THE PATHWAYS COALITION

SCANIA E.ON SIEMENS H&M Group

Fossil free alternatives for commercial road transportation in Sweden

April 2019

SUMMARY

Commercial transport is expanding rapidly around the globe as a result of rise in trade and diversification of value chains. Flexible and dependable commercial transports play an important role in the economic system and a central role for CO_2 emissions. Using road transport for freight, in particular trucks, is the most appropriate and effective solution for short and direct routes and thus also widely used. The solution will remain the dominant mode of cargo transportation for several years to come. In Sweden, close to one fourth of total final energy use derives from domestic transportation, whereof road transportation constitutes 70 percent.

The central question is; how can the commercial transport be fossil-free by 2050 and which renewable alternatives are effective? Although trucks stand for around 5 percent of vehicle stocks globally, they represent 20 percent of road transport fuels, a third of global diesel demand.

This report describes the current and near future situation of renewable commercial transport alternatives available within the Swedish transportation system. The report covers the current and future production level, fuel (or energy) providers, infrastructure availability, vehicle supply, pricing compared to fossil alternatives, important regulatory frameworks and additional values. The renewable alternatives that are viable within the Swedish context are;

- Biogas
- Biodiesel and renewable diesel (FAME/RME and HVO)
- Bioethanol (ED95)
- Electrification (including hydrogen fuel cells and e-highways)

The report shows that reducing future and current reliability on fossil fuel is a somewhat challenging, but highly possible task. The regulatory environment, withdrawal of state support, plays a significant role for the incentives. In a nutshell, there are six recommendations for commercial transport actors:

Increase your knowledge about available alternatives
The transport sector is developing rapidly. Keeping updated on current status as well as what lies in the pipeline is key to generate opportunities for action and make well-informed decisions.

Be certain of an uncertain world
Uncertainties are a natural part of a changing climate, economy and political landscape. Accordingly, decisions have to be made outside the comfort zone of certainty.

Put demands on your suppliers
Make use of all indirect possibilities to steer other transport actors towards a sustainable solution.

Cooperate with other actors in the value-chain
Cooperation will increase sustainability and drive more efficient use. Horizontal collaborations and coordinated transport will enable more resource efficient utilization of the transportation system.

Do not wait – solutions are available
There are several renewable fuels today that are viable. There are strong cases in terms of cost, efficiency and GHG-emissions already and in the near future the business case will be even stronger.

Create a fuel-strategy, don’t put all eggs in one basket
Find your business strategy for renewable fuels, establish a baseline and utilize multiple fuels/solutions to minimize your risk and create most opportunities for infrastructure.

Infrastructure availability – aggregated map

The filling station infrastructures for different fossil free alternatives are developing quickly – within a two year timeframe the availability of both LBG/LNG and ED95 will have increased substantially, and the network of filling stations for biodiesel/renewable diesel already has a good coverage. Aggregated information on existing and planned filling stations for ED95, LBG/LNG and HVO/RME can be found in this map. Note that all stations may not be represented, as the filling station networks for all alternatives are developing continuously. Filling stations for compressed gas are not included – those can be found on the website of Energigas Sverige.

Combined SWOT

	Strengths	Weaknesses	Opportunities	Threats
Biogas	• Low emissions of air pollutants • High GHG abatement • Primarily produced from waste and residues • Local energy security • Organic fertilizer • Possible night time distribution in cities due to low noise pollution from LBG trucks	• Requires specialized vehicles • Costly fuel distribution and filling infrastructure • Limited reach	• Increased sorting and collection of food waste • Broad feedstock spectrum • Potential production increase from manure and industrial waste water	• Limited supply of different vehicle models • Withdrawal of temporary production support • Uncertain secondary value of vehicles
HVO	• Flexible fuel – can be used in diesel vehicles • Existing fuel distribution infrastructure can be used • High GHG abatement	• Limited access to sustainable feedstock	• Potential domestic production from forestry residues • Stable demand could spur increased domestic production	• Changes in classification of PFAD • Potential deficit due to high demand
FAME/RME	• Competitive fuel price • Completely non-toxic fuel • Flexible fuel – can be used in diesel vehicles • Existing fuel distribution infrastructure can be used	• Low energy yield for rapeseed • Relatively low GHG abatement • Disadvantages of low quality FAME damage the reputation of high quality FAME in parts of the transport sector	• Rapeseed is an important in-between crop for soil fertility resulting in higher yields of the main crop • Increased demand for low blend biodiesel • Cultivation of rapeseed contributes to biodiversity	• Withdrawal of state support
ED95	• Ethanol is a mature biofuel with high global availability (fuel redundancy) • "Cheat free" in operational phase - secures use of fossil free fuel • Easy to handle	• Non-flexible fuel which requires specialized engines (new vehicles) • Primarily produced from food crops like wheat and maize • Higher fuels costs	• Domestic production potential in food waste and forestry residues • Near future expansion of infrastructure • Potentially cost efficient with regards to emissions reduction	• Few fuel providers • Only one provider of ED95 trucks (Scania) • Limited secondary market
Electrification	• Elimination of local air pollution • Increased energy efficiency • Low maintenance costs • Low noise volume • Use renewable energy for charging • Low charging costs • High efficiency	• Less capacity for cargo loading • Charging time • Complex charging infrastructure (Different standardizations for charging) • Infrastructure cost • Short/limited driving range • Higher vehicle cost • Not fully technically developed • Lifetime of the batteries	• Synergies with renewable electricity development • Fast technical development (batteries) • Demand for electric vehicle increase • The grid will evolve (charging • Low-cost batteries • Political support (road pricing, special lanes, subsidies) • Lower cost of use and service	• Energy and local grid access (underdeveloped infrastructure) • Uncertain supply of battery components • Other renewable alternatives • Limited charging infrastructure • Price uncertainty in secondary market

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INTRODUCTION

In the spring of 2018 Scania, H&M, Siemens Sverige and E.ON Sverige formed a coalition with the joint vision to achieve fossil-free commercial transport by 2050, in accordance with the Paris Agreement. The coalition pushes for an acceleration of the shift to renewable transport alternatives on the basis of the report The Pathways Study (Scania, 2018) which analyses different pathways to achieving fossil-free commercial transports by 2050.

Drawing on conclusions from *The Pathways Study,* this report attempts to describe the current and near future situation of renewable commercial transport alternatives available within the Swedish transportation system. Content is based on interviews with representatives and experts on different renewable fuels, as well as relevant transport- and fuel related reports, where attention is given to currently feasible renewable alternatives within the Swedish context: biogas, biodiesel/renewable diesel, bioethanol and electrification (including hydrogen fuel cells). These alternatives are described in terms of current and future production level, fuel (or energy) providers, infrastructure availability, vehicle supply, pricing compared to fossil alternatives, important regulatory frameworks and additional values. Given the significant emissions reduction potential from efficiency measures unrelated to fuel or powertrain changes, some examples of such measures are also highlighted.

The study may be subject to limitations, especially regarding the full price picture and the planned expansion of infrastructure. Fuel prices and additional vehicle costs vary over time and between different suppliers, and these parameters are typically also negotiable from case to case. Infrastructure development involves numerous actors, of which some may have been overlooked by this study. Furthermore, some contacted actors did not respond, in which case information has been gathered from relevant trade associations or other public sources.

Background: National fuel outlook

Close to one fourth of Sweden's total final energy use derives from domestic transportation, whereof road transportation constitutes 70%. The total energy demand from transportation currently amounts to 85 TWh and according to the Swedish Energy Agency's report on future energy system scenarios[1] the coming years will show an increase in energy demand, following increased traffic.

By 2050 the most optimistic scenario predicts a reduction of the energy use to 70 TWh given increased electrification and continuous energy efficiency measures. The share of biofuels is predicted to increase regardless of scenario but due to lack of long-term political instruments affecting the biofuels market, the rate of development after 2020 is uncertain. In 2017 the share of renewables was 21% of the total fuel market in Sweden[2], based on energy content. Compared to previous year (2016) this is a rise, largely explained by an increase in low blend use, see Figure 1.

1 Energimyndigheten, 2017. *Scenarier över Sveriges energisystem*.
2 Energimyndigheten, 2018. *Drivmedel 2017 - redovisning av uppgifter enligt drivmedelslagen och hållbarhetslagen*.

Figure 1

Share of renewable fuels for transport, based on energy content. Source: SPBI.

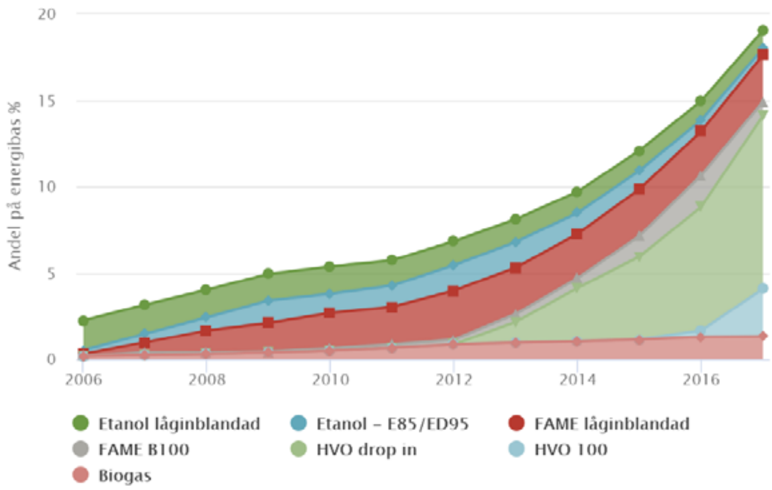
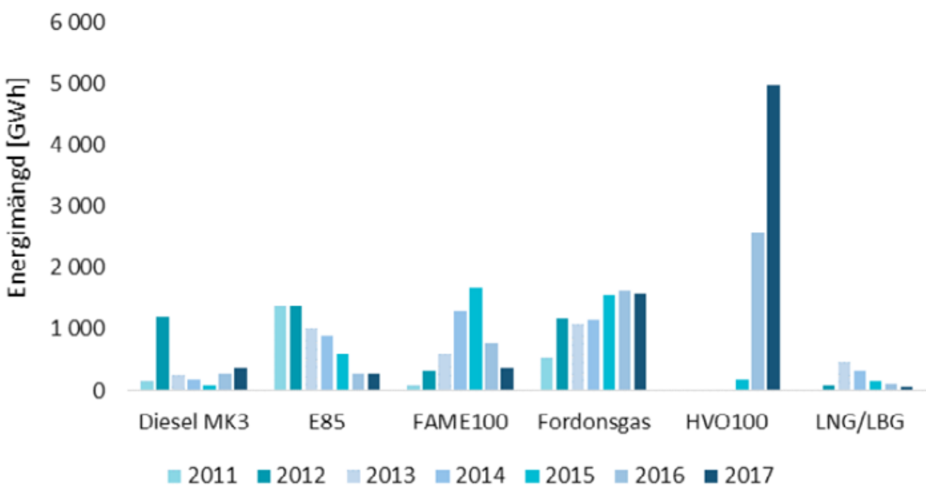


Figure 2 shows the distribution of the different biofuels delivered to the Swedish market between 2011 and 2017. The amount of HVO100 nearly doubled from 2016 to 2017 while both quantities of FAME100 and ethanol E85 have declined. Diesel MK3 is fossil diesel with an environmental classification level in line with EU-limitations regarding e.g. sulphur content.

Figure 2

Delivered quantities of biofuels and diesel MK3. Diesel MK3 is fossil diesel with environmental classification level 3, limiting the content of several harmful substances. Source: Energimyndigheten, Drivmedel 2017.



Commercial transport

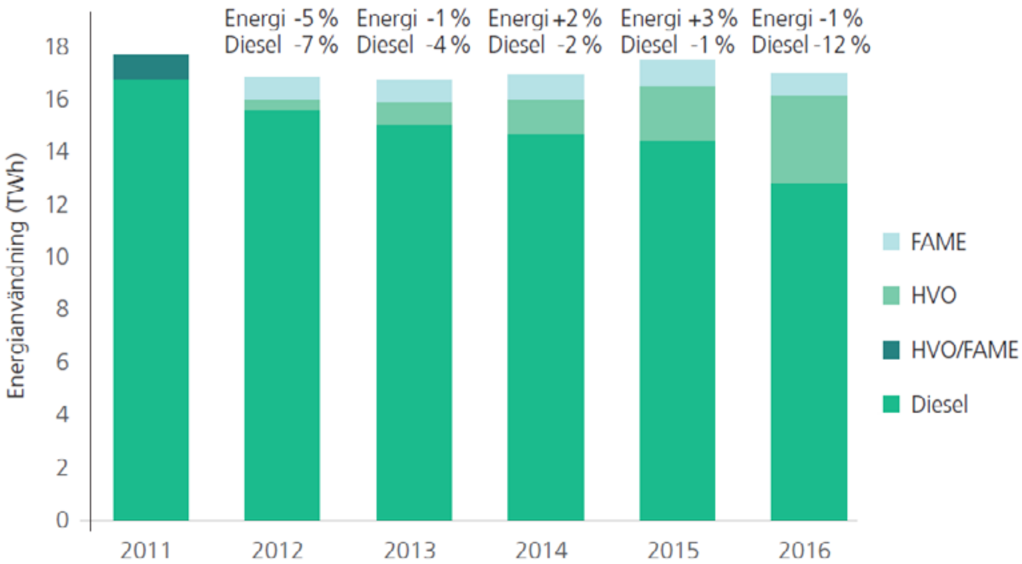
Flexible and dependable commercial transport play an important role for competitiveness and economic growth and in many cases implies using road transport. Nonetheless, road transport is also coupled with high GHG emissions intensity in relation to transported load. Light and heavy-duty trucks were the source of 30% of total domestic road transport GHG emissions in 2015[3]. Better efficiency through fewer load free transports and increased use of biofuels have contributed to emissions reductions but this positive development is challenged by growing national and international traffic volumes.

3 KNEG, Resultatrapport 2017.

The largest emissions reductions for trucks have been achieved through an increased share of biofuels, primarily in the form of higher low blend use of HVO. Figure 3 shows the development of biofuel use in heavy-duty trucks until 2016. The effect of the 2018 reduction quota is therefore not accounted for, nor the change in fuel composition over the last two years.

Figure 3

Energy use in heavy-duty trucks 2011-2016. Source: KNEG, Slutrapport 2017.



To reach the national 2030-target on fossil free transports, actors within the transport sector need to make use of and support currently available renewable alternatives as well as continue improving logistics and develop vehicle-related efficiency measures. Compared to private cars the lifetimes of heavy vehicles are shorter and therefore allow for a swifter readjustment to vehicles adapted for any of the renewable alternatives available today[4]. Opportunities also lie in the comparatively limited need for filling stations, and as infrastructure for several biofuels is expanding quickly within the immediate years this opens up for a more widespread adoption.

Key actors

Apart from fuel- and vehicle suppliers as well as hauliers, both private and public transport buyers can play a key role in a swifter shift to a sustainable commercial transport sector. Through well-informed procurement processes transport buyers can dictate the demand for more sustainable alternatives, hence creating long-term space for growth of the market for fossil free transport solutions. One of many good examples of this is the partnership between McDonald's, their haulier HAVI and Scania, aiming at adapting or substituting 70 percent of HAVI's vehicle fleet to alternative fuel technologies (e.g. gas and electric hybrids) by 2021. By supporting this collaboration, McDonald's will reduce transport emissions and contribute to turning expertise from different actors in the value chain into practical use. This kind of cooperative solutions can be seen in the public sector as well.Introduction

4 Trafikutskottet, 2018. *Fossilfria drivmedel för att minska transportsektorns klimatpåverkan.*

BIOGAS

Biogas upgraded for vehicle fuel use is mainly comprised of methane gas and thus has the same chemical composition as natural gas. Biogas as vehicle fuel is available in compressed or liquefied form (CBG or LBG). In compressed form biogas is sold as vehicle gas – a mix of biogas and natural gas – where the biogas share depends on the input of biogas as well as natural gas into the gas grids. The biogas share has increased steadily over the last years to a current level of a little over 90%.

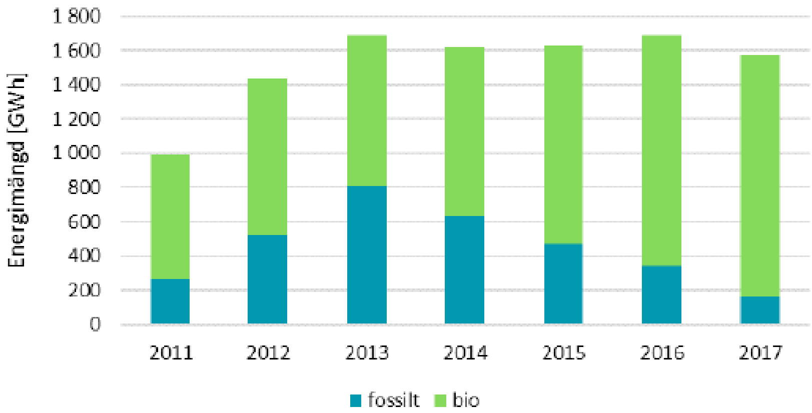


Figure 4

Development of biocomponents in vehicle gas. Source: Energimyndigheten, Drivmedel 2017.

Liquefied biogas (LBG) is produced through an additional purification and cooling step in the biogas production, making it less voluminous and therefore more efficient to store and distribute than compressed biogas. Accordingly, the higher energy density allows an extended reach for vehicles on LBG in comparison with CBG, given the same size of onboard fuel storage.

The largest area of application for produced biogas is upgrading to vehicle fuel, where buses have comprised the main market within commercial transports since the 90's. However, the liquefication of biogas and natural gas opens up new applications, not least within the transportation sector in terms of shipping and long haul truck transports.

Through an initiative from Fossilfritt Sverige (Fossil free Sweden, supported by the Swedish government), a biogas arena for accelerating the shift to fossil free commercial transports has been launched. Kalmar region is home for the arena, that gathers actors from across the nation with the aim to support development of the national market for LBG and act as an international showroom for LBG solutions within the transport sector.

Current production level and future potential

According to the Swedish Energy Agency's annual report on fuel properties and amounts, vehicle gas was the fourth most common fuel on the Swedish market 2017, in total 1,57 TWh[5]. The total production of biogas 2017 amounted to 2 TWh – a slight increase from 2016 – with most of the production originating from co-digestion facilities and sewage treatment facilities. Assessments of future production potential indicates a possible production increase to at least 6,2 TWh[6] through utilization of already available organic residue, such as manure, and the long-term strategic goal is 15 TWh (whereof 12 TWh for the transport sector) by 2030[7].

5 Energimyndigheten, 2018. *Drivmedel 2017 - redovisning av uppgifter enligt drivmedelslagen och hållbarhetslagen*

6 Börjesson, P., 2016. *Potential för ökad tillförsel och avsättning av inhemsk biomassa i en växande svensk bioekonomi*. Lund University, Department of Technology and Society.

7 Energigas Sverige, 2018. *Förslag till nationell biogasstrategi 2.0.*

Biogas can be produced from a wide range of different organic products, including energy crops, but the main feedstock (90%[8]) in Swedish biogas production is waste and residues such as sewage sludge, industrial sludge, sorted food waste and manure. Sewage sludge is a well-used feedstock while only a fraction of available manure is currently used for biogas production. Industrial sludge is also a feedstock with relatively untapped potential[9] where waste water from pulp industries is an interesting alternative.

Compared to other biofuels biogas is often produced locally due to distribution limitations and locally available feedstock. This contributes not only to efficient waste treatment but also to domestic energy security. In 2017 production from domestic feedstock satisfied 82% of the demand for biogas[10].

LBG/LNG

The Swedish production of liquefied biogas is currently limited to a single facility in Lidköping, with a production capacity of approximately 60 GWh. Gasum is planning a new production site, in connection with Nymölla pulp mill, with a capacity of 75-100 GWh[11] and Svensk biogas in Linköping has been granted funding from Klimatklivet for a liquification facility in Linköping. The production start for these new sites is 2020 and 2019 respectively.

To ensure security of supply to new filling stations for liquefied gas, Gasum will initially distribute LNG. However, with growing demand and increased production, the share of LGB is expected to increase, similar to the development for compressed biogas in vehicle gas.

Energy & Fuel providers today

2016 there were around 30 distributors of biogas[12]. E.ON Gas AB is a big distributor as well as AGA and FordonsGas. Several distributors, like Svensk Biogas, operates regionally and many of them cooperate with larger fuel providers like Circle K and Preem.

Providers of LBG is currently FordonsGas in Lidköping, soon joined by Gasum and Svensk Biogas.

8 Trafikutskottet, 2018. *Fossilfria drivmedel för att minska transportsektorns klimatpåverkan*
9 Interview, E.ON.
10 Energimyndigheten, 2018. *Drivmedel 2017*
11 Interview, Gasum.
12 Energimyndigheten, 2016. *Marknaderna för biodrivmedel 2016.*

Infrastructure availability - current and predicted future status

Regarding infrastructure for CBG there are currently two main gas grids: the Southwest grid (reaching from Dragör in Denmark to Stenungsund, north of Gothenburg) and the vehicle gas grid in Stockholm.[13] Complementary to the main grids there are several smaller regional grids, e.g. in Linköping, with limited coverage.

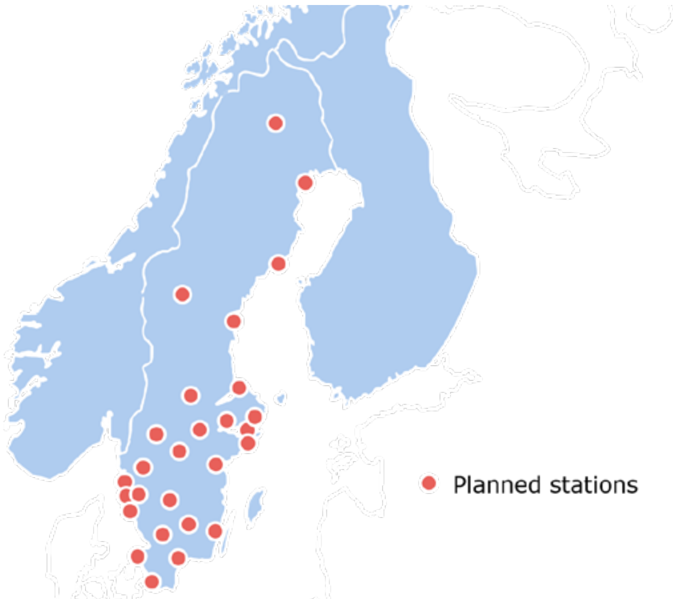
Over the last ten years the number of filling stations for vehicle gas has shown a year-on-year growth[14]. All together there were a little over 170 public and an additional 60 non-public filling stations for vehicle gas in the beginning of 2018[15], the vast majority of which can be found south of Uppsala. The few filling stations in the north of Sweden are concentrated to the coastline. For a more detailed description of current filling stations status, see Energigas Sverige's interactive map.

Today the infrastructure for liquefied gas is limited to 6 filling stations – 2 in Stockholm, 1 in Örebro, 1 in Gothenburg, 1 in Jönköping and 1 in Helsingborg[16] – but the planned growth in the coming years will significantly expand the network of available filling stations and offer better geographical coverage. Gasum – among several other actors within the gas segment – has received funding from Klimatklivet to establish 25 new filling stations for LGB/LNG in Sweden by 2020[17], see Figure 5. The first of those will be up and running by 2019. FordonsGas is another actor planning infrastructure expansion, beginning with two stations in Götene and Mjölby, with ten more in the pipeline.

Located strategically along important transportation core networks an estimated 30-40 filling stations could be enough to cover national transports. This development is also driven by the EU directive on infrastructure for alternative fuels, through requirements of a maximum distance of 400 km between filling stations by 2025[18].

Figure 5

Planned expansion of Gasum's Swedish network for LNG/LBG stations, by 2020. Source: Gasum.



13 Energimyndigheten, Energigas Sverige, 2018. *Produktion och användning av biogas och rötrester år 2017*
14 SPBI, 2018. "Försäljningsställen med förnybara drivmedel".
15 Energigas Sverige, 2018. "Tanka gas ".
16 Interview, E.ON.
17 Interview, Gasum.
18 Interview, E.ON.

Vehicle supply – current and coming

Vehicle manufacturers providing heavy trucks for LBG/CBG are currently Scania, Volvo and Iveco, although Iveco is a smaller player on the Swedish market. Mercedes is also developing heavy gas vehicles and will probably launch once the market is more mature. Current vehicle models were all introduced to the market by the second half of 2018 and development is still ongoing.

Vehicles available today (introduced in 2018):

- Heavy trucks, 13-liter engines (Scania, Volvo, Iveco)
- Light trucks, 9-liter engines (Scania, Iveco, MAN). Adapted for compressed gas, some models available for liquefied gas
- Vans (Iveco, Fiat)

CBG or LBG can also be used in adapted gasoline- or diesel engines where the latter is more effective but requires diesel for ignition[19]. However, there is currently little economic incentive to convert trucks, due to value losses in used vehicles and secondary market insecurities.

Regulatory framework

Important regulations:

- **Tax exemption for high blend biofuels:** an incentive for increased demand, but short-term decisions hamper long-term investments in new production.
- **Production support:** temporary production support for specific feedstocks.
- **Green gas exchange:** different taxations currently prevent green gas exchange across states of aggregation.
- **Reduction quota (effective since July 1, 2018):** some distributors see an increased demand for biogas as a larger share of biodiesel is used for low blend purposes.
- **Environmental zones:** biogas vehicles will be allowed in the strictest zero emission zones that are likely to be implemented in the central parts of larger Swedish cities in a near future.

Since 2015 biogas producers receive a temporary production support (maximum 0,4 SEK/kWh) for biogas produced from manure[20]. This temporary production support is effective until 2023. Many biogas producers request a more permanent production support to match financial preconditions for competing biogas production in Denmark.

Biogas sold as vehicle fuel is fully exempted from both energy tax and carbon dioxide tax until 2020. These tax exemptions are favourable for the demand side but since the prolongation of the exemptions has only been decided in short-term intervals, investments in new production have been somewhat stunted[21]. Instead the main drivers for investments have historically been requirements for fossil free public transport and efficient food waste treatment. A continued and more durable tax exemption for biogas, as well as for other biofuels, is of importance for both maintaining a reasonable consumer price and to incentivize future production expansions.

19 Trafikutskottet, 2018. *Fossilfria drivmedel för att minska transportsektorns klimatpåverkan.*
20 Energimyndigheten, 2016. *Marknaderna för biodrivmedel 2016.*
21 Interview, E.ON.

Current regulations make it difficult (if possible at all) to apply green gas exchange across states of aggregation (the physical state of the biogas; liquid or gaseous) due to different taxations of gaseous and liquid gas. This limits the possibility to sell LNG (or a mix of LNG and LBG) as LBG through warranties of origin. Actors within the energy gas sector push for amendment of these regulations.

According to some distributors, the reduction quota has increased the demand for biogas since a larger share of biodiesel is used as low blend drop-in in fossil diesel.

Comparative pricing

Purchase price

The purchase price varies with model, size and supplements but roughly estimated a heavy truck for LBG/LNG costs an additional 300 000 - 500 000 SEK compared to a diesel equivalent. For CBG/CNG-trucks the difference is less, approximately 200 000 SEK.

Secondary market

Given that trucks for LBG are quite new to the Swedish market there are some uncertainties regarding the secondary value. However, on the European market there is a growing interest in and demand for LNG-trucks, opening up the whole of Europe as a potential secondary market. The attractiveness of secondhand vehicles is also dependent on regulations, which with time could offer pre-requisites for a domestic secondary market.

Cost of maintenance

Gas vehicles require more frequent maintenance than diesel vehicles which in relative terms imply an additional cost of maintenance of approx. 50%. However, in a TCO context this is a relatively small extra cost. The technical lifetime of a gas vehicle is correspondent with a diesel vehicle.

Fuel cost

A simplified comparison between diesel and biogas based on energy content equals one liter of diesel with 0,9 kilogram of gas. Example of the fuel price for liquid vehicle gas as of January 2019:

- 14.39 SEK/kg, VAT excluded[22]. For comparison the fossil diesel price from the same fuel provider is 12.62 SEK/l, VAT excluded.

Biogas vehicles have no need for Adblue (an additive for NO_x-reduction in diesel trucks) which reduces total fuel costs.

Total Cost of Ownership

In order to evaluate the total cost to move from diesel to biogas for a certain transport, it is vital to distinguish the different cost drivers that together sum up the total cost for the forwarder. How the total cost is distributed between different cost drivers is dependent on the type of vehicle as well as the pattern of the transport work executed by the vehicle. For long-haul transports with heavy loads, the fuel cost represents a larger share of the total cost, than for shorter distribution transports with relatively light loads. We have chosen to base the analysis of the cost structure on research that has been initiated by Sveriges Åkerier[23]. This analysis shows that approximately

22 https://www.circlek.se/sv_SE/pg1334072868904/foretag/Truck/Pris-truckdiesel.html
23 Åkerinäringen med verksamhetsområden - nyckeltal för lönsamhet och tillväxt - 1997 – 2016, September 2017.

20% of the total cost for a transporter is related to the fuel and additives. Ten percent is related to the depreciation of the vehicle and five percent relates to maintenance cost. The remaining 65% include cost items that are independent on the type of vehicle, such as salaries for drivers and administrative staff, insurance etc. The calculations based on this model offer an average of TCO between long-haul and distribution trucks. When used as a basis for selection of vehicle, all aspects of the real use-case scenario need to be taken into account.

Based on the cost ratio presented by Sveriges Åkerier and fuel prices in January 2019, a rough calculation shows that compressed and liquid biogas increases TCO with approximately 4-5%. Other similar calculations show a slightly higher TCO increase (6-10% depending on use case).

Additional values

There are several environmental and social values of biogas that go beyond the direct use as transportation fuel. Biogas production is a natural part of a circular economy, where resources and materials are used and reused for further areas of applications. The added values arise in different stages of the lifecycle, both in the production process where waste is utilized and nutrients can be recovered (as a biofertilizers that replace mineral fertilizers), as well as in the use of biogas for vehicles, replacing fossil fuels and thereby reducing emissions of greenhouse gases and other air pollutants. When making use of local waste products and recirculating the residues from local agriculture in biogas driven transports and usage of biofertilizers, biogas production is particularly in line (or loop) with the intentions of circular economy.

The total environmental benefits of biogas depend on several factors; for example, from which substrate the biogas is produced, how it is produced and what it is used for. Management of the digestion residues and use is also important. In the best cases, the greenhouse gas reduction is more than 100 percent. This applies when biogas is produced from manure and the methane emissions from manure management is reduced. Significant reductions also occur when the digestion residue is used as (organic) fertilizer and emissions from mineral fertilizers can be avoided. Moreover, using waste products from the agricultural sector, such as manure, can contribute to reducing leakage of nutrients to waterways and thereby decrease the harmful effects of eutrophication on ecosystems in rivers, lakes and seas.

Indirect benefits coupled with biogas production are creation of local job opportunities and added economic value, as well as increased export opportunities, through production growth. Several regional and national calculations show that one job opportunity is obtained per produced GWh[24]. Furthermore, biogas contributes to increased food security, for example by increasing Sweden's self-sufficiency rate of nutrients.

According to assessments by the Swedish Energy Agency, the average GHG reduction from compressed biogas is 85%. To compare the GHG reductions to a real use case, it is central to compare with the diesel sold on the Swedish market. Due to the reduction duty, regular diesel has a reduction of 20% CO_2 emissions. Taking this into consideration, we have calculated the comparable GHG reductions of compressed vehicle gas to be 68%, assuming a 91% share of biogas (based on SCB statistics for 2019).

Since the volumes of liquid vehicle gas sold in earlier years is limited, there are few reliable figures for the actual GHG emissions. The GHG reduction potential will completely depend on the ratio between biogas and natural gas. Assuming a 50% blend of biogas (which is a likely scenario for the next two years according to suppliers), the calculated GHG reduction compared to regular diesel sold in the Swedish market is 40%.

SWOT - Biogas

Strengths	Weaknesses	Opportunities	Threats
• Low emissions of air pollutants • High GHG abatement • Primarily produced from waste and residues • Local energy security • Organic fertilizer • Possible night time distribution in cities due to low noise pollution from LBG trucks	• Requires specialized vehicles • Costly fuel distribution and filling infrastructure • Limited reach	• Increased sorting and collection of food waste • Broad feedstock spectrum • Potential production increase from manure and industrial waste water	• Limited supply of different vehicle models • Withdrawal of temporary production support • Uncertain secondary value of vehicles

24 Nationell biogasstrategi: Energigas Sverige. Kan Energi 2012, Sysselsättning inom biogasområdet i Västra Götaland. WSP 2011, Biogas, Sysselsättning och tillväxt i Biogas Öst region.

RENEWABLE DIESEL & BIODIESEL

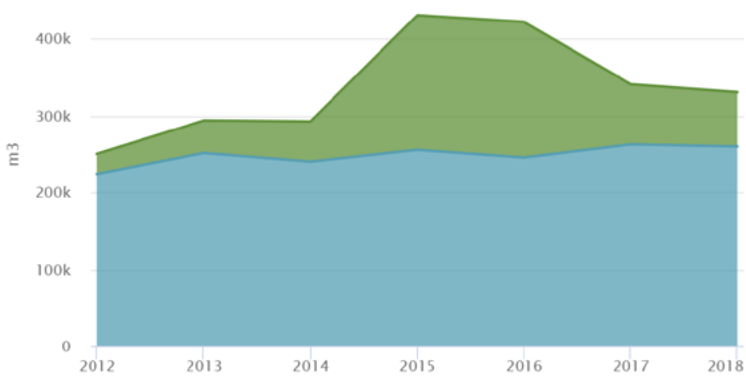
Renewable diesel (synthetic diesel) and biodiesel can be produced from a variety of sources with the final product showing different properties with regards to GHG abatement, energy content, quality and compatibility with conventional diesel powertrains. HVO (or XTL) is the most common renewable diesel in Sweden while biodiesel goes under the generic term FAME (Fatty Acid Methyl Esters). RME (Rapeseed Methyl Ester) constitutes the majority of FAME available on the Swedish market. As high blend biofuels, renewable diesel is called HVO100 while biodiesel is labelled FAME100 (or B100) and RME100.

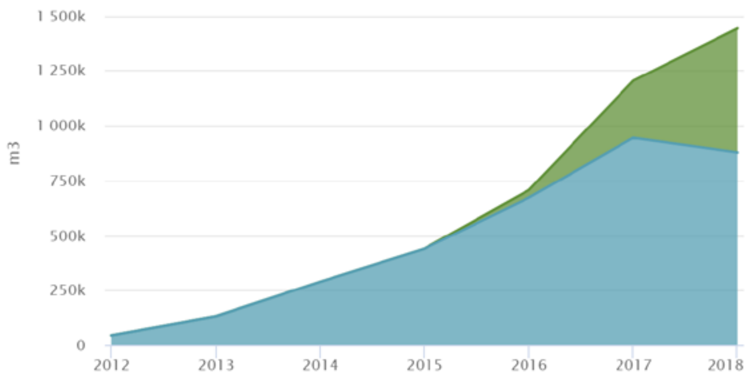
HVO (Hydrated Vegetable Oils) have been available in Sweden since 2011, originally through limited domestic production based on residues from forestry (pine oil)[25]. Eventually, the main substrate became slaughter waste, and substantial growth since 2016 is due to HVO produced from PFAD (Palm Fatty Acid Distillate) – a residue or bi-product from palm oil production. In 2017, the total sale of HVO100 amounted to 5 TWh[26], correspondent to 5,4 % of the total fuel demand. The sale of FAME100 totalled 357 GWh 2017, reducing sales levels by half from previous year. This was mainly due to a price adjustment initiated by the government that overcompensated earlier state subsidies that had been too high. In 2018 the market has regained some of its earlier volumes.

Use of HVO and FAME as high blend and low blend fuel between 2012 and 2018[27]:

Figure 6

Use of HVO and FAME as low blend (drop in) and high blend fuels between 2012 and 2018. Source: SPBI.





25 Trafikutskottet, 2018. *Fossilfria drivmedel för att minska transportsektorns klimatpåverkan.*
26 Energimyndigheten, 2018. *Omvärldsbevakning - biodrivmedelsmarknaden: Promemoria rörande biodrivmedelsmarknaden i Sverige och i världen.*
27 SPBI. Statistics FAME and HVO https://spbi.se/statistik/volymer/fornybara-drivmedel/fame/.

Current production levels and future potential

HVO

The majority of HVO sold in Sweden is imported, from either Finland or the Netherlands. In 2016, the domestic production was less than 4% of the total use[28]. The feedstock spectrum for HVO is broad and complex since it can be produced from most bio oils, both virgin and waste based, including animal fat, used cooking oils, maize oil, waste from food production and PFAD. Globally, PFAD and palm oil are important feedstocks. In 2017, 39% of HVO sold in Sweden was produced from PFAD and 5% from palm oil[29], although most distributors denounce selling the latter. For Swedish production the main feedstock (90%) is waste and residues[30].

The view on future production levels and potential is divided. Some fuel providers predict a deficit in HVO100 within a near future due to increased low blend use (as a result of an increased reduction quota) and the change in classification of PFAD (from residue to bi-product). This classification change requires improved traceability which results in higher costs and lower CO_2 abatement from HVO produced from PFAD. However, as other providers highlight, this does not mean production from PFAD is banned and the importance of HVO with regards to sold amounts could spur increased domestic production.

Increased international demand could affect the availability since the current use in Sweden corresponds to one third of the total global production. In a future perspective the nation with strictest tax policies on greenhouse gas abatement will probably be the primary market for HVO, due to high alternative costs.

FAME/RME

As already mentioned, most FAME in Sweden is RME, produced from virgin rapeseed oil. Compared to other energy crops rapeseed has a comparatively low energy yield[31] which affects the greenhouse gas abatement potential. The quality of the RME is highly influenced by the quality of the rapeseed which is reflected in a relatively wide price range[32]. Generally though, the quality exceeds that of other types of FAME, which like HVO can be produced from various residual vegetable oils. Perstorp BioProducts has the largest domestic production of RME (approximately 110 000 tonnes per year), using Danish rapeseed as feedstock. The largest producer of RME from Swedish rapeseed is the factory in Karlshamn run by Energifabriken with a yearly production of 25 000 tonnes. The current annual production level in Sweden is approximately 200 000 tonnes[33].

Energy & fuel providers today

Two important HVO providers are Neste[34] and Preem (Preem however only produces HVO from pine oil as a blend in their regular diesel and does not produce HVO100), though all the larger conventional fuel providers as well as a number of specialized biofuel providers sell high blend HVO and some of them also sell high blend RME (see infrastructure availability). HVO has a drop-in limit around 50% while for RME there is a low blend cap around 7%.

A typical customer is a haulage contractor with a sustainability profile or demands for fossil free transport from upstream customers[35].

28 Energimyndigheten, 2018. *Omvärldsbevakning - biodrivmedelsmarknaden: Promemoria rörande biodrivmedelsmarknaden i Sverige och i världen.*

29 Energimyndigheten, 2018. *Drivmedel 2017 - redovisning av uppgifter enligt drivmedelslagen och hållbarhetslagen*.

30 Trafikutskottet, 2018. *Fossilfria drivmedel för att minska transportsektorns klimatpåverkan*.

31 Ibid.

32 Interview, Energifabriken.

33 Ibid.

34 Energimyndigheten, 2016. *Marknaderna för biodrivmedel 2016.*

35 Intervju, Circle K.

Infrastructure availability - current and predicted future status

According to SPBI (Swedish Petroleum and Biofuels Institute), the number of filling stations totalled 162 for HVO100 by the beginning of 2018[36]. However, the situation changes quickly with altered demand and regulations affecting the price and incentive to sell high blend renewable diesel.

As a response to the reduction quota, Circle K has cut down on the number of filling stations for HVO100 from approximately 90 to approximately 35 in the last couple of years[37]. Nevertheless can a continued demand for HVO100 stabilise the availability, and apart from the large petroleum providers there are a number of smaller providers of exclusively high blend renewable diesel and biodiesel, who together operate around 80 filling stations[38]. After acquisition of Ecobränsle, Energifabriken will operate approximately 55 filling stations with HVO100 and FAME100, covering most parts of Sweden. The availability of FAME100 is currently limited but a beneficial pricing has increased demand and some infrastructural expansion could be expected. Energifabriken also offers mobile tank solutions which can be placed temporarily at a customer specific site. Currently a couple of hundred of such mobile tanks are in use.

More specific information about current quantity and location of filling stations for both HVO100 and FAME100 can be found on the websites of fuel providers.

Filling stations for providers specified in high blend renewable diesel and biodiesel (non-exhaustive list):	Filling stations for conventional fuel providers:
• Biofuel Express • Colabitoil • Energifabriken (Ecobränsle)	• Circle K • OKQ8 • Preem • Shell

Vehicle supply – current and coming

High blend renewable diesel as well as biodiesel is compatible with conventional powertrains for fossil diesel but vehicles need to be approved for HVO100 or RME100/B100 use for guaranteed high performance. A switch to RME100 requires filter adjustments but vehicle suppliers can offer truck models already prepared for this switch.

36 SPBI, 2018. "Försäljningsställen med förnybara drivmedel".
37 Interview, Circle K.
38 Interview, Energifabriken.

Regulatory framework

Important regulations:

- **EU's ILUC-directive:** affects the reporting of biofuels towards the EU targets on renewable fuels, limiting the tax exempted share of biofuels produced from food crops.
- **The reduction quota:** affects the share of renewable diesel/biodiesel for high blend and low blend use, possibly decreasing the availability of high blend HVO and FAME.
- **Regulations regarding classification of PFAD:** affects the cost and availability of PFAD and the assessment of greenhouse gas abatement for HVO (see Production level).
- **Tax exemption for high blend biofuels:** uncertain to what extent further tax exemptions will remain after 2020.

The revised renewable energy directive[39] defines the minimum level of greenhouse gas abatement requirements to 60% compared to fossil alternatives for new production of renewable fuels. When calculating the fulfilment of EU targets, the share of biofuels produced from food crops in relation to the total energy use in transports, is limited to 7% by 2020. Possible interpretations of this limitation could pose a risk to further tax exemptions for RME100.

The Reduction quota has resulted in a larger overall demand for biodiesel, but also increased the share of biodiesel for low blend use. In 2018 the reduction quota for diesel is 19,3% and by 2030 the requirement will be 40%. The Swedish Energy Agency is currently working on defining the intermediate targets. These will affect the development regarding availability of high blend versus low blend biodiesel, but an established demand also creates opportunities for increased domestic production.

39 Directive (EU) 2018/2001 of the European parliament and of the council on the promotion of the use of energy from renewable sources

Comparative pricing

Since HVO100 can be used directly as a substitute for fossil diesel the most substantial difference in TCO compared to a vehicle on fossil diesel is the fuel cost. For B100/RME100 there are some differences regarding the maintenance cost. However, in relation to the total TCO this has a minor effect. The potential additional cost with regards to purchase price for a B100/RME100 approved or prepped vehicle is marginal.

Cost of maintenance

Maintenance cost differs between various RME vehicle models but generally RME-vehicles require more frequent maintenance than conventional diesel vehicles, due to different fuel characteristics. In general terms the maintenance cost is about 2-2.5 times as high as for an equivalent diesel vehicle. This depends to some extent on the quality of the fuel – high quality RME has a higher energy content and also wears the vehicle less[40] which reduces the need for maintenance.

Fuel cost

At the moment the fuel price for HVO100 is slightly above the levels of fossil diesel whereas RME is cheaper. Note that the fuel consumption for RME may be slightly higher than fossil diesel (approximately 5%), somewhat reducing the price difference. Examples of fuel prices for business customers as of January 2019[41]:

- HVO100: 13.10 SEK/liter, VAT excluded
- B100: 11.04 SEK/liter, VAT excluded

In comparison, the current fossil diesel price is 12.62SEK/liter, VAT excluded. Additionally, the cost for handling the fuel is less for RME than for fossil diesel.

The price of RME has shown to be much more predictable than the diesel price which is very volatile over time. This is due to the fact that the diesel price depends on the fluctuations of the crude oil price, while the RME price depends on the world market price of rape seed, which is more stable.

Total Cost of Ownership

Based on the cost ratio presented by Sveriges Åkerier (please see explanation on page 13) and fuel prices in January 2019, a rough calculation shows that RME increases TCO with approximately 4%. This is based on the assumption that the maintenance cost is 50% higher than for regular diesel usage and that the fuel consumption is 5% higher. This is not always the case, and with lower maintenance cost the TCO could even be less than for regular diesel trucks, which is confirmed by. calculations made by other parties that show a 3-4% lower TCO for RME.

Additional values

According to assessments by the Swedish Energy Agency, the average GHG reduction from HVO100 is 86.4% and from FAME100 it is 59.1% compared to conventional diesel[42]. The GHG reduction potential depends on feedstock, and different assessment methods show slightly different results. For HVO100, produced from waste and residues, the GHG reduction can be over 90%[43] and for RME, produced from crops, the GHG reduction varies between 59 and 68%[44].

40 Interview, Energifabriken.
41 Business costumer prices from “https://www.circlek.se/sv_SE/pg1334072868904/foretag/Truck/Pris-truckdiesel.html, https://www.preem.se/foretag/kund-hos-preem/drivmedelspriser/ and OKQ8.
42 Energimyndigheten, 2018. *Drivmedel 2017.*
43 Interview, Circle K.
44 Interview, Energifabriken.

To compare the GHG reductions to a real use case, it is central to compare with the diesel sold on the Swedish market. Due to the reduction duty, regular diesel has a reduction of 20% CO_2 emissions. Taking this into consideration, we have calculated the comparable GHG reductions of HVO to be 83% and for RME the figure is 50%.

In addition to climate benefits an important advantage with RME (and to some extent HVO) is its completely non-toxic nature. This reduces both environmental and health related risks when handling the fuel and in case of unintended spillage. Approximately 60% of the demand for rapeseed in Sweden derives from RME production and this supports continued self-sufficiency, strengthens the agricultural sector, improves future harvests when used as an in-between crop as well as contributes to preserving open landscapes and biodiversity among pollinators[45]. Regarding HVO there is an attractiveness in creating value from waste material, contributing to a more circular resource usage. Providers also predict a future expansion of domestic production, building new technological knowledge and creating job opportunities.

SWOT - HVO & FAME/RME

	Strengths	Weaknesses	Opportunities	Threats
HVO	• Flexible fuel – can be used in diesel vehicles • Existing fuel distribution infrastructure can be used • High GHG abatement	• Limited access to sustainable feedstock	• Potential domestic production from forestry residues • Stable demand could spur increased domestic production	• Changes in classification of PFAD • Potential deficit due to high demand
FAME/RME	• Competitive fuel price • Completely non-toxic fuel • Flexible fuel – can be used in diesel vehicles • Existing fuel distribution infrastructure can be used	• Low energy yield for rapeseed • Relatively low GHG abatement • Disadvantages of low quality FAME damage the reputation of high quality FAME in parts of the transport sector	• Rapeseed is an important in-between crop for soil fertility resulting in higher yields of the main crop • Increased demand for low blend biodiesel • Cultivation of rapeseed contributes to biodiversity	• Withdrawal of state support

45 Interview, Energifabriken.

BIOETHANOL

ED95 is a biofuel based on 95 percent bioethanol, with an additive of ignition improver, lubricant and corrosion protection constituting the remaining five percent. The fuel is compatible with modified diesel engines in which the ethanol has potential to be used more effectively than in a gasoline engine[46].

ED95 has primarily been used as a fuel in city buses since the 80's. The market for heavy trucks has been limited due to underdeveloped infrastructure with regards to long haul transport, but it is growing. The joint vision for Etha (a cooperation between Lantmännen Agroetanol, Scania and SEKAB) is to gain 25% of the market for heavy transports by 2030.

Current production levels and future potential

Bioethanol can be produced from almost any product rich in sugar or starch, but for ethanol sold in Sweden maize and wheat are the major feedstocks[47]. Agroetanol and SEKAB (Domsjö Fabriker) are the largest domestic producers, followed by St1[48]. The main feedstock for Agroetanol's production – with a current capacity of 1,4 TWh (or 230 000 m^3) – is grain and starch rich waste from food industries[49]. SEKAB's domestic production is based on forestry residues, but imported ethanol is primarily crop based.

Ethanol is an internationally well-established biofuel with large global production which makes it more available, less price sensitive (on an international market) and less affected by domestic feedstock competition than many other biofuels. There is also potential for increased domestic production using feedstock from agriculture and forestry.

Currently the blend of ethanol in regular gasoline in Sweden is 5%. The EU has recently approved E10, containing 10% blend of ethanol. If this is adopted in Sweden, the domestic production may increase.

46 SEKAB. "ED95", http://www.sekab.com/sv/biodrivmedel/ed95/
47 Energimyndigheten, 2018. *Drivmedel 2017.*
48 Etanolarena Östergötland, 2018.
49 Interview, Lantmännen Agroetanol.

Energy & fuel providers today

Ethanol produced and imported to Sweden is distributed by several retailers, as E85 or ED95 (see Infrastructure availability). SEKAB currently delivers 10 000 m^3 ED95, partly through cooperation with other fuel distributors. The amount of ethanol sold as ED95 depends on demand, as all the domestically (and imported) ethanol theoretically could be converted to ED95. Solutions for ED95 is also offered by Lantmännen Agroetanol.

Transport customers today are typically road carriers for distribution – like Arla, Axfood and Kyl- & frysexpressen – and city buses, but with availability of heavy trucks and an expanding filling network there is a market for long haul transports.

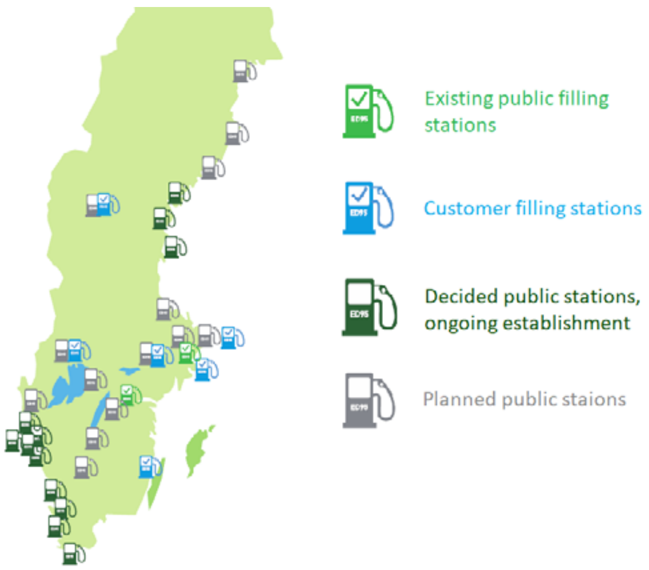
Infrastructure availability - current and predicted future status

The infrastructure for ED95 is currently limited to eight locations, most of them in the region around Stockholm and none north of Gävle. The majority of existing filling stations for ED95 are private or customer stations (e. g. Arla and Kyl- & Frysexpressen) where transport patterns allow vehicles to return to the point of departure. The only two public stations can be found in Linköping and Stockholm (Kallhäll). For more detailed information on current status, see map.

In the coming years infrastructure development will accelerate, with both Agroetanol and SEKAB planning new filling stations along transportation core networks. SEKAB alone is establishing 12 new stations within the next two years[50]. Focus is on the South/Southwest of Sweden as well as the coastline in the north, but the ambition is to also offer ED95 for distribution vehicles in larger cities, see Figure 7 below.

Figure 7

SEKAB's planned expansion of filling stations for ED95. Decided public stations should be available by 2020. Source: SEKAB.



Vehicle supply – current and coming

Scania is currently the only provider of trucks for ED95, offering vehicles for both distribution and long haul transport. The supply so far is limited to two engine sizes – one 13-liter 410 hp engine and a smaller 280 hp engine under development. ED95 requires a specialized engine and it is not possible to convert existing diesel vehicles[51].

50 Interview, SEKAB.
51 Etanolarena Östergötland, 2018.

Regulatory framework

Important regulations:

- **Tax exemption for high blend biofuels:** Short-term exemptions inhibits investments. A cue on continued tax exemption is relevant for further infrastructure development and production expansion.
- **EU's ILUC-directive:** could limit the amount of tax exempted ethanol produced from food crops. Not a problem at current sales levels but could pose a risk within a five-year timeframe[52]. SEKAB however sees forestry products as a promising feedstock for future production.

The production cost for ED95 is high compared to fossil fuels and producers request economic instruments that promote not only use of ED95 but also support production (similar to the production support for biogas).

Comparative pricing

Purchase price

An ethanol truck has an additional cost of approximately 60,000 SEK compared to corresponding conventional diesel vehicles.

Secondary market

The secondary value of ED95 trucks is uncertain since the primary market is almost exclusively limited to the Nordic countries. However, SEKAB produces an additive which can be mixed with ethanol to fuel ED95 vehicles, and export of this additive could help expand the secondary market.

Cost of maintenance

An ED95-truck requires more frequent maintenance than conventional diesel vehicles. The total additional cost is uncertain and may change once batch production of ED95-trucks takes off, but a likely estimation is at least three to four times the maintenance cost of a diesel counterpart.

Fuel costs

Due to lower energy content the fuel demand is approximately 70% greater for a vehicle on ED95 than on conventional diesel. However, taking into account the lower fuel price the total cost difference is reduced to about 10%. Additionally, the consumption of catalyst additive (Adblue) is only about half of that of a diesel vehicle.

Example of customer fuel price for ED95:

- 9.44SEK/liter, VAT excluded, as an average for 2018. For comparison the fossil diesel price as of January 219 is 12.62 SEK/liter, VAT excluded.

Total Cost of Ownership

Based on the cost ratio presented by Sveriges Åkerier (please see explanation on page 13) and fuel prices in January 2019, a rough calculation shows that ED95 increases TCO with approximately 10-15%. Similar calculations show a TCO increase of 12%. There is room for negotiation on the fuel price, which could make ED95 comparable with RME100 and CBG.

52 Interview, SEKAB.

Additional values

The average GHG reduction potential for ethanol (includes both E85 and ED95) sold in Sweden is 60,9%, according to the Swedish Energy Agency's report on fuel properties[53]. However, since ED95 has a lower proportion of fossil additives than E85, this figure is not fully representative. As for other biofuels, the reduction potential depends on production feedstock. ED95 produced by Agroetanol has a GHG reduction potential of up to 90% due to feedstock composition and a circular production process. In Lantmännen Agroetanol's production, waste products from the food industry as well as agriculture are used. One biproduct from the process is a highly nutritious animal feed that goes back into the agricultural sector. This is another good example of a circular resource flow.

To compare the GHG reductions to a real use case, it is central to compare with the diesel sold on the Swedish market. Due to the reduction duty, regular diesel has a reduction of 20% CO_2 emissions. Taking this into consideration, we have calculated the comparable GHG reductions of ED95 to be 56% (this calculation is based on pure ED95).

Other aspects of societal benefits connected to ED95 is job creation and employment within production and connected agricultural activities, as well as significantly reduced emissions of NO_x and particles. Depending on the type of feedstock, the cost efficiency for GHG reduction from ethanol is very high[54].

ED95 does not offer the same flexibility in fuel options as biodiesel and biogas (which can be substituted by fossil alternatives in the operational phase of the vehicle), but this also works as a guarantee for purchasers of transports that their carriers always operate on fossil free fuel.

Production from forestry residues creates a welcome new market for forestry waste and products as demand for paper and paper products decrease[55]. It is also a way to make use of products that are currently unutilized.

SWOT - Bioethanol

Strengths	Weaknesses	Opportunities	Threats
• Ethanol is a mature biofuel with high global availability (fuel redundancy) • "Cheat free" in operational phase - secures use of fossil free fuel • Easy to handle	• Non-flexible fuel which requires specialized engines (new vehicles) • Primarily produced from food crops like wheat and maize • Higher fuels costs	• Domestic production potential in food waste and forestry residues • Near future expansion of infrastructure • Potentially cost efficient with regards to emissions reduction	• Few fuel providers • Only one provider of ED95 trucks (Scania) • Limited secondary market

53 Energimyndigheten, 2018. *Drivmedel 2017.*
54 Trafikutskottet, 2018. *Fossilfria drivmedel för att minska transportsektorns klimatpåverkan.*
55 Intervju, SEKAB.

ELECTRIFICATION

The adoption of electric vehicle technology in the transport sector is developing fast. How big the market share of fully-electric trucks may be in the near future is still uncertain. However, a review of future scenarios predicts a significant increase of electric vehicles in global truck sales – expected to reach 15% by 2030. With even higher volumes in the European market, reaching 21-29% of total truck sales in 2030. The uptake in Europe will be driven by TCO advantages and regulatory environment, such as emission-free zones and carbon dioxide fleet targets.

One of the key factors for electric vehicle development is the cost of batteries, this has been a major hurdle standing in the way of widespread use today. Falling prices will pave the way for a more rapid transition. On the up side the cost development is faster than experts expected, as the technology evolves, and demand rises, the price decreases. The price drop will close the gap of the traditional internal combustion engine (ICE) vehicles. The relatively low maintenance and charging cost are other attractive attributes for an EV owner. Estimates predict that the price parity of the majority in the electric truck segment (compared to diesel trucks) is to be reached within 10 years[56]. Still, the challenge remains for charging infrastructure, which requires a collaborative effort and effective investments.

There are different types of electric vehicles in the truck segment, the two main technologies are:

- **Plug-in hybrid (PHEV)**
- **Battery electric vehicles (BEV)**

Another type of electric vehicle is the **Fuel cell electric vehicle (FCEV**), using fuel cells instead of a battery – generating electricity by using oxygen from the air and compressed hydrogen (emitting only water and heat in a tank-to-wheel perspective).

The electric solutions for heavy trucks also include;

- **E-highways**
- **Autonomous electric trucks**

The electric solutions/technologies have the potential to play a significant role in the near future. The benefits that come with electric vehicles, such as no exhaust emissions and low noise levels, create logistic opportunities. One example is the possibility to drive at night in cities and in environmental zones. It is not likely that a single electric solution will dominate the future scenario for goods transportation. A fleet requires customization based on specific routes and application.

56 McKinsey, 2017, https://www.mckinseyenergyinsights.com/insights/new-reality-electric-trucks-and-their-implications-on-energy-demand/.

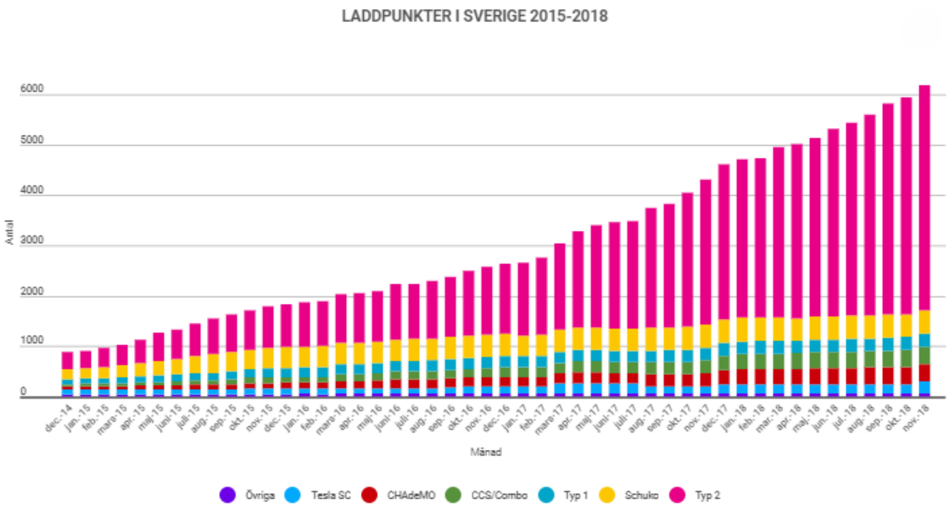
Infrastructure availability - current and predicted future status

The expansion of charging stations infrastructure is central for the development of electric vehicles.

Charging infrastructure for automobiles in Sweden is rapidly developing. Four years ago, there were about 1000 stations in the country, today that number is six times higher[57]. The charging stations are limited to major roads and urban areas such as Stockholm (1500), Gothenburg (850) and Malmö (500). In the more rural areas, charging stations are more scarce.

Figure 8

Charging stations in Sweden – per type (2015- November 2018) Source: Laddinfra.se



The future availability of charging stations is likely to increase. However, the market is faced with a 'chicken or the egg' dilemma. The number of charging stations needs to increase in order to shift demand from ICE to EV. So far, about 9,000 public charging stations have been granted support from Klimatklivet, which increases the spread of the infrastructure[58].

The public charging infrastructure for trucks and heavy vehicles is in its infancy. Even though the same power stations can be used in theory, the issue is more practical – concerning power characteristics, different charging standards (CCS, Type-1 ,Type-2, CHAdeMo) and the physical space of parking. Today, the heavy vehicles are mainly driving short daily routes and charging is mostly done during night time, eliminating the sudden need for roadside charging. The roll out of electric buses, e.g. in Stockholm, could also benefit development of charging infrastructure, where co-charging of both buses and trucks could be an opportunity in urban areas.

For trucks, the infrastructure is likely to consist of terminals for charging – owned by either the truck manufacturer or the purchasing company. Using overnight charging in a depot is the likely scenario for heavy trucks driving longer haul, whereas opportunity charging is a better option for urban deliveries – charging while loading and unloading goods. There are still many uncertainties regarding the development of the charging infrastructure, concerning both the ownership and types. However, in the next two years on-site chargers will likely be the most frequently used solution. To support a 24/7 utilization rate, using the truck full time for deliveries, overnight charging is a limitation. Nonetheless, with smart planning the charging could be combined with the drivers' necessary rest periods.

57 Laddinfra.se, https://www.laddinfra.se/elbilist

58 Trafikverket, 2018. *Laddinfrastruktur för snabbladdning längs större vägar.*

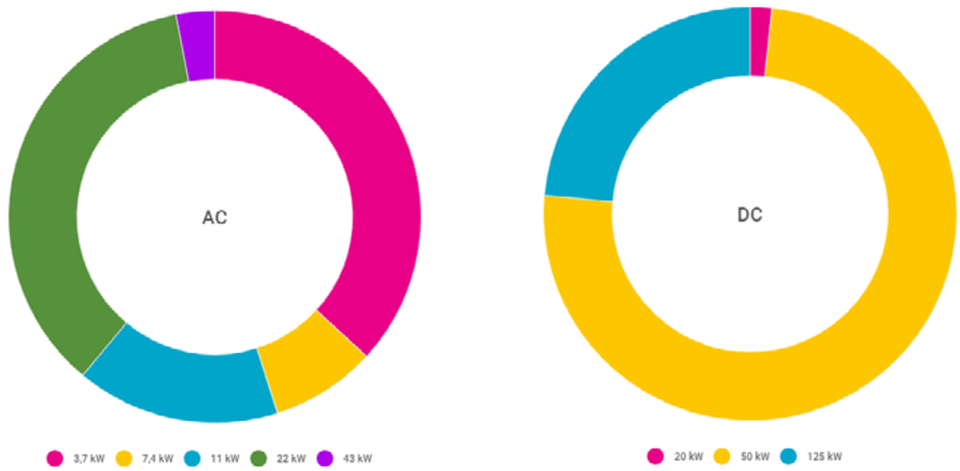
For example, early adopters of Tesla's upcoming Semi are installing charging equipment in their own premises and may eventually share these facilities with other companies. At the same time Tesla is looking into developing their own charging stations, enabling them to sell the electricity.

Charging capacities – AC/DC

Electric trucks require large batteries and high capacity to charge. At the moment, most charging stations in Sweden provide capacities of 50 kW or less – a few can deliver 125 kW. This summer, Fortum opened the first HPC (High Power Charger) charging location with a 350 kW capacity, seven times higher than a regular charger. The two main types of chargers are for Alternating Current (AC) and Direct Current (DC). The AC charging supplies an on-board charger which converts the AC power to DC power. The DC charger supplies the power directly to the vehicle's battery and is capable of charging faster than an AC charger.

Figure 9

AC vs DC charging supply in Sweden (AC: 3,7KW-43KW, DC: 20KW -125KW) Source: www. Laddinfra.se



Current production levels and future potential

The production level of the vehicles is dependent on one major factor; the battery pack components and costs. While the production level of the "fuel" is dependent on the infrastructure and power supply from the electric grid.

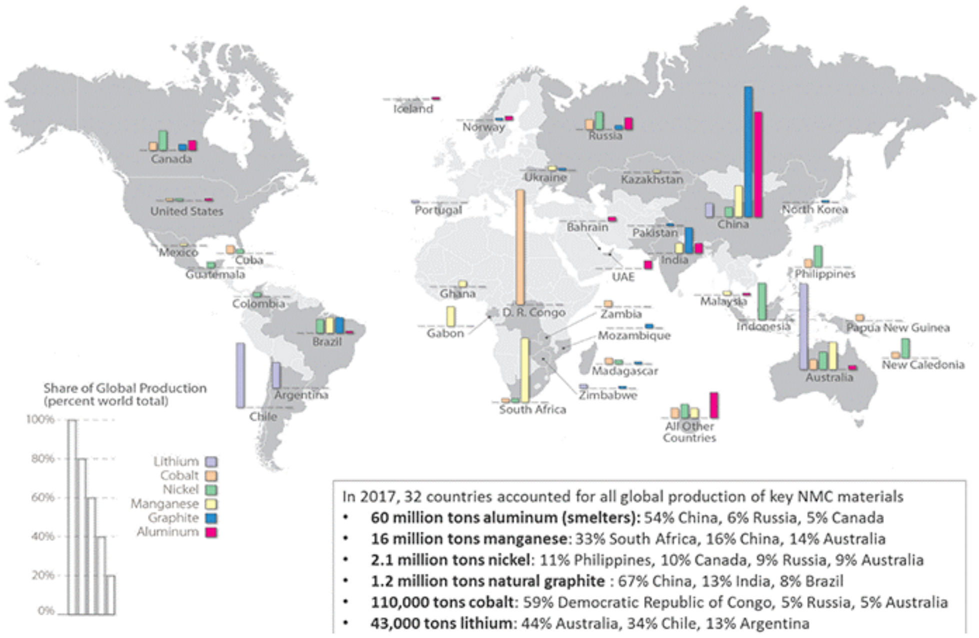
Battery components and costs

The battery mainly consists of the metals Nickel, Cobalt and Lithium. For instance, to make a Tesla battery; 46kg Nickel, 9kg Cobalt and 7kg Lithium is needed. In 2030, an estimate of 125 million electric cars will be in traffic, which means that the demand of these metals will increase rapidly[59]. Among these metals, Cobalt is by far the most expensive component of the battery. Cobalt also has high human and environmental cost, as the majority (55%) is mined in the Democratic Republic of Congo with child labour, environmental pollution, health issues and corruption as part of the supply chain. A high priority for the battery and vehicle industry is to reduce the cobalt dependency, and other rare metals. Researchers are already exploring methods to replace the materials and developing advanced techniques to recycle used or faulty batteries. For example, Stena Recycling is conducting a research project with Luleå University to review the entire chain – from the disassembly of lithium-ion batteries from the vehicle until the battery cells are recycled[60].

However, according to the European Joint Research Centre, mineral exploration and battery recycling is not going to cover the gap as the demand is likely to exceed supply in 2020[61]. In Sweden and EU, there is a high dependency on imports from third world countries which spurred the launch of the European Battery Alliance in 2017, with the objective to create a competitive, innovative and sustainable value chain in Europe with sustainable battery cells at its core[62].

Figure 10

In 2017, 32 countries accounted for global production of elements in lithium Ion batteries. Source: CEMAC, august 14, 2018 (Ahmad Mayyas, National Renewable Energy Laboratory)



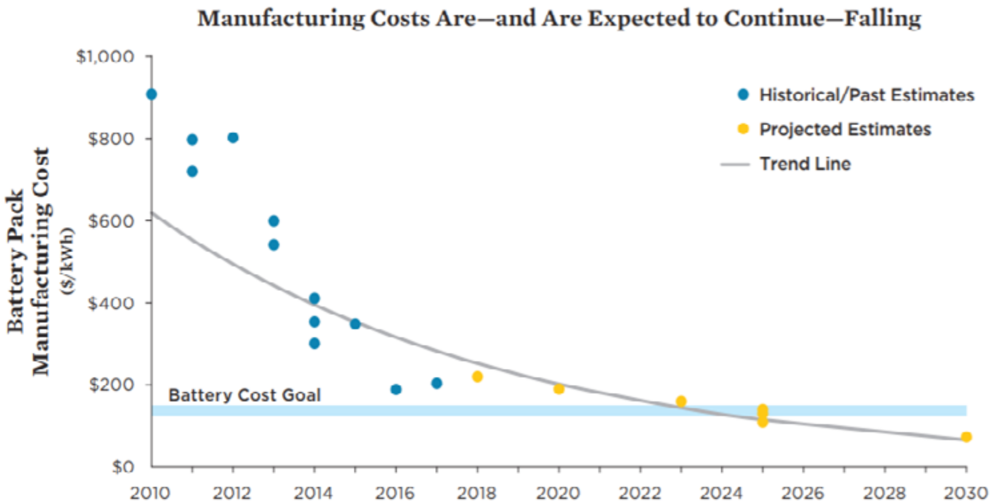
59 Gray, S. 2018, http://fortune.com/2018/05/31/electric-vehicles-international-energy-agency/
60 Stena Recycling. "Forskningsprojekt: återvinning av litium-jon batterier".
61 JRC, European Commission, 2018, http://publications.jrc.ec.europa.eu/repository/bitstream/JRC112285/jrc112285_cobalt.pdf
62 European Commission, 2018, http://europa.eu/rapid/press-release_IP-18-6114_en.html.

The battery size, in terms of mass and volume, influences the payload capacity of the truck. Research has improved the capacity over the last decade. One of the first consumer fully electric vehicles (Nissan Leaf, 2009) had a battery weight of 1000 kg and a range of 190 km. Today's batteries weigh the same but have twice the range of 370 km. Nano technologies have been one reason for this development.[63]

The manufacturing cost of an EV battery pack has fallen significantly over the past eight years, due to manufacturers developing more cost-effective methods. Compared to 2018, prices have come down by around a factor of four, and densities have more than doubled[64].The cost will continue to decline as EV production increases, with projected estimates, from automakers and academic research, reaching 125-150 USD per kWh in the next ten years[65]. By 2030 Bloomberg New Energy Finance sees 70 USD per kWh possible due to mass manufacturing[66].

Figure 11

The battery cost goal of $125-$150 reached within the next ten years. Multiple data points compiled by Union of concerned scientist, 2017. http://www.ucsusa.org/EV-incentives



Energy & Fuel providers today - The electric grid

One of the most common discussions of broad market penetration is if the electric power sector and grid can support the growth in electric vehicles. McKinsey Energy Insight estimates that the global electricity demand for electric trucks will be approximately 30 TWh by 2030. This is less than 0.3% of global electricity demand. However, the electricity demand for electric trucks is likely to grow fast – just before 2050 it is estimated to reach more than 1,000 TWh (3% of projected electricity demand)[67]. The increased demand at new locations will put pressure on the power sector during peak periods. This will require local grid upgrades along highways and industrial sites for overnight charging.

In a Swedish context, the upcoming increasing demand for electricity will require expansion and reinforcement of the local power grid. The yearly consumption of electricity is not a limiting factor for electric vehicles in Sweden. However, the demand for high capacity (kW) supply may cause disturbances. The electric grid must be able to support high capacity during peak periods at local

63 Nanowerk, 2008. https://www.nanowerk.com/spotlight/spotid=5210.php
64 McKinsey, 2017. "New reality: electric trucks and their implications on energy demand". Earl m.fl., 2018. "Analysis of long haul battery electric trucks in EU."
65 Union of Concerned Scientists, 2017. https://www.ucsusa.org/sites/default/files/attach/2017/09/cv-factsheets-ev-incentives.pdf
66 Hodges, J., 2018. "Electric Cars May Be Cheaper Than Gas Guzzlers in Seven Years", Bloomberg.
67 McKinsey, 2017. "New reality: electric trucks and their implications on energy demand".

sites. In 2050, the total demand for energy in Scandinavia is expected to increase by 25% due to electrification of vehicles (e-highways and BEV)[68].

Electricity providers, such as E.ON and Vattenfall, are planning to expand the renewable energy production. This is in line with the Swedish goals for energy and climate adaptation, 100% renewable energy production by 2040 and net zero emissions of greenhouse gases by 2045.

Vehicle supply – current and coming

Today there is a wide range of different types of commercial vehicles from several manufacturers, suiting different needs. There is a much wider adoption of smaller electric vehicles (light-duty trucks) compared to medium and heavy-duty trucks. Heavy-duty trucks driving longer routes are technically more challenging compared to smaller delivery trucks for urban delivery.

Vehicle manufacturers providing heavy electric trucks today include, among others, Daimler, Einride, Volvo Group, Volkswagen, Tesla, Mercedes, Emoss, MAN and Scania. Several of these manufacturers just released full electric trucks or are planning to do so in the near future.

68 Kristensson, J., 2018. "Så ska elnätet försörja fem miljoner elbilar", Ny Teknik.

Manufacturer	Model	Available	Range (km)	Maximum load (tonnes)	Charging time
Daimler	Mercedes-Benz eActros	2021	200	18-25	100% in 660 min
Daimler	eCascadia	2021	400	36	80% in 90 min
Daimler	eM2	2019	370	12	80% in 60 min
Daimler	Mitsubishi e-Fuso Vision One	2019	350	11	n/a
Einride	T-Pod & T-Log (autonomous/remote controlled)	2018	200	16	n/a
Volvo Trucks	FL electric	2019	300	16	100% in 60-120 min (fast DC) 100% in 600 min (normal AC)
Volvo Trucks	FE electric	2019	200	27	100% in 90 min (fast DC) 100% in 600 min (normal AC)
Volvo Trucks	Vera (autonomous)	-	-	32	-
Volkswagen	e-Delivery	2020	200	3.5-13.5	100% in 280 min
Cummins	Aeos	2019	161	20	100% in 60 min
Tesla	Semi	2020	483-805	36	80% in 30 min
Emoss	EMS 10, 12, 16, 18	2014	50-250	10-18	100% in 180-360 min
MAN	CitE	2018/2019	100	6	Overnight charging, but fast charge possible
Scania	Hybrid HVO and biodiesel	2015	2	19	n/a
Scania	Plug-in Hybrid HVO and biodiesel	2019	5-10	27	1hour charging= 20 km driving range
Renault	Master Z.E	2019	120	-	-
Renault	Trucks D Z.E + Trucks D wide Z.E	2019	200-300	-	-
Iveco	The Daily Electric (not heavy)	2017	200	1,5	100% in 120 min
DAF	CF Truck	2019	100	37 (Gross Combination Weight)	100% in 90 min

As can be seen in the above table there are some technical challenges with fully electric vehicles; the range, the load capacity and the time it takes to charge the battery. Compared to today's combustion engines, the fully electric vehicles are also dependent on infrastructure developments.

Therefore, Scania, for instance, has developed a hybrid truck, which is charged while using the brakes and has a range of 2 km if only driving on electricity. The truck has a main diesel engine which can operate on biodiesel (HVO or FAME) reducing CO2 emissions by up to 92% when distributing in cities[69].

The payload allowance is another important factor for delivery trucks. In general, an electric truck with four batteries can carry about one tonne less payload compared to ICE counterparts[70].

69 Scania, https://www.scania.com/se/sv/home/products-and-services/trucks/our-range/scania-hybrid.html
70 Volvo, https://www.volvotrucks.com/en-en/news/volvo-trucks-magazine/2018/jun/quick-facts-electric-trucks.html

However, the capacity varies with application areas. Trucks operating in urban conditions can be optimized to maximize the payload and minimize the battery need.

The list of electric trucks suggests that by 2020 there will be several different alternatives on the market. The big manufactures will continue to offer electric solutions and new entrants will challenge and compete for the growing market.

The vehicles will be viable commercial solutions for different logistics needs in the near future. Short-haul transport is expected to be the primary use, but as the technical challenges are overcome and price parity is reached, all segments will be of high demand. The short and medium-haul battery electric commercial vehicles could reach 8-35 % sales by 2030 - in US, China and Europe - depending on scenario[71].

Regulatory framework

Regulations can facilitate and accelerate the shift towards electric trucks and give the underpinning that makes battery electric solutions more attractive for manufacturers and consumers.

Targets that impact the development of electric vehicles:

- **Sweden's climate policy framework;**
    - 70% emissions reduction in the transport sector by 2030
    - 100% renewable energy production by 2040
    - net zero emissions of greenhouse gases by 2045.
- **European Commission legislative proposal for heavy duty trucks[72];**
    - In 2025, 15% lower CO_2 emissions than 2019
    - In 2030, at least 30% lower CO_2 emissions than 2019.

Current regulations supporting charging infrastructure:[73]

- "Klimatklivet" – support for local and regional climate initiatives (as of the new state budget presented in April 2019 this support will remain, though in a slightly different form).
- CEF (Connect Europe Facility) Transport – EU funding for infrastructure investments.

Important regulations/incentives that could impact the future of electric vehicles include:

- Low emission environmental zones, that only allow electric and gas vehicles, are likely to be implemented in urban areas.
- Introduction of diesel bans in urban areas.
- Tolls, taxes and user charges for heavy goods vehicles with high emissions.
- Electric vehicle penetration targets – for example the Norwegian national goal that all new cars sold by 2025 should be zero emission (electric or hydrogen).

71 McKinsey, 2017. "New reality: electric trucks and their implications on energy demand".
72 European Commission, 2018. "Reducing CO2 emissions from heavy-duty vehicles".
73 Trafikverket, 2018. *Laddinfrastruktur för snabbladdning längs större vägar.*

Comparative pricing

Purchase price

Currently there is a higher price on heavy electric vehicles compared to corresponding conventional diesel vehicles. For example, the Tesla Semi cost 180 000 USD compared to new diesel trucks starting at 80 000 USD. However, for a custom featured diesel truck the price can reach 200 000 USD. The electric trucks are often designed to fit a specific customer need and the price will therefore vary depending on model.

However, the purchase price of the vehicle does not account for the total cost of ownership. This is also made up by battery cost, daily driving distance, electricity consumption and fuel price. By 2025 the cost parity with diesel trucks is likely to be reached. This point is not a fixed date and is highly dependent on the specific ranges and routes driven by the trucks. The clearest economic rationale seems to be for light duty trucks – with a distance of 100-200 km/day.

Secondary market

The secondary value of electric trucks is uncertain as the market is still in its infancy. When it comes to the secondary market of the components of the vehicle, such as batteries and motor, the electric vehicle has an advantage compared to ICE. The components can be reused for other purposes, in completely different products – for example storing solar energy.

Cost of maintenance

The technical lifespan of electric trucks is expected to be longer than for ICE trucks (with a lifespan of around 8 years). This is due to fewer service needing components resulting in a lower cost of maintenance. In general, the motor contains less than ten components compared to more than a hundred in an ICE. Lithium-Ion batteries can last for up to 10 years before they become useless. However, current vehicles are still in their infancy and may suffer from teething problems.

Fuel costs

The fuel cost for electric vehicles is directly dependent on the price of electricity. The electricity cost is uncertain as it varies with the seasons and specific time of day as well as the electricity contract. For example Vattenfall inCharge, the cost per kWh is 0-5 SEK and per minute 2,4 SEK[74].

Another important aspect is the cost of a charging station. The construction cost varies depending on different factors: type of charger, location, proximity to electricity supply and the grid's capacity at the location. To invest in a fast charging (DC) station the cost is approximately 500 000 SEK – of which 50% of the cost derives from connecting the station to the electricity grid. A station for night-time charging cost approximately 15 000 SEK including installation.

The fuel cost is also indirectly dependent on the time spent charging, as this can be a productivity loss for the driver.

Other TCO factors

Insurance and personnel cost are other factors that need to be accounted for in the operational cost of a vehicle. The regulatory environment is also highly significant for the total cost, for example road charges, tolls and fuel taxes. An increased diesel tax could be used to fund the transition towards electrification.

74 https://www.goincharge.com/se/pages/hitta-laddstation/

Additional values

Reduced harmful exhaust emissions from heavy duty vehicles leads to cleaner air. According to a study by the European Federation for Transport and Environment, pollutants such as NOx, SOx and PM are zero from a battery electric truck powertrain perspective. The study also shows that long range battery electric trucks in EU have 51-67% less CO_2-emissions compared to equivalent fossil fuel powered trucks.[75] With a Nordic electricity mix, the reduction of CO2-emissions are most likely substantially higher.

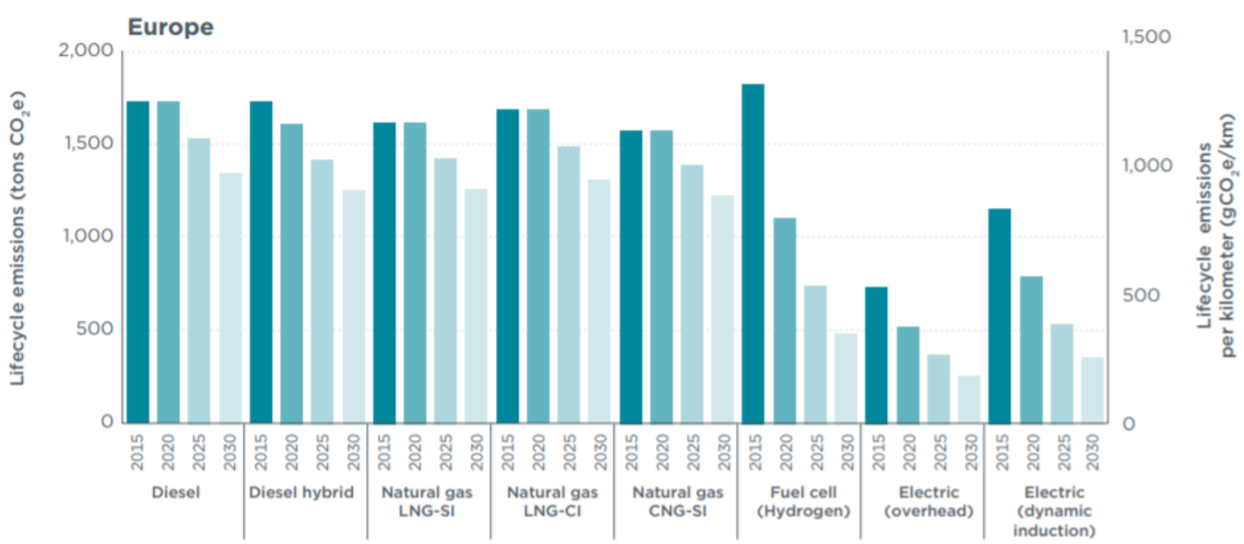
There are additional values such as;

- Safety improvement – lower risk of fires, explosions.
- Reduction of noise – potential for driving during off-peak hours reduces the burden on frequently traveled roads.
- New job creation – electrification of transports will create job opportunities in both vehicle development and charging infrastructure construction.
- Health benefits – it is estimated that electric vehicles can save billions of dollars annually in health care cost due to harmful pollutant reduction.

From a well to wheel perspective the electric trucks have the potential to significantly reduce CO2 emissions.

Figure 12

Well-to-wheel lifecycle analysis in CO2e for long-haul heavy-duty freight truck in Europe purchased in 2015 through 2030. Source: Moultak, M., Lutsey, N. och Hall, D., 2017. Transitioning to zero-emission heavy-duty freight, ICCT.



75 Earl, m.fl., 2018. "Analysis of long haul battery electric trucks in EU."

SWOT - Electrification

Strengths	Weaknesses	Opportunities	Threats
• Elimination of local air pollution • Increased energy efficiency • Low maintenance costs • Low noise volume • Use renewable energy for charging • Low charging costs • High efficiency	• Less capacity for cargo loading • Charging time • Complex charging infrastructure (Different standardizations for charging) • Infrastructure cost • Short/limited driving range • Higher vehicle cost • Not fully technically developed • Lifetime of the batteries	• Synergies with renewable electricity development • Fast technical development (batteries) • Demand for electric vehicle increase • The grid will evolve (charging • Low-cost batteries • Political support (road pricing, special lanes, subsidies) • Lower cost of use and service	• Energy and local grid access (underdeveloped infrastructure) • Uncertain supply of battery components • Other renewable alternatives • Limited charging infrastructure • Price uncertainty in secondary market

FUEL CELL ELECTRIC VEHICLES

Fuel Cell Electric Vehicles (FCEV) also use an electric powertrain, but instead of an electric battery FCEVs carry fuels cells which are fueled with hydrogen gas. The fuel cells then generate electricity by using oxygen from the air and the compressed hydrogen gas – emitting only water and heat in a tank-to-wheel perspective. This is beneficial for improved ambient air quality in urban areas.

Hydrogen gas is mainly produced from water or natural gas through electrolysis or gas reformation respectively – two quite energy-intensive processes. To what extent the end product of electrolysis is fossil free depends on the energy input. With electricity from renewable sources the well-to-wheel emissions can be significantly lower than conventional fossil fuel alternatives. Gas reformation of natural gas is in itself not a fossil free alternative, but several research projects on how to produce hydrogen gas through more sustainable processes, e.g. photosynthesis, are ongoing. Theoretically hydrogen gas can be produced from biogas as well, but as biogas is already a viable biofuel this is not common practice.

Currently the primary application scopes for hydrogen gas are chemical industries and oil refineries, while the use as vehicle fuel is limited due to significant economic disadvantages compared to conventional powertrains and battery electric vehicles. Costs related to infrastructure, hydrogen gas production and fuel cell production are relatively high, and FCEVs are not forecasted to be a competitive alternative in a two-year perspective[76].

Infrastructure availability

There are currently only four domestic filling stations for hydrogen gas, supplied by AGA Linde, H2 Logic and Woikoski, located in Gothenburg (Woikoski), Mariestad (H2 Logic), Arlanda (AGA Linde) and Sandviken (AGA Linde), see: http://www.vatgas.se/tanka/.

Nikola Motor Company is planning to develop infrastructure for filling stations in both the US and Canada as well as Europe, but this is a long-term plan where the first stations will not be up and running until 2021[77]. Norwegian NEL Hydrogen is one of the producers that will deliver hydrogen gas to Nikola's Nordic filling stations.

Vehicle supply - current and coming

On a global arena, especially in the US, there is an interest for heavy FCEV and a couple of models have recently been announced. However, these are still to be tested before being launched for public availability. The Nikola Tre is adapted for the Nordic market and Bring has already ordered a truck to be part of the testing that will take place in Norway, beginning in 2020[78].

Scania is developing a fuel cell refuse truck together with the waste handling company Renova[79]. Scania has also announced delivery plans of four fuel cell distribution trucks for the Norwegian food wholesaler Asko, a company which has established its own production facility for sustainable hydrogen gas.

76 Larsson, M. 2015, "The role of methane and hydrogen in a fossil-free transport sector". Doktorsavhandling, KTH, Skolan för kemivetenskap

77 Nikola Motor Company, https://nikolamotor.com/press_releases/nikola-raises-100-million-in-august-49

78 https://via.tt.se/pressmeddelande/bring-har-bestallt-vatgasdriven-lastbil?publisherId=110414&releaseId=3244636

79 https://www.scania.com/group/en/scania-delivers-fuel-cell-refuse-truck/

Manufacturer	Model	Available	Range (km)	Maximum load (tonnes)
Nikola Motors	Nikola Tre	2022/2023	500-1200	-
Nikola Motors	Nikola One/Two	2019/2020	800-1600	30
Toyota	Beta Truck	-	480	36
Scania	-	2019/2020	500	n/a

Drivers and obstacles

Primary drivers[80]:

- Potential environmental benefits: GHG reduction, no air polluting emissions and less noise pollution.
- Export opportunities: early efforts can create business opportunities and technological lead on a global market.
- Increased energy security through domestic fuel production.
- Increased energy system flexibility: surplus electricity from intermittent renewable sources can be stored as hydrogen gas.

Primary obstacles:

- Implementation requires a paradigm shift: simultaneous development of infrastructure, hydrogen gas production and demand is needed.
- Low energy density: limited reach and difficulties regarding storage and distribution.
- Lack of political support: focus is often on other alternatives.
- General lack of up-to-date knowledge on the development status among transport actors.

80 Cecilia Wallmark, Farzad Mohseni, Geert Schaap mfl, ”Vätgasinfrastruktur för Transporter - Fakta och konceptplan för Sverige 2014-2020”. TEN-T, HIT-1 NIP-SE, 2014-12-31, www.vatgas.se

ELECTRIC ROADS (E-HIGHWAYS)

There are currently three main technologies of interest for development of electric roads:

- Conductive transmission via air conduit (over-head catenary)
- Conductive transmission via rail or conductor in the road
- Inductive transmission via electromagnetic fields from the road body

Trafikverket (the Swedish Transport Administration) decided last year to give support to two test facilities of electric roads. The pilot tests will continue through 2018 and provide knowledge on future practices.[81]

National overview

Arlanda pilot – "the rail road"

Two kilometers of electric rail links Arlanda Airport to a logistics site. The energy is transferred via a movable arm attached to the bottom of the vehicle from two tracks of rail integrated into the road.

Sandviken pilot – "the roof road"

The test stretch is two kilometers. The energy is transferred via a conductor on the roof of the truck that can connect to contact lines roughly five meters above the road. The connection is automatic and available at speeds up to 90 km/h.

Elonroad's[82] demonstration outside Lund and Alstrom's electric road project at Volvo Groups headquarter[83] are other examples of the over head solution.

Planned

Gotland – March 2019: Inductive road (wireless charging)[84]

West Sweden – "Västsvenska elvägar": Planned pilot (similar to Arlanda) [85]

Early assessments show that on a 250-300 km stretch of highway with relatively high traffic volumes, carbon dioxide emissions from trucks could decrease by more than 200,000 tonnes, if 70% of trucks use an electric highway.

In a study, RISE[86] presents three characteristics required for electric roads to offer a decent business case:

- A distance of at least twenty kilometers
- Annual average daily traffic (AADT) for electrified road trucks should, in both directions, be around twice the number of electrified kilometers in one direction (approximately 700 e-road trucks Gothenburg-Stockholm every day during the year, representing 43-86% of overall flow)
- The electrified stretch should comprise 60 % percent or more of the trucks' overall distance driven each year.

81 https://www.greenmatch.se/blogg/2016/07/tvaa-el-vaegar-mot-framtiden
82 http://elonroad.com/
83 https://www.alstom.com/press-releases-news/2017/11/alstom-presents-aps-for-road-its-innovative-electric-road-solution
84 https://teknikensvarld.se/varldens-forsta-induktiva-elvag-planeras-pa-gotland/
85 Volvo, https://www.volvogroup.se/sv-se/news/2018/sep/volvo-plans-to-build-electric-roads.html
86 Trafikverket, RISE, 2017. "Förstudie av affärsekosystem för elvägar".

It is too early to draw conclusions from the pilot projects, but irrespective of preferable technology, the technical aspects will not be the challenge – the primary challenge is the business model and cooperation between different actors. There is not a strong business case for large scale implementation at the moment as the technology is still in the demonstration and development stage.

Early predictions state that the technique is likely to reach public roads in the coming years – expected late 2020. However, the characteristics of such roads are still uncertain. The solution requires large investments and business collaborations, as well as regional authority approval, involving substantial decisions that could take time, given the complex decision-making process.

According to the national road map for e-highways, the next step is performing a larger pilot project to raise the technology matureness – from Technology Readiness Level 6 to 7 – as well as demonstrate functionality of payment- and access systems. As of April 2019, the stretches of highway to be included in the pilot are under discussion, with a planned project start by 2021. Parallel to this, Trafikverket is producing a long-term national action plan for construction and roll-out of e-highways, expected to be delivered by 2022.

International examples

In Germany, Siemens is building three pilot stretches of over-head catenary electric highways – of which the first is already in place along A5 Autobahn (five kilometers) in Hessen. The fifteen test vehicles that will traffic these pilot e-highways are delivered by Scania and will be operated by local haulers while Scania offers maintenance and collects vehicle operation data in order to evaluate the trial.

OTHER EFFICIENCY MEASURES

A general framework for sustainable transport is the Avoid-Shift-Improve hierarchy, which primarily advocates reduction of transport needs, secondly shifts to more sustainable transport modes (railway or shipping) and lastly improvements of inevitable road transports. In addition to adopting alternative fuel and powertrain solutions – which are examples of improvement measures – there are several other efficiency measures related to logistics systems, vehicle operation and non-powertrain improvements available to push the shift to fossil free commercial transport. These kinds of actions have potential to cut GHG emissions from commercial transport by more than 20%[87] and are also often linked to cost-savings.

Efficiency measures include e.g. digital solutions, behavioral changes, collaborations between actors in different parts of the transportation system and regulatory development. One source of inspiration in this territory is CLOSER – a neutral platform for cooperation and innovation within transport and logistics. CLOSER has several ongoing projects in different areas, promoting a more efficient transportation system.

Multi-modal solutions

Multi-modal solutions are – as the name suggests – a combination of different modes of transport where road transport (when possible) is shifted to rail transport or sea freight, in line with the Avoid-Shift-Improve hierarchy. This is a solution especially suitable for loads of high weight or volume[88], as both the economic gain and climate effect is served by economy of scale. Better information sharing through digitalized platforms could facilitate multi-modal solutions through a better overview of available options within different modes of transport.

Horizontal collaborations

Horizontal collaborations are cross-company collaborations between actors at the same level of the logistics provision chain. The idea is to enable more resource efficient utilization of the transportation system as well as knowledge sharing between organizations. Shared transports and combined material flows (up-scaling) make for higher fill rates and open up possibilities for shifts to other transportation modes which can be both cost-effective and reduce emissions. One successful example is the collaboration between SSAB and LKAB where shared transports between Borlänge and Luleå for some sections resulted in a 60% reduction of freight cost and 40% GHG emissions reduction, as well as improved delivery precision and substantially reduced delivery time[89]. Potential challenges that need to be overcome are business model conformation, sharing of risks and technical obstacles.

Coordinated transports

Coordinated transports is an effective way of solving logistic issues with collaboration. The idea is to have a collective distribution center and coordinated system with a mix of actors in one region.

In Sweden, *Beloved City* is one example of a successful collaboration between the city council and corporates with the aim of reducing the impact of traffic in Stockholm's city center. The solution replaces a waste (recycling) truck and delivery truck with a shared smaller electric vehicle with a

87 Scania, 2018. "The Pathways Study: Achieving fossil-free commercial transport by 2050".
88 https://www.dbschenker.com/resource/blob/488558/c71cb87de94becb963563b7ab7a7d642/tuote-esite-multimodal--fi-en--data.pdf
89 https://closer.lindholmen.se/nyheter/stort-intresse-i-naringslivet-nya-transportlosningar-genom-horisontella-samarbeten

load carrier specially built for this transport service. One of the greatest values is the reduced use of vehicles in use, which has a direct effect of emission reduction, noise reduction and increased traffic safety. A study from KTH Royal Institute of Technology in Stockholm shows that the project reduces emissions by 73 percent (50g CO_2/kg compared to 13,4g CO_2 /kg)[90].

Eco-driving and route optimization

Combined measures on eco driving and route optimization have a cost-saving potential in parity with an energy efficiency increase of 10-20%[91]. This is a result of reduced fuel use and wear on vehicle components due to forward-thinking driving and smart planning of routes in time and stretch. Adoption at operational level can also improve working conditions and contribute to keeping and recruiting personnel.

Successful implementation requires convincing leadership to ensure the drivers operate in accordance with guidelines. To build credibility and engagement at the operational level it is important to address the problems that the drivers experience in their every-day work environment, e.g. stress to keep up with lead-times as well as delegating responsibility. Results from mapping of driving patterns and fuel use can be useful in communication promoting behavioral changes. Another helpful tool can be check-lists reflecting set priorities, where fuel saving might be prioritized over delivery time.

High Capacity Transport (HCT)

Allowing greater load and/or additional trailers (higher capacity) for long haul trucks can increase energy efficiency and thereby reduce costs and contribute to lowering CO_2-emissions by up to 20%[92]. 2016 a new maximum gross weight of 74 tonnes for large trucks was established and CLOSER is currently testing a number of HCT vehicles to evaluate the benefits. However, allowing heavier vehicles will also require reinforcements of the current road network and key bridges.

Design optimization

Potential energy efficiency through design optimization of vehicles is limited, but a fuel reduction of up to 5% can be possible[93].

90 http://www.alskadestad.se/artikel/spara_energi_kth-rapport/
91 Interview, Deviaq.
92 https://www.trafikverket.se/resa-och-trafik/forskning-och-innovation/aktuell-forskning/transport-pa-vag/branschprogram-for-godstransporter-med-hog-kapacitet---hct/
93 Interview, Scania.