TRAFIKVERKET

REPORT

Conditions for using hydrogen gas as fuel for heavy road transport

With case studies on Region Örebro County and Region Blekinge

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Summary

The purpose of this study is to describe the conditions and development trends that may have an impact on the introduction of hydrogen gas as fuel for heavy road transport (above 3.5 tonnes) in Sweden. The study has also examined regional conditions for the introduction of hydrogen gas in two geographical areas: Örebro County and Blekinge County. These are referred to in the report as Region Örebro and Region Blekinge. The study has been conducted using a qualitative method and is largely based on interviews and previously published material.

Hydrogen gas as fuel for heavy road transport requires trucks equipped with fuel cells, even though trials with internal combustion engines using hydrogen gas are also underway. One advantage of fuel cell trucks often cited in comparison with battery-powered trucks is the longer range. Another advantage is short refuelling time. Several truck producers have launched initiatives with fuel cell trucks, but with none yet at a commercial stage. Large-scale commercialisation is expected in the late 2020s.

A necessary condition for using hydrogen gas as fuel is the establishment of filling stations. Some plans are already underway for the establishment of filling stations in Sweden, and their establishment is likely to be affected by decisions at EU level. In July 2021, proposals from the EU included that Member States should ensure the establishment of hydrogen gas refuelling infrastructure along major roads at intervals of 150 km by 2030.

One possible development scenario for the establishment of refuelling infrastructure is that it takes place simultaneously in many locations in order to reach a scale large enough to make the hydrogen gas alternative attractive. Another possible development scenario is that hydrogen gas infrastructure (production, distribution and filling stations) will be established in certain locations at an earlier stage, and that the use of fuel cell vehicles will be higher in these regions than elsewhere. Production costs and distribution strategies will determine which development strategy prevails, and it may vary around the country.

A very small proportion of the hydrogen gas currently produced in Sweden and globally is fossil-free. This means that a comprehensive development of the fossil-free production of hydrogen gas will be needed for several different applications. Hydrogen gas is also seen to have great potential for, among other things, storing electricity during more variable electricity production, and as feedstock in industry. Developments in these areas are likely to affect the possibilities to use hydrogen gas as fuel for vehicles to a large extent. Increased use in other sectors may mean that hydrogen gas becomes more readily available, but shortages may also occur.

In the long term, fuel cell trucks are likely to be primarily used for long-distance transport. However, fuel cell trucks may also be used for local and regional transport, such as in shuttle services and very heavy road transport. Fuel cell truck investment is likely to be initially made by major hauliers. This is due to the high costs, as well as the uncertainty involved with investing in new technology. However, there is also a willingness among some smaller market players to transition to hydrogen gas at an early stage.

Production and distribution of hydrogen gas as fuel can be both centralised in terms of transporting the hydrogen gas, and decentralised adjacent to the filling stations. These different strategies have different cost structures in which economies of scale are set against distribution costs.

Something often mentioned as an attractive production alternative is to produce hydrogen gas using "excess electricity". Excess electricity refers to the production surplus that arises

when wind power and solar cells produce a lot of electricity while demand is low. However, it is possible to call into question the foresightedness of such a production strategy because the conditions in the electricity market can change over time. For example, more flexible electricity consumption, the development of other storage methods, and the construction of additional electricity grid capacity can cause the imbalances in the electricity market to be evened out.

Another condition that could promote the increased use of hydrogen gas as fuel within a certain region is whether the production or use of hydrogen gas for purposes other than transport takes place in the region. However, it is not a foregone conclusion that other use of hydrogen gas "spills over" to the transport sector, as it requires clear incentives for a company to move from being producer and user of hydrogen gas in, for example, its own industrial processes, to using the hydrogen gas for its own transport or selling it on.

Opportunities and challenges of taking on a role as producer for other users may differ between industries already producing hydrogen gas through electrolysis for use in their own processes, and industries planning to do so in future, such as steel industry and refineries. In relation to the establishment of new hydrogen gas production, it may be easier to weigh in opportunities to collaborate with the transport market.

The examination of Region Örebro and Region Blekinge highlights how the prerequisites for the introduction of hydrogen gas for heavy road transport can differ between geographical areas. Factors determining hydrogen gas production include the local electricity supply and the potential filling station utilisation rate, which affect the dimensioning of electrolysers and storage.

Örebro County's very good strategic transport location leads to a large flow of long-distance transport that could generate use of hydrogen gas. One or more hydrogen gas filling stations in the region could be part of a larger network.

A development in Blekinge County is more likely to be based on industrial collaboration rather than on large flows of long-distance transport. The ports in Blekinge are potentially suitable for hydrogen gas infrastructure because there is a lot of truck transport passing though and because hydrogen gas can be imported by ship.

The study has been conducted by Anna Malmberg and Erik Falenius. Björn Hasselgren and Elin Näsström have supervised the work. All belong to National Planning, (PLnpv) in the Swedish Transport Administration.

Keywords: electrification, hydrogen gas, fuel cells, heavy road traffic

1 Introduction

1.1. Background

Sweden has a target of reducing greenhouse gas emissions from domestic transport (excluding domestic aviation) by at least 70 per cent by 2030 compared to 2010 emission levels (Government Offices, n.d.). In 2019, heavy trucks accounted for approximately 20 per cent of greenhouse gas emissions from domestic transport (Swedish Environmental Protection Agency, 2020). In 2020, approximately 94 per cent of the total vehicle fleet of heavy vehicles were powered by diesel (Swedish Transport Administration, 2021a). One way to reduce emissions is to replace diesel with alternative fuels and energy carriers such as biofuels, electricity, and hydrogen gas.

Ever since the 1980s, hydrogen gas has been discussed as a fuel for vehicles both with internal combustion engines and for the fuel cell alternative with electric powertrain. Inside a fuel cell, hydrogen gas is converted to electricity that powers an electric motor. The process only emits heat and water vapour. Interest in fuel cell technology has increased in recent years, especially as a means to lower CO2 emissions from heavy vehicles. This includes development efforts by truck manufacturers and proposals from the EU Commission for the establishment of hydrogen gas filling stations for both light and heavy road transport. At the same time, uncertainty remains over what form the development of the hydrogen gas alternative will take. Many questions remain unanswered about fuel cell vehicles driven on hydrogen gas, but despite this, many recognise the potential of hydrogen gas as part of the transition of the transport sector.

However, the transport sector is only one of several applications where hydrogen gas is likely to make a contribution to the climate transition, as shown in Figure 1. The development in these other applications may affect the role of hydrogen gas as fuel for vehicles by changing production and demand patterns, for example. Hydrogen gas as energy form is therefore to be considered as the basis of a new part of the overall energy system, not just an alternative fuel for road vehicles.

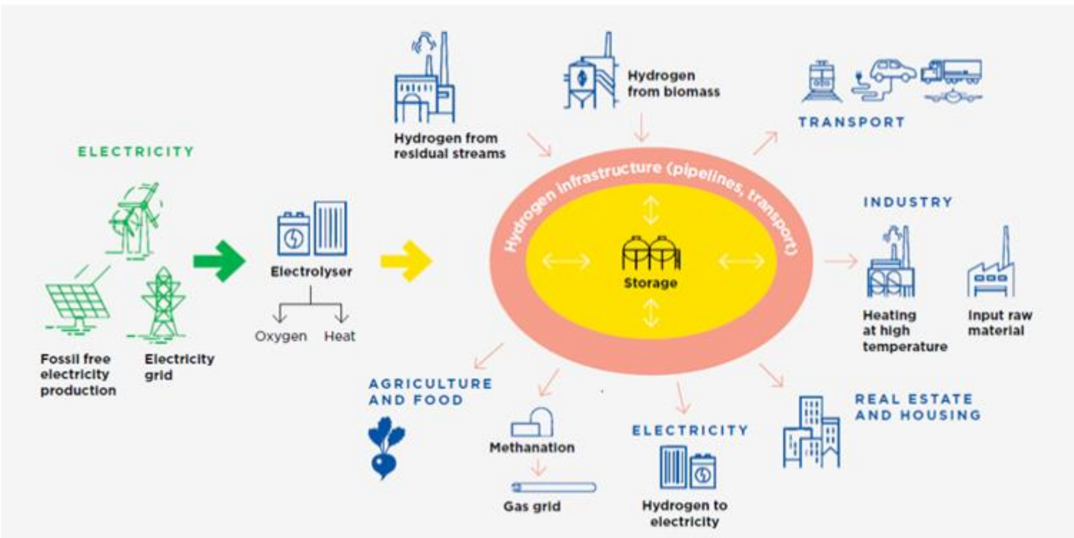

Figure 1: The hydrogen gas value chain. The figure is produced by Fossil Free Sweden in the report entitled Hydrogen strategy for fossil-free competitiveness. (Fossil Free Sweden, 2021)

At the beginning of 2021, Fossil Free Sweden presented the report "Hydrogen strategy for fossil-free competitiveness" containing proposals for action to allow Sweden to utilise the full potential of hydrogen gas. The Government has also tasked the Swedish Energy Agency to draw up an overall strategy for the role of hydrogen gas in the Swedish energy system, which shall be reported to the Government Offices on 25 November 2021 (Swedish Energy Agency, 2021).

A cornerstone for the introduction of hydrogen gas as a sustainable energy carrier is that it is produced fossil free. This primarily takes place through the electrolysis of water using renewable electricity. A very small proportion of the hydrogen gas currently used in the world and in Sweden is renewable. Approximately 180,000 tonnes of hydrogen are produced in Sweden each year, of which, 67 per cent are produced by the conversion of fossil natural gas. Three per cent are produced through electrolysis using electricity from the Swedish electricity grid, and the remainder from industrial residual streams. (Fossil-free Sweden, 2021)

The use of hydrogen gas as fuel in Sweden is very limited. The development in the Swedish market is likely to be affected by decisions at EU level. The EU has ongoing work aimed at contributing through various public support measures and other measures to reduce greenhouse gas emissions in accordance with the Paris Agreement. In December 2019, the EU presented the European Green Deal and has since developed a range of strategies and directives on emission reduction from the transport sector. In July 2021, the Commission presented a reform package with a proposal for a holistic approach towards a green transition of the European economy. (European Commission, 2021)

Part of the Commission's proposal consists of a regulation on alternative fuels to replace an existing directive. It contains proposals for ambitious rules on how the Member States should ensure the establishment of hydrogen gas infrastructure (Revision of the Directive on deployment of the alternative fuels infrastructure, 2021). This establishment shall take place along the TEN-T *Core Network*, which connects large European cities and other important nodes, as well as along the *Comprehensive* TEN-T network. A simplified illustration of the TEN-T Core Network is given in Figure 2.

According to the Commission's proposal, there should be a hydrogen gas filling station along these routes at intervals of 150 km by the end of 2030. The establishment of filling stations should also take place in major cities as well as around industrial areas. The proposal also includes the establishment of charging infrastructure for battery vehicles along the same routes. The proposal gives an indication of the EU's ambition level, and that member states are expected to participate actively in the establishment of refuelling infrastructure in close collaboration with market players.

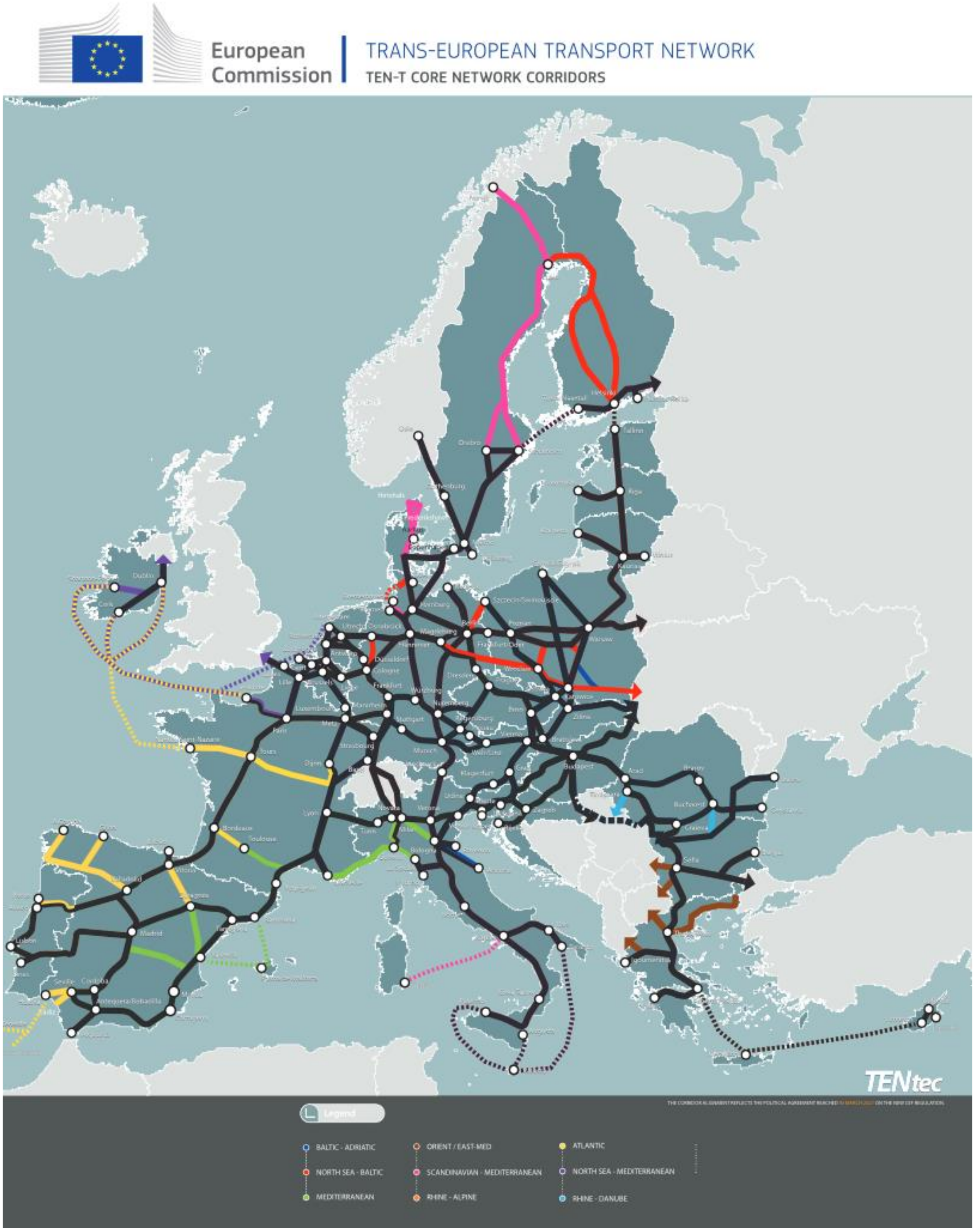

Figure 2: TEN-T Core Network (North Sweden European Office, 2021)

The reform package also contains several other parts that concern transport issues and which may affect the development and introduction of hydrogen gas for road transport. Among other things, it proposes that road transport should be included in an expanded emissions trading system. The Renewable Energy Directive has been updated with specific targets for renewable energy use in the transport sector. Higher demands are also set for the amount by which member states should reduce their emissions, which includes road traffic at national level. (European Commission, 2021)

The proposals presented by the EU therefore include promoting a large-scale establishment of filling stations for hydrogen gas. One possible development scenario for the establishment of filling stations is that it takes place simultaneously in many locations in order to reach the scale required to make the hydrogen gas alternative attractive. Another possible development scenario is that filling stations are established in more limited geographical locations (regional/local clusters) at an earlier stage, and that the use of fuel cell vehicles will be higher in these regions than elsewhere. This will lead to a more gradual development of the system, which may provide a more flexible introduction of the hydrogen gas alternative.

This report highlights regional conditions for initiating such a gradual development via regional/local clusters for two geographical areas: Örebro County and Blekinge County. Different regions have different conditions that are linked to geography, traffic flows and transport needs, as well as when it comes to the local/regional energy supply - which may affect the introduction of hydrogen gas as fuel for heavy road traffic. In this regard, the two regions represent different conditions and opportunities for the future introduction of hydrogen gas.

1.2. Purpose

The purpose of this study is to describe the conditions and development trends that may have an impact on the introduction of hydrogen gas as fuel for heavy road transport (above 3.5 tonnes) in Sweden, as well as to apply this analysis in two geographical areas: Örebro County and Blekinge County. These are referred to in the report as Region Örebro and Region Blekinge. The study covers issues related to the production of hydrogen gas, the distribution of hydrogen gas, and its use in the road transport system, see Figure 3.

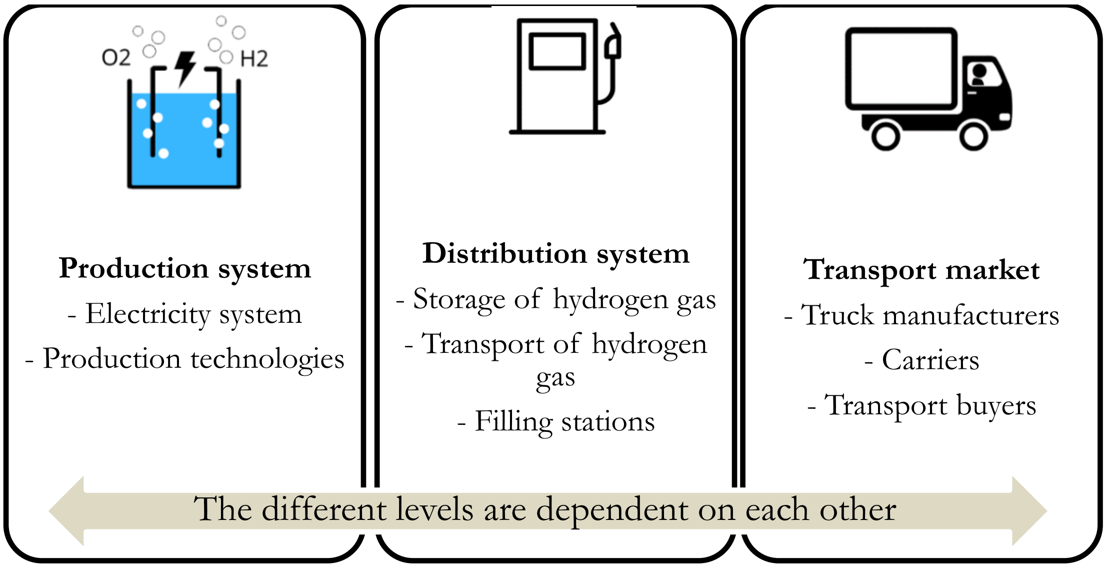

Figure 3: Levels of the value chain for hydrogen gas as fuel

The overall focus on the study means that it only takes into account the general factors that can affect the costs of different alternatives. Furthermore, no detailed examination of the technical specifications for vehicles, fuel cells, electrolysers, refuelling infrastructure and distribution has been carried out.

1.3. Method

This study has been conducted using a qualitative method and is largely based on interviews and previously published material. The interviewees are representatives of road hauliers, truck producers and local industries from the regions being studied. Interviews have also been held with researchers, officials and politicians, as well as market players related to technologies for the production and use of hydrogen gas.

Literature studies have been conducted of bills and public inquiries, and of reports on the future role of hydrogen gas carried out by academia, consulting companies and public sector actors, among other things. Information has also been gathered on ongoing and planned hydrogen gas projects in Sweden and abroad, in particular on the establishment of hydrogen gas infrastructure for heavy road transport.

1.4. Delimitation and implementation

The study has been conducted at an overall level. The study reports a selection of ongoing projects and certain potential future scenarios for hydrogen gas for heavy road transport in Sweden, without the ambition to be comprehensive. Observations made at regional level supplement an EU perspective and national development trends. The starting point in this part consists of the two regions being studied. In order to make comparisons with other fuel and energy carriers for transport, this study has focused on battery-powered trucks with stationary charging, due to the recurrence of this alternative in reports and interviews. Hydrogen gas can be produced in several different ways, but here the focus of the analysis is on the production of fossil-free "green" hydrogen gas through a process of electrolysis.

A limiting factor to the scope of the study is that it was carried out during summer 2021 from June to August. The holiday season limited the number of interviews that could be held, which can be assumed to have resulted in a certain distortion in the responses and the absence of certain perspectives. Through holding interviews with a large number of market players and the broad range of information collected, the ambition is to provide an objective view of the issues relating to hydrogen gas as an alternative to the electrification of heavy road traffic.

2 Hydrogen gas

2.1. Production

Hydrogen gas can be produced in several different ways. A common approach is to categorise hydrogen gas as green, blue and grey hydrogen gas:

- Green hydrogen gas is produced by electrolysis driven by renewable electricity that splits water, the gasification of biomass, or the reform of biogas. Also known as *clean hydrogen*.
- Blue hydrogen gas is hydrogen gas produced using fossil fuels along with carbon capture. It can also refer to hydrogen gas from nuclear power or electricity mix with low carbon content. Also known as *low carbon hydrogen*.
- Grey hydrogen gas refers to hydrogen gas produced using fossil fuels. (Fossil Free Sweden, 2021)

The production cost for fossil-free hydrogen gas is currently around twice as high as for fossil hydrogen gas: approximately SEK 40-50 per kg compared with SEK 10-20 per kg. There is likely to be a need for a comprehensive development of the fossil-free production capacity in order to supply the volumes of fossil-free hydrogen gas that road vehicles and other applications are expected to demand in 2030 at reasonable prices. (Material Economics, 2020)

2.2. Hydrogen gas for heavy road traffic

2.2.1. Fuel cell trucks

Several truck producers have launched initiatives with fuel cell trucks, but with none yet at a commercial stage. The pace of future commercialisation can be indicated by the March 2020 letter of intent signed by 43 industrial companies, including several leading truck producers. It presents a target of a pre-commercialisation of 5,000-10,000 vehicles in the European market by 2025. For full-scale commercialisation, the target is up to 95,000 vehicles by 2030. (Hydrogen Europe, 2020)

Several observers suggest that one of the most important reasons why hydrogen gas and fuel cells for transport have not made a large-scale entry into the market is the high overall cost of fuel cell vehicles, including both the manufacture of vehicles and the establishment of filling station infrastructure. Several factors lie behind the increased transport sector interest in hydrogen gas, including increased proportion of renewable electricity production where conversion to hydrogen gas can be used to handle relatively high variations in production using an increased proportion of solar power and wind power, as well as increased interest at European level, and the longer service life of fuel cells. (Fossil Free Sweden, 2021)

Fossil Free Sweden suggests that the range of fuel cell trucks is about 800-1,000 kilometres and the refuelling time is estimated at 10-15 minutes, which is comparable to what it takes to fill with diesel (Fossil Free Sweden, 2020). However, these numbers are only estimates.

A fuel cell truck is based on similar technology as a battery truck for the propulsion, with a similar electric powertrain and an additional battery. However, for fuel cell trucks, system efficiency, i.e. how much of the electricity supplied in the production of the hydrogen gas is available as useful energy on the drive wheels, is only about 30-50 per cent. Hydrogen gas also has a relatively low energy density per unit of volume (almost eight times lower than diesel at 700 bar), which contributes to smaller load capacity as the fuel tank is more bulky. (Ibid.)

The different components of a fuel cell vehicle are described as below in the Swedish Transport Administration's fifth report on business models for electrified heavy road transport (Swedish Transport Administration, EY, 2021) based on information from, among others, the Hydrogen Sweden organisation:

- Hydrogen gas tank - used to store the hydrogen gas that is used as energy carrier for the fuel cell system.
- Fuel cell stack - produces electricity through a reaction that converts hydrogen gas and oxygen to water, creating an electric current at the same time. This current is supplied onward to the vehicle's electric motor and battery.
- Battery - when the energy is stored primarily as hydrogen gas, only a smaller battery is needed in order to meet higher peak loads, such as when accelerating the vehicle, and to harness brake energy.

2.2.2. Distribution

Distribution of hydrogen gas to vehicles using filling stations spread across the road system is similar to conventional fuels. Refuelling a hydrogen gas truck works in a similar way to refuelling internal combustion engines. (Swedish Transport Administration, EY, 2021)

Distribution of hydrogen gas from production facilities to hydrogen gas filling stations could take place using tanker trucks (hydrogen gas in liquid form or as a pressurised gas), using hull tankers and/or using pipelines, depending on the geographical conditions and which distribution technology is established in different countries (Hydrogen Council, McKinsey, 2020). In some cases, the production of hydrogen gas can also take place locally, directly adjacent or close to hydrogen gas filling stations (Swedish Transport Administration, EY, 2021).

There are currently only five active hydrogen gas filling stations in Sweden, designed for passenger cars (Hydrogen Sweden, n.d.). Some establishment of hydrogen gas filling stations for heavy road traffic is taking place. One example is in Borlänge, where a haulier has received funding from the Klimatklivet (a government initiative that supports local climate investments) to build a hydrogen gas filling station (Annonsbladet, 2020).

Circle K has also announced that it will build a charging and hydrogen gas filling station for heavy road traffic in the Port of Gothenburg, in collaboration with the Port of Gothenburg, the Volvo Group, Scania, and Stena Line. Hydrogen gas refuelling is likely to be possible by

2023 or 2024 and the facility will have a capacity for 15 trucks per day. Refuelling time is stated as 15-20 minutes per refuelling session (Circle K, 2021). Furthermore, Danish company Everfuel has the aim of building at least eight hydrogen gas filling stations in Sweden by 2023. The development will be partly financed through contributions from the EU (Everfuel, 2021) (Hydrogen Sweden, 2021).

2.3. Other end uses

Fossil-free hydrogen gas has the potential to contribute to the climate transition in several sectors, such as the energy sector, processing industries, the real estate and housing sector, the agricultural sector, and the food processing industry.

Within the energy sector, energy storage will play an increasing role with an increased proportion of fossil-free, weather dependent, electricity production. Hydrogen gas can act as energy storage through electrolysis and storage of hydrogen gas in hydrogen gas tanks. It can then be re-converted to electricity in a fuel cell. Within the steel industry, development work is currently underway to use hydrogen gas in place of carbon when processing iron ore to iron. There are also plans for heating through the combustion of hydrogen gas for steel production (Ovako, 2021). In connection with several refineries, development is also underway of large-scale hydrogen gas production via electrolysis (Wind Power Centre, 2021) (Ny Teknik technology magazine, 2019).

Developments involving hydrogen gas in other sectors will affect the transport sector. One possibility is that the infrastructure for hydrogen gas as fuel will be established in connection with other uses of hydrogen gas and form so-called hydrogen gas clusters.

2.3.1. Cross-sectoral local and regional clusters

Discussions are currently being held in different parts of Sweden about establishing local and regional clusters for hydrogen gas, which are reported in "Hydrogen strategy for fossil-free competitiveness" (Fossil Free Sweden, 2021).

These clusters can include larger industries and infrastructure that already have hydrogen gas or will be able to use it. Collaboration can take place by means of connecting existing and new industries with local and regional hydrogen gas networks and/or common hydrogen gas storage. For heavy road traffic, the benefits of having filling stations adjacent to large industries is highlighted, and dialogue about this is ongoing between base industry and automotive manufacturers. (Ibid.)

The justification for creating clusters is economies of scale, with lower production cost per unit and shared risk taking for new infrastructure, by means of hydrogen gas being produced, distributed, stored and utilised in larger volumes. This can facilitate the installation of larger electrolysers by combining new hydrogen gas production infrastructure with existing infrastructure for electricity or hydrogen gas production in some places. This type of cluster is described in the EU Hydrogen Strategy, where it is referred to as *Hydrogen valleys*. (Ibid.)

Fossil Free Sweden writes in "Hydrogen strategy for fossil-free competitiveness" of the need for further analysis of and comparisons between the alternatives of centralised and decentralised hydrogen gas production via electrolysis. Among other things, such analysis should include a comparison of the cost of distribution of hydrogen gas over long distances for centralised production with any costs for reinforcing the electricity grid in the case of decentralised production. Other factors affecting costs include economies of scale in production and the need for hydrogen gas storage. (Ibid.)

Building hydrogen gas infrastructure in a limited geographical area could be one way to increase the rate of utilisation of one or more hydrogen gas filling stations. This can take place as a part of a cross-sectoral cluster, or isolated to the transport market. In addition to increasing the rate of utilisation, it can also contribute to the development of skills in the service and maintenance of vehicles and filling stations.

3 Conditions for using hydrogen gas as fuel for heavy road transport - observations and analysis

In order for hydrogen gas as fuel for heavy road transport to be introduced to a greater extent requires the establishment of refuelling infrastructure, that hauliers invest in fuel cell trucks, and that there is access to fossil-free hydrogen gas at competitive prices. The different areas are interdependent, as illustrated in Figure 4, and are characterised by major uncertainties. This can create deadlocks that can slow development.

An adequate rate of utilisation is required for profitability at a filling station, and filling station availability is required to be able to use a fuel cell truck. Filling stations require a supply of hydrogen gas, which is a question of both production and distribution. For truck owners, the availability of hydrogen gas is a question of both price and security of supply. In turn, the availability of hydrogen gas can depend on both the demand in the transport market and on the demand in other end uses. In addition, it is a question of electricity supply, electricity grid capacity, and technology development.

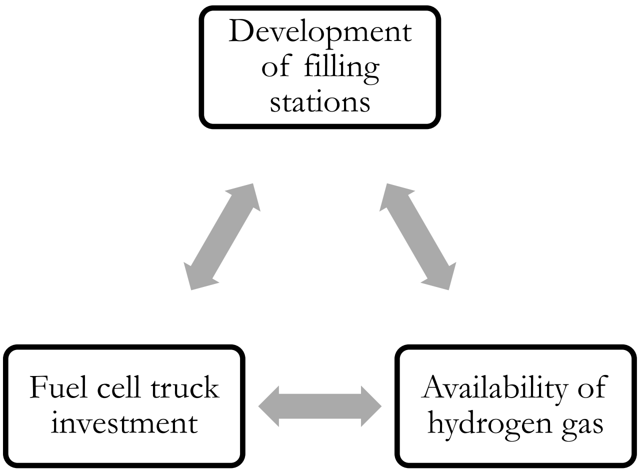

Figure 4: Interaction between different parts of the hydrogen gas transport system

In an analysis of the hydrogen gas market, Eriksson (2021) points out that pilot projects and public support at early stages would probably help overcome some of the obstacles involved in the continued development. Pilot projects can provide actual costs, not just theoretical estimates. Uncertainty for other market players can also be reduced through examples of practical implementation. Uncertainty and risk in investments could also be reduced by public support through, for example, subsidies or partnerships.

Investment and operating costs are determinants in all three areas of Figure 4. As noted above, this study only analyses these costs on an overall level. Instead, the focus is on describing different conditions that may affect the development. Different transport segments and the types of transport in which fuel cell trucks can be regarded as having their main and clearest potential are described in relation to fuel cell truck investment.

There is also a description of factors that affect hauliers in the decision-making process, such as uncertainty and attitudes to investment in new technology, or the willingness to take risk. For the establishment of filling station networks and access to hydrogen gas, there is a description of the grounds for various production and distribution strategies, as well as what challenges market players can face.

3.1. Segmentation based on mileage and driving patterns

A majority of the market players interviewed in this study point out that a combination of alternative fuels will be needed in order to replace the existing fossil fuels. Several market players also point out that it is difficult to predict future conditions in the market, such as because vehicles are not yet available for several of the segments under discussion. Furthermore, the supposed relative advantages of the hydrogen gas alternative may decrease or increase over time, depending on technology development for other vehicles and fuels.

In a number of reports, including in Swedish Transport Administration's analyses of electrification alternatives for heavy road traffic, heavy road transport has been divided into local, regional and long-distance transport, as well as into short shuttle services. Descriptions of the various sub-markets are shown in Table 1.

Short shuttle services	**Local and regional transport**	**Long-distance transport**
Involves continuous journeys back and forth between two points, for example between a port and a factory. The vehicles drive for shorter distances than planned long-distance transport and are often driving around the clock.	Used in limited geographical areas such as for urban distribution or between neighbouring districts. Shorter daily mileage than long-distance transport, and often with a number of stops during the day. The vehicles are often parked during the night in a depot/terminal.	Linking cities, regions and countries. The vehicles drive long daily mileages beyond the delimited geographical area that qualifies as regional transport.

Table 1: Descriptions of sub-markets. (Swedish Transport Administration, EY, 2021)

In addition to these categories, subdivisions can be made into *planned* and *flexible* transport, which are presented later in this section. It is also possible to make subdivisions based on the type of goods transported.

Several of the market players interviewed believe that local and regional goods transport routes are likely to be electrified with battery-equipped heavy vehicles. The technology development for these vehicles is more advanced compared to hydrogen gas vehicles, and the vehicles are likely to meet the transport needs without being affected to a great extent by the shorter range and charging time involved with battery operation compared to diesel operation. Charging can often take place during loading, during rest breaks, and at night.

The major potential for fuel cell trucks is considered to be in the heavy long-distance transport segment. This has emerged from earlier analyses, as in Fossil Free Sweden's "Roadmap for heavy road traffic", as well as in the interviews. However, fuel cell vehicles are also considered to have good potential for shorter shuttle service flows. In general, the types of transport that hydrogen gas is considered to be suitable for are largely justified in terms of the limitations of battery-powered trucks.

Longer range and shorter refuelling time compared to battery-powered vehicles are the main reasons why fuel cell trucks are considered suitable for heavy long-distance transport. One limiting factor for battery vehicles is that large energy needs require higher battery capacity, which increases vehicle weight and reduces load weight. Therefore, there may be potential for fuel cell vehicles in local and regional transport with higher gross laden weights, as well as for transport where energy is also required for systems other than for propulsion, such as concrete mixer trucks. (Bark & Treiber, 2019)

Regulation of driving and rest times plays a major role in planning routes for long-distance transport. Currently, driving periods of 4 hours and 30 minutes are permitted, followed by 45 minutes of rest break (Swedish Transport Agency, 2021). In order for charging or refuelling not to affect the rate of utilisation of a truck, it is almost a prerequisite that the range and charging time for a truck is within the frameworks of the regulations for driving time and rest time. In this respect, fuel cell trucks may have an advantage over battery-equipped vehicles.

For shuttle services, charging and refuelling times are considered a decisive factor in terms of which solution should be used. If loading and unloading times are too short, there will be uncertainty over driving continuously on battery operation.

During a discussion on various transport segments in the interviews, one stakeholder in the transport industry also made a subdivision based on driving patterns between *planned transport* and *flexible transport*. *Planned transport* was often described as following predetermined and fixed routes, and even following a fixed schedule. For example, this could be a fixed flow between terminals or a bus service between two cities. *Flexible transport* is to a lesser extent predetermined and is driven more according to needs. The degree of flexibility may differ a lot between different transport assignments.

As an example, there may be one regular destination for loading or unloading, and then several varying supplementary destinations. One example is timber transport, where the exact pick-up point differs each journey, but where the delivery destination is often the same. Another type of transport is one that is completely flexible, i.e. where both starting point and final destination differ from journey to journey depending on the customer's needs.

For the planned long-distance transport segment, both battery operation and hydrogen gas operation are put forward as possible alternatives. Battery operation is suitable if the transport assignment starts and ends at terminals, where charging can take place. For flexible long-distance transport, interviewees identified varying driving routes as one reason why hydrogen gas could be an effective alternative. In Fossil Free Sweden's road map for heavy vehicles too, hydrogen gas is identified as an alternative in order to reduce the need for charging infrastructure, in particular in areas with little or no traffic and otherwise weak infrastructure (Fossil Free Sweden, 2020).

The extent to which hydrogen filling stations would need to be established depends on how flexible the transport assignments are, and which geographical areas are involved. For transport with one fixed end point, it may be adequate to have one option for refuelling in the vicinity of the end point. For more flexible transport assignments, higher demands are set for the establishment of refuelling infrastructure in order to ensure the availability of hydrogen gas. For timber transport, interviewees expressed a degree of uncertainty about how well suited the fuel cell technology would be with regard to the need for cooling, for example.

3.2. Incentives to invest in new vehicles under prevailing uncertainty.

In order for hydrogen gas trucks to be introduced to a greater extent in heavy road traffic, it is necessary that hauliers will purchase these trucks. There is agreement between the interviewed hauliers that diesel will not be the right alternative in ten years time, viewed from a sustainability perspective and based on likely changes in legislation and public support measures. However, there is uncertainty among many of the haulier representatives interviewed over the path towards a situation in which new vehicles are introduced to a greater extent, who reiterated the difficulty of knowing in which of the fuels to invest.

Diesel operation not being considered a sustainable solution in the long term is already having an effect on the investment by hauliers in the short term, since they are replacing their trucks on an ongoing basis. New investment in a truck is made on the basis of the calculation that it can/should be used for up to seven years, often shorter. Buying a diesel vehicle is not perceived as optimal in the long term, especially as several of the interviewees highlighted problems with HVO from a sustainability perspective and because the price is expected to rise.

For the majority, however, battery and fuel cell trucks are not a viable alternative in the current situation. Battery-powered trucks are much more expensive and adequate charging infrastructure is not available. Several of the hauliers interviewed also expressed concern that the long charging times are not compatible with their driving patterns. With regard to fuel cell trucks, commercial alternatives are currently not available to purchase. They are expected to initially be very costly, and have high fuel cost.

One recurring perspective from the interviews with road haulier representatives was that the road transport market is characterised by fierce competition and that many hauliers are operating on narrow margins. It complicates a haulier's decision to make an investment that increases costs without the possibility of a direct return on it. Several interviewees felt there was little scope for large investments, especially when facing uncertainty over technology development and willingness to pay.

Compensation could come in the form of transport buyers paying a higher price for sustainable transport, or of public support being given to such transport assignments. Even longer agreements with transport buyers are something that several market players believe could reduce the uncertainty of investments. Longer agreements could be one way to ensure revenue streams, and reduce the uncertainty linked to technical and commercial fossil-free alternatives.

One example described in the interviews to illustrate the problem was whether a haulier would have customers who were willing to pay a higher price for fossil-free transport. If so, the haulier would then be able to choose to invest in a hydrogen gas truck. However, after two years, another haulier could have a new type of battery-equipped truck, with a lower total cost of ownership (TCO) than for the hydrogen gas truck. Then the customer could choose to buy its transport from that other haulier instead. The customer still pays for fossil-free transport, but chooses a cheaper alternative. This shows that an instantaneously higher willingness to pay on its own will not necessarily offer sufficient security to invest in a hydrogen gas truck.

The used value of a fuel cell truck may also affect the willingness to invest. The entire service life of the truck is included in an investment calculation. Trucks can be purchased for one certain application area, and later used in other parts of the activities, or sold on directly. In both cases, an investment in a hydrogen gas truck may create challenges due to the technology being so new, and it requires established refuelling infrastructure in order to be used. It could be difficult to use a hydrogen gas truck in other parts of the activities without appropriate refuelling infrastructure and interested customers. When a truck is sold on, it is often to hauliers in other countries. If these countries do not have an equally established hydrogen gas infrastructure, the used market may be limited, which in turn could adversely affect the investment calculation.

3.3. Attitudes at hauliers

The ability and desire to use new technologies at an early stage differ greatly between different hauliers. Some show a willingness to "go first" and test new technologies on an ongoing basis while others have a more "wait-and-see" approach.

The different approaches of hauliers and carriers can be divided into different attitudes or points of view:

- Passive role in the development.
- Some active role in the development. May mean purchasing a fuel cell truck if there is a hydrogen gas filling station and a customer who is demanding it. Within the core activities.
- More active role and participates in the development work, even outside its core activities in the form of, for example, the establishment of refuelling infrastructure.
- Driving role by continuously testing and evaluating different technologies on a larger scale. Searches more actively for electrification methods.

Differences in attitude towards investing in new environmentally friendly technologies have a certain link with the organisation's size and its customers. Larger hauliers often have more room to manoeuvre, both financially and through the adaptation opportunities they have due to their size. However, the interviews draw attention to the fact that there are also differences in attitude between market players of a similar size. An example of this is the current differences between hauliers in terms of what proportion of their fleets drives on "environmentally friendly" fuels, such as HVO and biogas. Even smaller market players/hauliers with a great interest in CO_2-efficient transport can therefore be market players who drive the development, even if they have a more limited financial room to manoeuvre than larger market players.

3.4. Production and distribution strategies for hydrogen gas

Based on the interview study and previously published material, it is possible to distinguish three main ways to organise and coordinate the production and distribution of hydrogen gas as fuel:

- Centralised production and long-distance distribution to filling stations via trucks or pipelines.
- Production adjacent to filling station. Electricity is transferred either via the electricity grid or via its own power lines from adjacent electricity generation.
- Filling station adjacent to a hydrogen gas producing industry. Either with location directly adjacent, or transported shorter distances by truck or pipelines.

A justification for centralised production is to benefit from economies of scale. Large electrolysers with high rate of utilisation can reduce the cost of hydrogen gas. Production can be located where large land areas are available for solar power, adjacent to, for example, sea-based wind power or in other areas where the electricity supply and electricity grid capacity are good. This type of centralised production could also take place in cooperation with other sectors, such as industries.

With production adjacent to a filling station, there is no need to transport the hydrogen gas. Falling electrolyser prices could support this type of production strategy (Fossil Free Sweden, 2021). One example of this type of strategy is located in the municipality Mariestad, where the first hydrogen gas filling station with locally produced hydrogen gas was built with an adjacent solar cell installation (Dagens Nyheter newspaper, 2021).

To produce hydrogen gas for vehicles, along with hydrogen gas for other purposes (here named "co-production"), can have the potential to be cost effective. There are examples of industries producing hydrogen gas with a certain amount of unutilised production capacity, when the electrolyser is not operated for their own purposes. This provides an opportunity to increase the production of hydrogen gas for use as fuel. In the event of new electrolyser investment, production capacity could be increased by purchasing a larger electrolyser in order to produce hydrogen gas for the industry's own transport needs or for those of others. However, the interviews revealed that there have been some challenges with this type of strategy, which is developed in the next section "The challenges of co-production".

Something also referred to by several market players interviewed is the possibility of producing hydrogen gas using so-called "excess electricity". Producing hydrogen gas using "excess electricity" is an attractive way of reducing the price of hydrogen gas. Electricity production surplus arises, among other things, when wind power and solar cells are very productive while demand is low. A lack of adequate storage facilities will result in low prices, or in production shutting down. The larger the variations in electricity generation, the greater the profitability of different storage alternatives such as hydrogen gas.

It is possible to produce hydrogen gas from the surplus, both for local production with limited distribution, as well as with centralised production with more long-distance distribution. Hydrogen gas produced using excess electricity can also be used to produce electricity when there are power shortages. At the same time, questions can be asked about the long-term perspective of a production strategy based on excess electricity, since conditions in the market could be changed by more flexible electricity consumption, the development of other storage methods, and the development of electricity grid capacity.

A representative of a local energy company with its own wind power made the observation in the interview that they recognise a market potential for hydrogen gas in order to take advantage of the electricity currently sold at a very low price on the Nordic electricity exchange, Nord Pool. The company has examined various hydrogen gas projects, but has currently chosen not to invest in anything. Among other things, hydrogen gas could be used to balance the power requirement as described above, for transport or in industrial processes. Any production of hydrogen gas would then preferably be at a wind farm with its own power line to the electrolyser.

To transport the hydrogen gas, the energy company would not take care of the distribution itself, but use a wholesaler. However, this representative believes that the company will not produce hydrogen gas for transport until clear standards are in place regarding requirements for building filling stations. Another limiting factor highlighted was the difficult and uncertain permit process for wind power production.

3.4.1. The challenges of co-production

This study has identified challenges to be addressed with co-production. However, these may differ between industries already producing hydrogen gas through electrolysis and using it in their own processes, and those planning to do so in the future. However, in both cases, there may be a reason to take into consideration any organisational and strategic business conditions.

One challenge in co-production, viewed from the perspective of hydrogen gas production, is that the needs of the core activities are likely to be prioritised first. One stakeholder interviewed stressed that another challenge in co-production is to ensure that there is sufficient hydrogen gas to cover transport needs. Even with unutilised production capacity at certain times, the amount varies based on the needs of the core activities. Co-production where hydrogen gas as vehicle fuel is the by-product therefore requires sufficient incentives and good coordination in order to be implemented. If the hydrogen gas producing industry increases its production capacity in order to supply hydrogen gas for transport, it means yet one more step away from the core activities, and is likely to require additional incentives and coordination measures.

In order for the hydrogen gas to be used for the industry's own transport, the routes must also be suitable as follows: either short enough to ensure that its own filling station covers the needs, or that additional hydrogen gas infrastructure is available. It will become particularly challenging if the transport is purchased and co-loading takes place with transport for other transport buyers, which may lead to transport patterns that are not suitable for hydrogen gas supply.

For industries planning to introduce hydrogen gas into their processes, such as the steel industry, one enabling factor could be that it coincides with ongoing production changes that may facilitate cooperation with other market players. Here, new facilities may have an advantage over industries that already have an established way to supply their processes with hydrogen gas. Industries planning for co-production right from the outset have equally good conditions as industries currently using fossil hydrogen gas, such as refineries, but which are planning to change to using fossil-free hydrogen gas.

4 Regional Perspective - Region Örebro and Region Blekinge

Different regions in Sweden differ in terms of, among other things, infrastructure for natural gas and biogas, and electricity supply (Fossil Free Sweden, 2021). Conditions for establishing cross-sectoral collaboration on hydrogen gas also differ between different regions based on the composition of the business sector, local public sector actors, and existing meeting places. In this study, the conditions for production and use of hydrogen gas have been examined from a regional perspective, for Region Örebro and Region Blekinge.

The Swedish Transport Administration has previously studied Region Örebro and Region Blekinge regarding the introduction of other electrification alternatives for heavy road traffic. The present study is based on the combined knowledge and analysis of the various electrification alternatives at a local and regional level.

Active work is underway in both regions at regional level to develop energy-efficient and CO2-efficient transport solutions through collaboration between research, the business sector, and the public sector. At the same time, the regions differ in terms of size, geographical location and traffic flows, which affect the conditions for introducing fuel cell vehicles. Together with the interest in developing infrastructure, this means that the regions are interesting and relevant to study.

4.1. Area descriptions of the regions studied

4.1.1. Region Örebro

In 2020, Örebro County had approximately 300,000 inhabitants, and it consists of 12 municipalities, of which Örebro municipality has about half of the county's inhabitants (SCB, 2021). The region is an important hub in the Swedish transport network. Both the E18 and E20 roads pass through the region, interconnecting Stockholm with the metropolitan regions of Oslo and Gothenburg, among others. Örebro is located along the EU TEN-T Core Network. The Western Main Line railway and the goods railway through the region Bergslagen, as well as the rail terminal in Hallsberg and the E18, are included in the TEN-T Core Network. The E20 to Gothenburg and Örebro Airport is included in the overall TEN-T Core Network. In July 2021, it was announced that Sweden's first pilot section of an electric road would be built between Örebro and Hallsberg (Swedish Transport Administration, 2021b).

The region is also an important transport link for rail transport since, among other things, it interconnects eastern and western Sweden through the Western Main Line, as well as southern and northern Sweden with the goods railway through Bergslagen. Both tracks extend through Hallsberg, where the Nordic region's largest marshalling yard is located (Region Örebro County). Örebro Airport handles large amounts of goods every year and is Sweden's fourth largest cargo airport after Arlanda, Sturup and Landvetter (Ministry of Enterprise and Innovation, 2018).

Several companies have their national central warehouses in the region, including Lidl, XXL Sport & Vildmark, Ahlsell and Würth. Several companies use the airport as a gateway to Sweden, including DHL and FedEx. Other major market players in the county include Kopparbergs Brewery, Lantmännen Unibake, BillerudKorsnäs and Epiroc Rock Drills. There is also a steel industry consisting of companies such as Scana and Ovako Steel.

4.1.2. Region Blekinge

Blekinge County consists of five municipalities and in 2020 had about 160,000 inhabitants (SCB, 2021). The E22 road runs through the region and interconnects Malmö and Stockholm via Norrköping. However, it is not the most direct route between Malmö and Stockholm but an important alternative route if the E4 road is not available or optimal for individual transport assignments. National highway 15 starts in Karlshamn and passes through, among others, the municipality Olofström northwest on the road to Halmstad. The ports of Karlshamn, Karlskrona and Sölvesborg are also located in Blekinge (Region Blekinge, 2018). The region's largest airport, Ronneby Airport, is a regional airport, which is also used by military aircraft (Swedavia, n.d.).

Several major manufacturing companies and forestry industries are located in the region such as Södra Cell, AAK and Volvo Cars. These companies and industries use the region's transport infrastructure, mainly for import and export. Several companies are also located in neighbouring counties; such as Stora Enso in Nymölla and IKEA in Älmhult, which both generate a lot of transport in the region.

Karlshamn and Karlskrona ports are included in the overall TEN-T Core Network, as are the E22 and Ronneby Airport. The ports are part of Motorways of the Sea (MoS), the maritime part of TEN-T, which is expanding and linking the core networks of TEN-T using maritime services. MoS connects Karlskrona with the Baltic - Adriatic corridor in Gdynia, Poland. It also connects Karlshamn with the North Sea - Baltic corridor in Klaipéda, Lithuania (European Commission, n.d.).

Region Blekinge is working in several projects aimed at developing the transport infrastructure. One of which was the EU-Interreg project TENTacle, in which the region was a leading stakeholder, examining how the region should be able to utilise its geographical position in the vicinity of several TEN-T corridors in order to increase the transport flow in the region, among other things (TENTacle, 2019).

A new railway called "South East Link" is also planned to connect Blekinge coastal line near Karlshamn with the Southern Main Line in Älmhult (Swedish Transport Administration, 2021c).

4.2. Interpretation of regional conditions for hydrogen gas as fuel

4.2.1. Region Örebro

The regional conditions for hydrogen gas in Region Örebro are good in several respects. The large transport flows with both vehicles passing through and goods that are handled in storage and then change type of transport in the region mean that a possible hydrogen gas filling station has the potential for a high rate of utilisation and to link together different cities. Örebro's geographical location and strategic importance for transport also create the conditions to cooperate with other regions.

According to the proposal from the EU, addressed in Section 1.1, hydrogen gas filling stations should be established along the TEN-T Core Network, along which Örebro is located, making its location particularly important. A further positive condition is that there is a certain overcapacity of wind power in the region that could be utilised for the production of hydrogen gas. Örebro is also included in the 15 locations in Sweden listed by Everfuel as being attractive for setting up hydrogen gas filling stations (Everfuel, 2021).

There is also a certain demand for hydrogen gas within the industry, which is likely to increase. Primarily from several companies active in the steel industry that may introduce hydrogen gas into their processes. Ovako Steel, which has a plant in Hällefors, also has a plant in another region where hydrogen gas has been introduced for heating steel. Ovako Steel has announced that the hydrogen gas produced at that plant may also be used for transport (Ovako, 2021).

There is an active interest in the region for the hydrogen gas alternative. At municipal level, Karlskoga municipality has decided to develop a strategy for how it should work with hydrogen gas (Karlskoga municipality, 2021). At regional level, Region Örebro County is working for the development of hydrogen gas in several places. Region Örebro County's action plan addresses hydrogen gas, biogas and electricity as the fuels that the region should prioritise, primarily for city buses and distribution trucks (Region Örebro County). The region is also involved in several projects to promote hydrogen gas and other fossil-free alternatives (Region Örebro County).

Region Örebro is also a participant in the CLOSER project that deals with transport efficiency and is managed by the Lindholmen Science Park based in Gothenburg. Another active stakeholder is Alfred Nobel Science Park. The region is also home to a number of companies that work with technology development for hydrogen gas production and fuel cells. Finally, Örebro University is actively involved in the hydrogen gas alternative, contributing with research competence.

4.2.2. Region Blekinge

Region Blekinge has a number of good conditions for developing hydrogen gas as fuel but also faces a number of challenges.

The region's business community is characterised by a few large industries as well as ports that link the region with Eastern Europe. Compared to Örebro County, for example, Blekinge does not have comparably large traffic flows through the county. Therefore, the size of the long-distance transport fleet that is likely to make use of a hydrogen gas filling station is smaller. However, Karlshamn, where one of the ports is located, has been identified by Everfuel as a possible site for a hydrogen gas filling station (Everfuel, 2021).

The ports in Blekinge have the potential to be suitable as nodes in a hydrogen gas infrastructure system, both for transport passing through, and when hydrogen gas can be imported into the port by ship. However, the goods traffic in the ports largely consists of RO-RO transport, giving road transport a direct link to abroad.

The fact that the trucks travel from or to other countries sets demands for a coherent European infrastructure in order to facilitate the use of fuel cell trucks. This means that the introduction of heavy fuel cell vehicles in Blekinge is dependent on developments in Europe, as well as that standardisation continues. This could be an obstacle to the introduction of hydrogen gas for certain road transport applications, but also paves the way for cross-border collaboration.

The Blekinge Institute of Technology, BTH, is located in the region and, together with Netport Science Park, has a collaborative and knowledge-enhancing function for the transition to fossil-free transport. Another public stakeholder is the Energy Office Southeast that is launching a feasibility study on renewable hydrogen gas in Blekinge County in 2021. A similar study has been carried out for neighbouring Kronoberg County, examining conditions for hydrogen gas as fuel, among other things.

Also located in the region is the food company AAK, which produces hydrogen gas through electrolysis and uses it in its processes. The conditions for expanding production of hydrogen gas through electrolysis in Region Blekinge may be affected by the region being located in an area of electricity shortages, characterised by the highest electricity prices in Sweden. However, there are plans to expand offshore wind generation in the region that could contribute to "overcapacity" as well as that hydrogen gas could become an attractive alternative for a range of end uses.

5 Conclusions

In the long term, fuel cell trucks are likely to be primarily used for heavy long-distance road transport. However, they may also be used for local and regional transport, such as in shuttle services and very heavy road transport. One condition that could promote local and regional use of hydrogen gas as fuel is whether the production or use of hydrogen gas for purposes other than transport takes place in the region in question.

However, it is not a foregone conclusion that other use of hydrogen gas "spills over" to the transport sector, as it requires incentives for a company to move from being producer and user for its own needs in industrial processes, to using the hydrogen gas for its own transport or selling it on. At local and regional local level, individual key market players in the transport sector could also influence the development. For example, it may be that hauliers build their own filling stations as part of strategic development work.

This study has identified several factors that could possibly affect the method for and likelihood of realising the successful establishment of hydrogen gas infrastructure for heavy road transport, as well as what could prevent an introduction. These are summarised in Table 2.

Investments in fuel cell trucks	**Establishment of filling stations**	**Availability of hydrogen gas**
Investment cost Fuel cost Technical development for fuel cell vehicles Filling stations suitable for routes Security of supply *Confidence that hydrogen gas will be available* Competence in operation and service Willingness to take risk Political decisions and public support measures *for fuel and emissions*	Investment cost Rate of utilisation Competence in operation and service Safety permits *The local emergency services are currently responsible for issuing permits* Political decisions on development *Allocation of responsibilities between private and public sector* Different development scenarios – in many places simultaneously or step-by-step	Development of production capacity - costs and technology Opportunity for co-utilisation of local production capacity in industries with transport sector needs. Technical development for electrolysers Electricity supply Electricity grid capacity Transport and storage facilities Different strategies on production - centralised or local

Table 2: Significant aspects of the establishment of a hydrogen gas system for heavy vehicles

Availability of fossil-free hydrogen gas is decisive in many ways, and dependent to a great extent on developments in sectors other than the transport sector. The price of hydrogen gas will depend on production costs and distribution costs, and forecasts on future price developments are uncertain. Production costs depend on the price of electricity, electrolyser efficiency, and economies of scale in production, among other things.

The establishment of hydrogen gas filling stations will require significant investments. They will probably need to be financed through both private funding and some public funding. There are indications that, in an initial stage, filling stations will primarily be built in certain geographical locations in so-called clusters. Usage may be limited to these areas, depending on the developments, even in the long term. At the same time, other factors indicate that the development could take place simultaneously in several locations, over a larger geographical area, including the EU's proposal on establishing filling stations, and that long-distance transport is a suitable segment for the use of fuel cell vehicles.

Filling station utilisation rate is an essential factor to take into account for achieving good distribution efficiency. It is a question of dimensioning the supply of hydrogen gas during production for the filling station, or the transport from centralised production. Intrinsically, these are essential factors that determine the potential for achieving profitability. Furthermore, no national guidelines currently exist for safety permits for hydrogen gas filling stations, which is an obstacle to development.

Fuel cell truck investment is likely to be made by major hauliers, but there is also willingness among some smaller market players to be early movers in the change to hydrogen gas. Investment cost and fuel cost will naturally be very important factors in the investment decision, as well as what benefit fuel cell trucks will bring to the individual haulier's routes.

The attitude of transport buyers towards sustainable transport will also affect the willingness and opportunity to invest in a new vehicle. It will also be important that dealers and workshops have the competence to handle the company's fuel cell trucks. Emissions legislation and any public support measures for vehicles will probably also affect the rate and scale of the introduction of both hydrogen gas as fuel and fuel cell vehicles.

Hydrogen gas is currently in the development phase, which is characterised by great uncertainties. The same also applies to other fossil-free transport solutions, to a varying extent. Cooperation and joint learning will therefore also be crucial factors. This needs to take place between the public and private sectors, between different geographical areas, and between market players in the value chain. It is a question of finding new business models, sharing risk taking, as well as transferring both practical and theoretical knowledge.

Studies are already being conducted, as well as strategic collaborations and pilot projects in different parts of Sweden, and these are expected to increase in number over the next few years. It is important to make use of the experience and lessons learned in these projects in order for the hydrogen gas alternative for heavy road transport to continue to develop.

5.1. Development in the regions studied

There are several factors indicating potential for hydrogen gas as fuel in Region Örebro, where the most prominent is the region's strategic transport location. There is a large long-distance transport fleet that both starts from and passes through the region. One or more hydrogen gas filling stations in the region could therefore be a natural part of a larger network. Market players outside the region could therefore be a driving force in the development.

A development in Region Örebro is more likely to be based on industrial collaboration rather than on large transport flows. This would primarily mean local and regional transport assignments using hydrogen gas. In order for it to be implemented requires sufficient incentives for carriers, but perhaps mainly that transport with appropriate driving patterns and/or heavy loads is identified. For example, it may be a question of shuttle services to and from the ports of the region. One possibility is that demand is driven by the by public sector through procurement.

There are several different ways in which production and distribution of hydrogen gas as fuel could take place in the regions. Several interviewees described the advantages and disadvantages of hydrogen gas from centralised production compared to local production as needing further investigation ahead of future establishments and choices. Factors that can play a role in these establishments are local electricity supply and possible rate of utilisation of the filling station, which affect the dimensioning of electrolysers and storage. There is the possibility to use excess electricity for local production in both regions.

The development of wind power in Region Blekinge may have a positive effect on the conditions for hydrogen gas production there. Co-production could be feasible in Region Örebro due to the steel industry located there, which may introduce hydrogen gas into its processes. In Region Blekinge, there is already a company located there that uses hydrogen gas produced with its own electrolysers.

The examination of the regions highlights how the conditions for introducing hydrogen gas for heavy road transport differ between geographical areas. It is important to weigh in these regional and local conditions for the continued development of the alternative of hydrogen gas and fuel cell vehicles for heavy road transport.

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