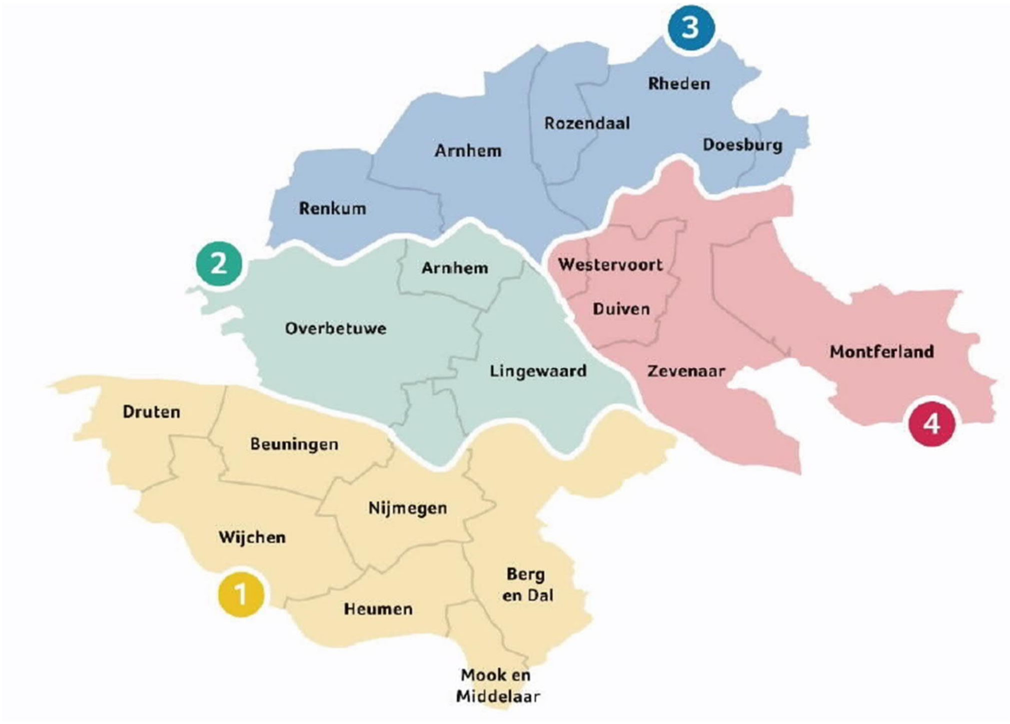

Figure 4. Lots for special purpose public transport in the Arnhem-Nijmegen region

The Arnhem-Nijmegen region is has not signed the Convenant zero-emission target-groups public transport. This Covenant aims at the deployment of a 100% zero-emission fleet in this public transport segment as from 2025. Instead the region focuses on the general zero-emission targets for public transport including a zero-emission demand for all newly added vehicles as from 2025 and a 100% zero-emission target as from 2030.

The total fleet operating these 13 public transport contracts consists of about 230, almost all taxi vans.

4.4 FCEV Upscaling Per Vehicle Type

4.4.1 Cars

The projects initiated at the regional level focus on the deployment of FCEV-buses (JIVE2) and trucks (H2 Truck Initiative). It's the intention to avail HRS capacity to other vehicle segments than buses and trucks too. There are not yet plans for specific car demand creation/aggregation as was the case in the H2Nodes demonstration project. The upscaling potential of the car segment is therefore expected to be the result of limited market pull effects (the availability of additional HRS capacity) instead of grant-driven push effects. The assumption is that the regional project will not add additional FCEV cars to the total number expected as a result of national incentives and legislation.

4.4.2 Vans

The tendering of target-groups public transport is a specific regional activity leading to FCEV-upscale potential in the taxi-van segment. The only information available as a basis for an indication of the FCEV potential is the estimate of the total number or vans (230), the geographical areas of the 13 awarded contracts and an estimate of the contract value of each of the 13 contracts.

The upscaling estimate is based on the following assumptions:

- FCEVs will be considered by the transport operators who service contracts that include Arnhem (so they can refuel on-route).
- The number of vehicles operating those contracts are assumed to be equal to the total share of the contracts including the Arnhem area in the total contract value of 13 contracts.
- The potential for FCEV-vans is estimated to 50% of the number of vehicles operation the Arnhem contracts.
- 50% of these FCEVs are estimated to be purchased in 2025 and 50% in 2030.

4 of in total 13 contract include Arnhem. The total value of these 4 contracts is EUR 9,2 million compared to an overall contract value of EUR 20,9 million for all 13 transport contracts. The "Arnhem-share" in those contracts is thus 44%.

The total number of taxi vans servicing Arnhem is 44% of 230 vans = 88 vans. 50% of these vans are estimated to be replaced with FCEV-vans, which equals a total of 44 vans.

50% is estimated to be purchased in 2025, which equals 22 FCEV-vans. The other 50% is added by 2030, again 22 FCEV-vans.

4.4.3 Medium trucks

The deployment of trucks is initiated by de H2-Truck project. We assume that 5 of the targeted trucks are medium trucks.

4.4.4 Heavy-duty Trucks

The deployment of trucks is initiated by de H2-Truck project. We assume that 5 of the targeted trucks are heavy-duty trucks.

4.4.5 Coaches

There are no regional initiatives specifically targeting coaches.

4.4.6 Buses

The regional level FCEV upscaling potential for buses is determined by a) the JIVE2 bus demonstration project and b) the tendering of public transport concessions.

Ad a) The JIVE2 bus demonstration project

Under the assumption that the vacated participation in the JIVE 2 project is granted to Gelderland, 10 FCEV-buses will be deployed in the Achterhoek-Rivierenland concession area from late-2020 to late-2023.

Ad b) Public transport concessions

Two concession contracts will be tendered by the joint public authorities Province of Gelderland, Province of Overijssel and Province of Flevoland in the period until 2030:

- Rijn-Waal: 2022-2032
- Berkel-Dinkel: 2023-2033

The extent to which FCEV-buses will be used to operate these concessions is a decision made by the public transport operating company. At this stage, the upscaling potential of public transport buses can only be determined on an assumption basis.

The assumptions with respect to the upcoming tendering of public transport concessions are as follows:

- The Berkel-Dinkel concession has good chances that fuel cell buses will be deployed in this concession, if the JIVE2 demonstration project is awarded to Gelderland, because:
  - Berkel-Dinkel is the area where the JIVE2 buses will be deployed. JIVE2 has the specific objective to proof the added value and competitiveness of FCEV-buses in a normal market situation. It may be expected that such experiences especially relate to the area where these JIVE2 buses were deployed.
  - 2b) IF the vacant position in the JIVE2 project is awarded to Gelderland, it means that a second HRS may be developed, as JIVE2 includes both buses and HRS infrastructure to refuel those buses. Two available HRSs make it easier for an operator to fit refueling of its buses in the public transport timetable and/or to deploy FCEV-buses on multiple routes.
- The Rijn-Waal public transport concession is well positioned for the deployment of FCEV-buses in the upcoming concession because HRS Arnhem is situated in this concession area. Even though it is expected that if an operator will prefer having a dedicated refueling facility in case he would operate a substantial number of FCEV buses, the availability of HRS Arnhem also offers an opportunity to operate a smaller number of FCEV-buses without having concerns about where to refuel them.

The hydrogen demand forecast is based on a total number of 30 fuel cell buses in JIVE2, Berkel-Dinkel and Rijn Waal. At such relatively small numbers of buses compared tot the total public transport fleet it may be assumed that these buses will refuel at a public HRS. When the share of FCEV buses is large, the refueling facilities will be included in the operator's plan. This would probably mean that these refueling facilities will be private, not open to other users.

5. Overall Regional upscaling of FCEVs and Refuelling Demand

5.1 Introduction

The conclusion from the previous sections is that a substantial upscaling of the number of FCEVS stems from policy and regulatory measures taken at the national level. The introduction of zero-emission zones will be a milestone for the deployment of zero-emission vehicle in city logistics. The proposed on the sale of ICE vehicles in 2030 in another milestone.

Regional FCEV demonstration projects support national level upscaling in two ways. They demonstrate the specific characteristics of FCEVs to a potential group of users, paving the path towards zero-emission mobility in general and FCEV mobility in specific. And as regional demonstrating projects also include the development of publicly accessible HRS they create additional regional refuelling capacity to service national-level upscaling.

The challenge in regional upscaling is the timing. The FCEV targets for the year 2025 and 2030 seem ambitious compared to the current number of vehicles.

From a policy point of view, it can be important to hold on to the targets set for 2025 and 2030. However, this milestone report is mainly written from a market point of view. Investing in HRSs which are not used is a waste of investment capital. Being too late with HRS development is a waste of market potential.

With respect to the upscaling we regard the introduction of zero emission zones in 30+ municipalities. This is referred to a zero emission zones without a substantial number of waivers for example Euro 6 diesel vehicles. This moment is currently planned at 2025, but the fact that FCEV vans and medium trucks are not yet widely available creates market uncertainty with respect to the number of FCEVs expected to be deployed in that year.

What is currently set as goals for 2025 and 2030 is translated into an upscaling of demand in two phases. Phase 1 is the situation that all zero emission zones are in place and fully operational. Phase 2 is the moment when all newly sold cars have to be zero emission.

The following paragraphs contain a calculation of the forecasted hydrogen demand for both phases.

5.2 Regional Hydrogen Refuelling Demand Development

The hydrogen demand at the Milestone 1 date (all zero emission zones in place and effective) is pro forma calculated in table 4.

This demand is calculated as follows:

a) number of FCEVs estimated at the national level per vehicle type
b) share of province of Gelderland in the total number of FCEVs per vehicle type[29]
c) a multiplied by b resulting in the total number of FCEVS added in Gelderland based on national level policies and incentives;
d) number of regional vehicles as calculated in chapter 4

[29] Based on the number of vehicles per category registered in the province of Gelderland compared to the total number of vehicles in The Netherlands.

e) the sum of c and d: the total number of FCEVS in Gelderland at given moment
f) the average distance covered by a specific vehicle type in km/year (bases on information from the Central Bureau of Statistics)
g) e multiplied by f and divided by 1 million resulting in the distance covered by all FCEVs in the region in million kilometres;
h) the average hydrogen fuel consumption in kg per 100 km
i) fuel consumption = (g*1 million) divided by 100 multiplied the average hydrogen fuel consumption
j) reference demand as determined in chapter 2
k) total hydrogen demand per vehicle type and in total, giving an impression about the required future total HRS capacity.

The driving ranges per segment type are based on existing date from reference vehicles: the driving ranges of per vehicle type are assumed to equal the forecasted driving ranges of diesel vehicles[30] in that segment (source: Central Burau of the Statistics).

Table 4 shows the forecasted amount for phase 1. Zero-emission zones are expected to be in place at 2025. However, given the fact that FCEV-vans and medium trucks are not yet (widely) available, may lead to a situation where zero-emission zones at first are mostly serviced by BEV-vans and medium trucks, with FCEVs reaching their target levels at some point later (between 2025 and 2030).

Phase 1. Zero-Emission Zone	cars	vans	medium trucks	heavy trucks	coaches	buses
a) # FCEVs national level	15.000	12.000	0	3.000	0	0
b) Province Gelderland share	12%	12%	16%	15%	15%	0%
c) # regional # FCEVs from national level	1.800	1.440	0	450	0	0
d) # regional FCEVs from regional level	20	22	0	10	0	30
e) total # regional FCEVs	1.820	1.462	0	460	0	30
f) distance/year/vehicle (kms)	22.663	23.980	20.226	41.048	41.230	75.358
g) distance/year all regional FCEVs (mln km)	41,25	35,06	0,00	18,88	0,00	2,26
h) H2 fuel consumption (kg/100 km)	1,0	1,4	4,0	10,0	9,0	9,0
i) H2 fuel consumption all regional FCEVs (kg/day)	1.130	1.345	0	5.173	0	557
j) reference fuel consumption (kg/day)	32	0	0	0	0	0
k) capacity (kg/day, rounded to thousands)	1.162	1.345	0	5.173	0	557
	8.000					

Table 4. Indication of demand in phase 1 (date when all zero emission zones are effective).

The hydrogen demand for phase 2 (most lighter vehicle segments are zero-emission) is pro forma calculated in table 4

[30] As diesel vehicles mostly serve the market segment with relatively long driving distances compared to other ICE vehicles.

Phase 2. All newly sold cars zero emission		cars	vans	medium trucks	heavy trucks	coaches	buses
a)	# FCEVs national level	300.000	26.000	1.600	10.000	1.000	0
b)	Province Gelderland share	12%	5%	16%	15%	15%	0%
c)	# regional # FCEVs from national level	36.000	1.300	256	1.500	150	0
d)	# regional FCEVs from regional level	20	22	0	10	0	30
e)	total # regional FCEVs	36.020	1.322	256	1.510	150	30
f)	distance/year/vehicle (kms)	21.864	25.995	17.595	40.733	40.260	75.104
g)	distance/year all regional FCEVs (mln km)	787,55	34,36	4,50	61,51	6,04	2,25
h)	H2 fuel consumption (kg/100 km)	1,0	1,4	4,0	10,0	9,0	9,0
i)	H2 fuel consumption all regional FCEVs (kg/day)	21.577	1.318	494	16.851	1.489	556
j)	reference fuel consumption (kg/day)	32	0	0	0	0	0
k)	capacity (kg/day, rounded to thousands)	21.609	1.318	494	16.851	1.489	556
		42.000					

Table 5 Indication of demand at Milestone 2 (most lighter vehicle segments are zero-emission)

The ambition for number of FCEVs that appear in the region based on national regulation and incentives are based on the targets included in the Climate Agreement. The phase 1 number of FCEVs in the car segment is set somewhat lower, given the relatively slow introduction of new vehicle brands and types. The assumed market share of FCEV-is set at 23%, as explained in paragraph 3.3.3.

The calculated hydrogen demand levels (8.000 kg/day phase 1 and 42.000 kg/day phase 2) are not particularly useful in this stage as especially the general upscaling of FCEVs based on regulations and incentive on the national level (including vehicle availability) is highly uncertain. The forecast based on regional developments has either a higher probability level (such as the number of FCEVs for target-group public transport) or will become 100% accurate in the near future (for example: when is known in the JIVE2 vacancy is awarded to Gelderland or when the Rijn-Waal public transport concession is awarded – in both cases the number of FCEV-buses are known with almost 100% accuracy).

The value of these tables as planning instrument lies in their structure. The allow for the calculation of demand for hydrogen forecasts at various moments in the future when all numbers can be forecast with gradually more accuracy. They will show the impact on the demand for HRS capacity.

6. HRS Upscaling

6.1 Development Phases

HRS development in the Arnhem region has two main components:

HRS development as part of regional demonstration projects. For example: The JIVE2 project includes the deployment of 10 FCEV buses and a refuelling station in the Achterhoek-Rivierenland concession are where these buses will operate. The H2 Truck project that includes 10 FCEV trucks and a refuelling facility. The HRS capacity is included in the vehicle upscaling and thus does not require any planning with respect to general refuelling capacity.

The possible deployment of FCEV buses in the Rijn-Waal public transport concession also does not require any specific planning at this point, because:

- these buses can use the HRS capacity that will be created by the JIVE2 bus project;
- concession contracts are usually rewarded one year before the public transport operations start, so there is time to secure the availability of HRS capacity in case the “JIVE2-HRS” does not fully cover the hydrogen refuelling requirements of the involved FCEV buses.
- it is too risky to anticipate on the deployment of FCEV buses and consequently pre-invest in (additional) HRS capacity – because the capacity required for bus refuelling cannot easily be filled in by other vehicles.

This means that developments that are initiated at the national level are the ones that for the most part fuel the regional upscaling need. The development phases are set by the the ambition levels set the national level, translated into actual upscaling potential from a market point of view and aligned with overall HRS development at a national level as currently the low availability level of FCEVs is an upscaling bottleneck. However, a future bottleneck may be the lack of upscaling of HRS capacity at the national level as drivers are not expected to use their FCEVs on a local basis. Additionally, the upscaling curve shown in chapter 1 refers to different user groups in various upscaling phases. Given the nature of these target groups it can be expected that customer demands will increase per added target groups. For example: the late majority will demand a more dense HRS network than a group of early innovators.

The development phases are two five year periods of national upscaling: 2020-2025 and 2025-2030, but also requires a mechanism to monitor the actual developments as currently development are lagging behind, but as soon as an incentive based policy framework is replaced by rules and regulations (such as the introduction of zero-emission zones) development may accelerate.

6.2 Development Strategies and Plans

6.2.1 Development Strategy

The development strategy is defined as the strategy for the region-specific stakeholders: The Province of Gelderland as well as the regional municipalities. The underlying assumption is not that these public entities will become HRS developers or operators as this is a specific private sector activity. However, provinces and municipalities play an important rule with respect to the spatial aspects of HRS upscaling. The tables presented in the previous paragraph are a tool to determine the regional effects of FCEV upscaling, not only in terms of HRS capacity, but also in terms of HRS location. This varies per vehicle type and per phase. The phase 1 upscaling is expected to have a more local character as phase 1 is the date that all zero-emission zones are in place and operated without waivers. The city distribution vehicles require a good refueling network for trips that have one or multiple inner-city destinations.

Phase 2 is most likely a mix of the upscaling of FCEVs in the region (people and businesses located there) as well as longer distance traveling, for example on the motorway connecting Arnhem tot major cities such as The Hague, Utrecht, Amsterdam, Rotterdam in the West and the German Ruhr area in the East. This will be described in more detail in the Milestone 9 report (Final report on plans for expansion with more HRS along the TEN T North Sea Baltic Core Network Corridor).

Deviation of the real upscaling of the demand for hydrogen compared to the phase 1 and 2 forecast does not necessarily indicate a delay. It may also indicate the BEV/FCEV tradeoff differs from previously assumed levels. This will have a direct impact on the strategic spatial planning as the spatial aspects of charging units for BEVs are very different from the spatial aspects for HRS facilities. The tradeoff between BEVs and FCEVs now is sometimes base on best guestimates only. As both technologies are being further developed while the upscaling is already taking place, intermediate effects of such developments should be taken into account.

6.3 Development Plans

The phase 1 required capacity as indicated in table 4 is about 3.000 kg/day. That is well over the current capacity of HRS Arnhem (260 kg/day).

There are two concrete development plans on the table: JIVE 2 and the H2 Truck project. These projects include the at least temporary deployment of FCEV-buses (JIVE2) and trucks (H2 Tuck). The HRSs which are developed as important components of these demonstration projects have the primary function to service demand initiated by these two demonstration projects, and not specifically intended to existing demand elsewhere. They are used to create demand and thus have become an important regional FCEV-upscaling component. However, as demonstration projects usually have a lifespan well shorter that the lifespan of an HRS, they also create refuelling capacity that can be used to services additional hydrogen demand from the general upscaling of FCEVs. By creating a larger HRS capacity than is strictly required by the demonstration project, there is a regional buffer for the cases that demand develops quicker than expected.

The capacity of the abovementioned additional HRSs are not know yet. However, it may be assumed that the refuelling of 10 JIVE2 buses requires additional refuelling capacity. If we assume a 250 kg/day capacity for the JIVE2 HRS and a 150 kg/day capacity for the Truck Project HRS, total regional capacity will be scaled up to 660 kg/day.

As stated earlier, it is expected that the phase 1 upscaling of FCEV cars and vans may actually go beyond the year 2025, assuming that zero emission zones initially are mostly serviced by BEVs. With a buffer of 660 kg/day the region is prepared for facilitating refuelling demand when the FCEV curve goes up, while still having time to avail locations that may be needed for future HRS developments.

The planned additional HRSs will be developed as a part of demonstration projects and can be used by other vehicles as well, both during and after the demonstration project period.

The spread in locations is very important for this region. Figure 5 explains why. It shows the map of The Netherlands including existing HRSs (green dots) and HRSs currently under construction. It shows to characteristics of upscaling of HRS capacity in The Netherlands:

- The HRSs are for the most part concentrated in the western part of the country. This is not a surprise as the western parts includes the areas with the highest population density and a significant part of the economic activity.
- According to planning these HRSs are for the most part opening between 2020 and 2023.

Figure 5. Existing and being developed HRSs in The Netherlands[31]

With such an HRS density, the availability of refueling capacity probably will not an upscaling bottleneck, given the fact that most OEMs focus on the development of BEVs in the car, van and medium truck market first, possibly followed by FCEVs. This may lead to the faster upscaling of FCEVs in this part of the Netherlands. In the Arnhem region HRS Arnhem is currently the only available refueling facility. HRS Arnhem has enough capacity to service additional demand from from FCEVs travelling on the A12 corridor (from Amsterdam, Rotterdam and The Hague via Utrecht and Arnhem to Germany). Given the fact that there are no additional HRSs in the nearby area, not only the capacity is a priority, but also the reliability, as some vehicles may not have sufficient fuel left to make it to the next HRS.

The plans for two additional HRS therefore do not only support FCEV upscaling purposes, but they also contribute to regional refueling reliability by serving as a backup in case HRS Arnhem is (temporarily) not available. These three HRSs together facilitate FCEV traffic on both the North Sea-Baltic Corridor and the Rhine-Alpine Corridor.

6.4 Conclusion

With a forecasted regional refueling capacity of about 660 kg/day in the next few years, the region should be able to facilitate additional hydrogen demand for the upcoming years. This 'strategic' capacity also allows the region to see how the trade-off between BEVs and FCEVs works out. This is important as BEVs require a different type of refueling infrastructure compared to FCEVs.

[31] source: H2Platform The Netherlands

The exact locations will also dependent on the type of vehicle use: long distance traffic may prefer HRSs directly situated at a motorway, more regionally or locally focused travel may have a need for a number of HRS well spread over the region. The planned reserve capacity allows for time to work on two important factors that will significantly speed up the development time of future HRSs:

1) The standardisation of public procedures, permits and licensing, which takes place at the national level[32]. This will lead to shorter development periods, which is an important factor to limit development costs and thus making HRS development commercially viable.

2) At the end of phase 1 / start of phase 2 HRSs development will be initiated by the private sector as a) development has a solid commercial basis and b) existing petrol stations will have a clear incentive to transition from the supply of fossil fuels to clean fuels (charging stations and HRSs). The BETA (organisation of petrol stations) is already preparing for the transformation of existing petrol station to clean fuel facilities. These stations are already strategically located on the current road network. Standard procedures in combination with a multitude of available locations and commercially-driven transition motives are the best guarantee that HRS capacity will be sufficient to facilitate the long-term hydrogen demand (until 2030 and beyond).

[32] https://opwegmetwaterstof.nl/h2tanken/