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# The contribution of Advanced Renewable Transport Fuels to transport decarbonization in Sweden - 2030 and beyond

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# 1 Summary

This report will be part of the contribution from Sweden to a joint IEA Bioenergy and IEA Alternative Motor Fuels project called “The contribution of Advanced Renewable Transport Fuels to transport decarbonisation in 2030 and beyond” aiming to showcase the role of advanced renewable transport fuels, considering all transport modes.

This Swedish report include (i) a description of the current situation for ART-fuels in Sweden today including e.g., policies and targets, (ii) a review of the potential of sustainable renewable fuels in Sweden for 2030 and beyond, (iii) a review of challenges and hurdles for the implementation of advanced renewable transport fuels in Sweden, and (iv) a review of the expected volumes of renewable fuel that is needed in Sweden to meet the emission reduction targets in an outlook for 2030/2045. More specifically, the report addresses (i) the production potential for renewable fuels, (ii) the usage potential for renewable fuels, (iii) an analysis of current policies in Sweden and indication of additional measures needed to further enhance the ART fuel implementation and (iv) challenges that need to be addressed to increase ART fuel usage in Sweden. The work is based on recently published studies in combination with input from experts from the Swedish Transport Administration and the Swedish Energy Agency partly via a dedicated workshop. The scenarios presented by these two agencies are described in Appendix A.

This report concludes that Sweden has the potential of reaching the targets set for 2030 and 2045 but it requires substantial investments in production, infrastructure and policy, linked to increased ART-fuel implementation.

The policy system to be used for this implementation needs to be applied long term. The system also needs to be transparent and predictable both for the market and for the consumers. If this is not the case, and if rapid or frequent changes are made, market-actors may lose faith in the instruments. Many of the policies implemented this far have tended to promote mature technologies. If the goal is to also promote more novel solutions efforts towards this needs to be included in the design of the instruments. Instruments must be put in a context where (at least) vehicles, infrastructure and fuel usage are included - and how it should be phased out. Furthermore, the strength of the individual policies must be thoroughly analysed so that they have the postulated effects. Even so, unpredicted effects may still arise that need to be adjusted for along the way. Moreover, the cost-effectiveness of the instruments needs to be compared and considered before implementation so that the efforts are put where that can have the strongest effect.

The need for biofuels can be greater for e.g. heavy trucks than for passenger cars, as the latter may have easier to switch to electrification. On the other hand, the turnover time is shorter for e.g. buses and trucks than for passenger cars. Particularly low -blend fuels (e.g. ethanol and FAME) and drop-in fuels (e.g. HVO) have many advantages: they do not require new vehicles, no new infrastructure for distribution and the blending in fossil fuels can be based on the current availability on different occasions.

## 2 Introduction

This report is part of the contribution from Sweden to a joint IEA Bioenergy and IEA Alternative Motor Fuels project called “The contribution of Advanced Renewable Transport Fuels to transport decarbonization in 2030 and beyond”. That project is executed under the IEA Bioenergy Special Task 41 with the EC, Finland and IEA AMF. The objective of this international effort is to showcase the role of advanced renewable transport (ART) fuels to decarbonizing transport by 2030 and beyond. To accomplish this, national strategies for transport decarbonization have been analyzed for all modes of transport, and possible challenges and hurdles for the implementation of ART fuels identified.

This Swedish report include is (i) a description of the current situation for ART-fuels in Sweden today including policies and targets, (ii) a review of the potential of sustainable renewable fuels in Sweden for 2030 and beyond, (iii) a review of challenges and hurdles for the implementation of advanced renewable transport fuels in Sweden, and (iv) a review of the expected volumes of renewable fuel that is needed in Sweden to meet the emission reduction targets in an outlook for 2030/2045. The work is based on recently published studies in combination with input from experts from the Swedish Transport Administration and the Swedish Energy Agency partly via a dedicated workshop.

### 2.1 The targets for transport decarbonization and key strategies.

#### 2.1.1 National targets

The overall goal of Sweden’s environmental policy is to be able to pass on to the next generation a society in which major environmental problems have been solved, without increasing environmental and health problems beyond the country’s borders. Sweden aims to become one of the world’s first fossil-free welfare countries. To achieve this, the fossil-fuel dependency of the transport sector needs to be broken. Several measures are needed, such as reducing the total energy demand of the transport sector and ensuring that the remaining energy is both renewable and sustainable.

In 2017 a new climate act was approved. The long-term climate goal means that by 2045, at the latest, Sweden will have no net emissions of greenhouse gases (GHG). In more precise terms, the long-term climate goal means that emissions from activities on Swedish territory will be cut by at least 85% compared with emissions in 1990. To achieve net zero emissions, flexibility measures are included. For the domestic transport sector, a reduction in emissions (not including air travel) of at least 70% by 2030, compared with 2010, has also been adopted.

The government has also decided on a goal that passenger transport by public transport, walking and cycling will account for at least 25 percent of passenger transport in the country by 2025 and the share will double in the long term. This goal also means limiting the growth of passenger car traffic which in the long run cannot increase if this goal is to be achieved. These goals are not matched to the climate target, and it may require more or less of these parts to reach the climate target in 2045.

## 2.1.2 CO<sub>2</sub> emissions from transport

Domestic transport accounts for just under one third of the national emissions of GHG. Road traffic completely dominates the emissions of GHG by domestic transport and constitutes 95 percent of these. Excluding domestic flights, road traffic accounts for 98 percent of the emissions. If bunkering to foreign shipping and aviation and domestic aviation is included, the distribution of road traffic will be 65 percent, shipping 25 percent, flight 10 percent and rail 0.2 percent. Passenger cars account for two-thirds of road traffic emissions, while light trucks account for just under 10 percent, heavy trucks for just over 20 percent and other vehicles for about 5 percent.

## 2.2 The gap between where we are and where we are heading

Although emissions from road traffic and domestic transport have decreased over the past 10 years and are also estimated to decrease by almost 40 percent between 2010 and 2030 with today's decisions, the pace needs to increase to reach the 2030 target (see figure 1). The simplest measures have already been implemented and further measures and instruments will be needed to get to the goal. New EU requirements for light and heavy vehicles, bonus-malus and reduction obligation only take us a bit.

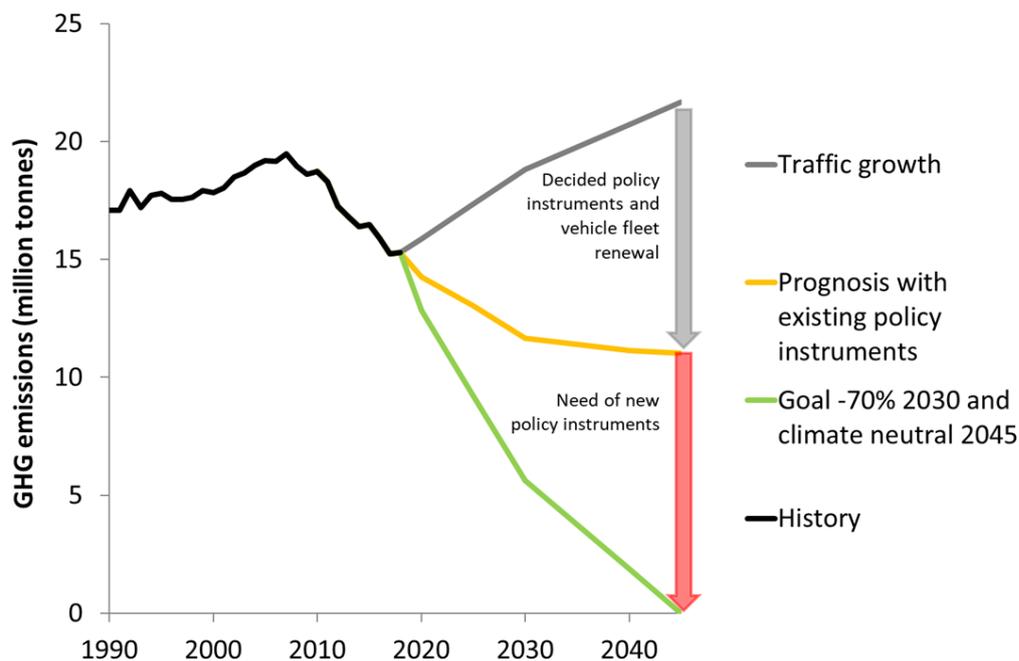


Figure 1. Forecast of possible future Swedish transport sector emissions. The black line shows the historical development up to today of road traffic emissions of carbon dioxide. The gray line shows how carbon dioxide emissions would develop if today's vehicles and fuel were used in the future with the traffic forecast produced by the Swedish Transport Administration. The yellow line shows the development with decisions made today on policy instruments and measures. This includes bonus-malus, decided reduction obligation up to 2020 and the EU Commission's proposal for CO<sub>2</sub> demands for light and heavy vehicles. The green line shows the goal according to the new climate goals decided by the Swedish parliament. Source: The Swedish Transport Administration Agency.

Emissions can be reduced by the same factors that explain its emissions (traffic, energy efficiency and share of renewable energy):

- Through a more transport-efficient society where the need for travel and transport is not as large and where transports take place more efficiently, the amount of traffic can decrease.
- Energy-efficient vehicles and energy-efficient use of the vehicles increase energy efficiency per completed traffic work. A transport-efficient society together with the increased energy efficiency reduces the amount of energy needed in the transport system.
- The fossil energy that remains needs to be replaced by biofuels, electricity and eventually hydrogen. The latter two contribute to further reducing the amount of fossil energy that needs to be replaced by biofuels.

Considering the rate of turnover of the vehicle fleet, the advanced motor fuels play an important role for reaching these targets. The share of renewable energy in the transport sector can be increased in three ways:

- Renewable fuels in conventional engines,
- Renewable fuels in adapted engines,
- Electricity, hydrogen and electro fuels produced from renewable energy.

A more transport-efficient society and a more energy efficient fleet have the potential to more than halve the energy consumption for domestic transport by 2030. The remaining energy demand needs to be covered partly by biofuels in order to reach the targets for 2030. Through electrification the need for biofuels can be reduced. This is crucial as the global supply of biofuels will be limited.

The use of biofuels in conventional gasoline and diesel engines has the advantage that it does not require any new infrastructure and that the transition to biofuels is not limited by the availability of vehicles that can use them. What limits the transition is access and thus the price of biofuels on the market. HVO can be used in admixtures up to 70-100 percent in diesel and run in conventional diesel engines.

Biofuels in customized vehicles have the advantage that they are usually simpler hydrocarbons and alcohols which give greater exchange of finished fuel from the biomass they are produced from compared with the propellants required to be able to blend high in conventional engines. The disadvantage is that they require dedicated vehicles and infrastructure. As for the latter, this is not as critical for local fleets and for specific routes where it is enough to build it locally. An example of local fleets is public transport by bus in the city or regionally. An example of specific routes is freight transport between points A and B.

# 3 Review of the potential of sustainable renewable fuels in Sweden for 2030 and beyond

## 3.1 Production potential for renewable fuels

### 3.1.1 Forecasts for global access to non-fossil fuels.

According to IEA there is a large potential to produce biofuels from sustainable raw materials that are not food crops using advanced processes [1]. These raw materials include e.g., agricultural residues such as straw or forest residues such as branches or sawdust. In Europe, sustainable raw materials could offer twice as much as the expected demand in 2040, according to the IEA. However, such a scenario is based on more efficient processes and lower biofuel costs as a result of research and development and public support in establishing the products [1]. However, there is a range of different estimates of the biomass potential. According to the IPCC, the global contribution from biomass may be between 100 and 300 EJ per year to the energy system around 2050 [2]. This can be compared with the total bioenergy supply in 2008 which was 50 EJ [2].

Today's biofuels on a global level are mostly based on agricultural crops. To avoid conflicts about land use, the focus is increasingly on biofuels from residual products from agriculture and forestry. The IEA expects that if 10% of the world's residual products from agriculture and forestry can be used for second-generation biofuels, this would correspond to 5–7 EJ per year by 2030 (which is assumed to correspond to 4–6% of the forecasted demand for fuel 2030) [2].

The OECD estimates that crops will be the primary raw material for biofuels in 2025 [3]. Approximately 22 percent of all sugar cane, 12 percent of the world's vegetable oils and 10 percent of feed seeds are believed to be used in fuel production 2025 [3]. The OECD's forecast of future agriculture indicates that global ethanol production is estimated to amount to 128 billion liters in 2025 (2015 production was 98 billion liters). It is mainly Brazil and Thailand that are believed to be responsible for the increase. Production of biodiesel is expected to increase to just over 41 billion liters in 2025 (2015 production was 28 billion liters). The EU is expected to be the largest producer followed by the United States, Brazil, Argentina and Indonesia [3]. An EU report in 2015 predicted that global production of biodiesel and bioethanol will almost double between 2011 and 2021, albeit from different levels [4].

### 3.1.2 Potential future Swedish production of renewable fuels.

A Swedish research group at IVL Swedish Environmental Research Institute and Lund University have made estimates of the potential Swedish biofuel production in 2030 for two different cases. The lower estimate reaches about 15 TWh of Swedish-produced fuels, while the more ambitious estimate yields approximately 28 TWh of Swedish-produced fuels in 2030 [5].

Biogas from digestion is expected to have the highest potential both in the less ambitious case (4 TWh) and in the more ambitious scenario (9.5 TWh) [5]. The largest increase is expected to come from co-digestion plants and farm facilities. The use of sludge from sewage treatment plants is already expanded and is not expected to grow to any great extent. Even though Sweden has a long tradition of knowledge in and development of biomass gasification technology, there is currently no commercial plant. Until recent years, there was however one active non-commercial test facility for SNG production, GoBiGas, where there was plans for expansion. In the less ambitious scenario, the test facility is estimated to produce with its entire capacity, and a new plant is being built. In addition, in the ambitious scenario, further production of the SNG takes place. However, the test-facility GoBiGas is currently mothballed which makes these assumptions less plausible.

In the less ambitious case, ethanol is estimated to be an alternative that can be increased by full utilization of the facilities that exist today. However, no new plants for crop-based ethanol were planned at the writing of that report and the EU sets a ceiling for the use of these raw materials, which is the basis for the assessment. The larger ethanol production seen in the more ambitious scenario applies to lignocellulosic ethanol. In both scenarios, Swedish ethanol production is believed to be able to provide 3-4 TWh of fuel. In the less ambitious scenario, 2 TWh of HVO is manufactured, which corresponds to the maximum plant capacity 2015. In the more ambitious assessment, Sweden could manufacture 4 TWh HVO in 2030, and the largest contribution would come from tall oil. Sweden is expected to be able to manufacture 2 TWh FAME 2030. No new plants are assumed to be built, and the assumption postulates that the facilities that exist today are fully used. In the more ambitious assessment, Sweden produces about 3.5 TWh of methanol. Methanol production was to take place at the test facility that exists today and at a newly built facility.

In a slightly older (2013) report from IVL and Chalmers, the future contribution of renewable fuels to the Swedish road transport sector is assessed. The contribution is assessed based on three scenarios. In a first scenario, existing facilities continue to be operational and planned facilities are put into operation as planned. Another scenario also includes an expansion of facilities. In the third scenario, it is assumed that existing facilities retain their production capacity but that the start year for planned facilities is delayed. The conclusion is that the domestic contribution of renewable fuels to the road transport sector could be within the range 5–13 TWh 2020 and 13–26 TWh 2030 [6]. A governmental investigation performed by several Swedish authorities concluded that the total net production of biofuels - i.e. only for transport - could be 17 –18 TWh 2030 [2]. The Swedish Transport Administration believes that there may be 10 TWh of biofuels for road traffic in 2030 if Swedish production at the same time must be sufficient for other modes of transportation and non-road mobile machinery [7].

In 2013, a governmental investigation was carried out on fossil-free vehicle traffic, the so-called FFF study [8]. The assignment was to map possible options for action as well as identify measures to reduce the transport sector's emissions and dependence on fossil fuels in line with the vision that Sweden 2050 will have a sustainable and resource-efficient energy supply without net emissions of greenhouse gases the atmosphere and the priority of a fossil independent vehicle fleet 2030. Production of bio-jet fuel in Sweden can be done either by development of new technologies and commercialization of those or by usage of technology that is already commercialized. It is important to point out that all process routes in addition to jet fuel also can produce fuel for the road sector. Certain process paths can rather be seen as biorefineries where the jet fuel constitutes a minor part of the total product composition [9].

It is argued that the biomass for increased biofuels production must primarily come from waste, by-products, lignin, cellulose and hemicellulose. This is where the largest production potential is

expected to be, i.e. largely forest-based raw material. A future need for 15-20 TWh of biofuels per year means a biomass requirement of about 23-30 TWh when the conversion efficiency from bio-based raw material to finished fuel lies around 65% [10]. Different production systems for biofuels have different conversion efficiency, however for technologies and systems under development, the conversion efficiency is usually considered to lie between about 55-70% [10]. Some proportion of biofuels will probably be based on raw materials other than forest raw material also in the future, such as biomass from the agricultural sector, organic waste, etc., but the bulk assumed here is based on forest raw material. A rough estimate is that about one third will be based on raw material other than forest raw material and that two-thirds will be based on forest raw material, which results in a demand for forest fuels of about 15-20 TWh per year [10]. Today approximately 1 TWh of forest-based raw material is used for biofuel production in the form of tall oil. Current facilities for biofuel production in Sweden are indicated in Table 1, where also R&D plants are included.

Table 1. Current (May 2019) production facilities for biofuel in Sweden.

Production facilities	Feedstock	Biofuel	
Domsjö Fabriker, Örnsköldsvik	Cellulose	Ethanol	
Lantmännen, Agroetanol, Norrköping	Grain and some food waste	Ethanol	
ST1, Gothenburg	Food waste	Ethanol	
Adesso Bioproducts, Stenungssund	Rapeseed	FAME (RME)	
Ecobränsle, Karlhamn	Rapeseed	FAME (RME)	
Sunpine, Piteå	Tall oil	Raw Tall oil diesel	
Preem, Gothenburg	Tall oil and other renewable sources	HVO	
Approximately 280 biogas facilities in Sweden	Mainly waste and residues including sewage sludge, manure and domestic and industrial food residues	Methane	
GoBiGas, Gothenburg	Mainly solid biomass	Methane	Not in operation
LTU Green fuels (LTU, Chemrec, Haldor Topsö), Piteå	Various biomass-based feedstocks	MeOH, DME, etc.	R&D Plant. Not in operation
Biorefinery demo plant, Örnsköldsvik	Various biomass-based feedstocks	Various Biofuels	R&D plant
ETC, Piteå	Lignin-based biooils and other biomass-based oils	Various Biofuels	R&D plant
Renfuel, Bäckhammar	Lignin from forest biomass	Bio-gasoline/-diesel via lignin oil	R&D plant
Södra, Mönsterås	Methanol	Purified from pulping plant waste stream	For use as fuel or chemical

## 3.2 The usage potential for renewable fuels in Sweden

### 3.2.1 Transports are expected to continue to increase

The proportion of renewable energy in Sweden's transport sector in 2016 amounted to 20% (22% for 2017, see section 2.2.2) in terms of energy content and to 31% according to the calculation method specified in the Renewable Energy Directive which double-count fuel produced from waste and residual products [11]. The proportion of biofuels, in terms of energy content, amounted to 19% in the same year [11]. For the period 2007-2016 the use of HVO has increased significantly, while the use of FAME and ethanol decreased [12]. The use of biogas in transport increased slightly. However, the use of CNG/CBG (which consists of biogas and natural gas) has in principle stagnated since 2013 and but the proportion of biogas in the mixture has increased. Sweden has had various pilot and demonstration projects for cellulose-based fuels. These have previously been described in literature [6, 13, 14].

The uneven growth of individual fuels can be interpreted as not supporting them for enough time to reach commercial maturity. The predictability of Swedish policy instruments has also been perceived as very low by various fuel actors [13-17].

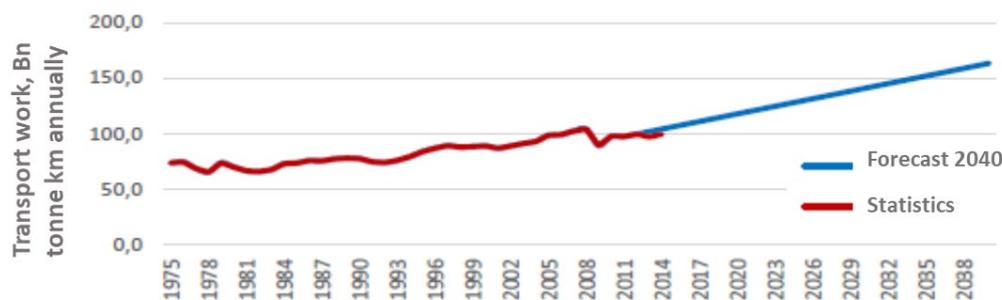


Figure 2. Transport work 1975-2014 and forecast to 2040. The values in the forecast are based on statistics for the base-year in combination with modelled values for annual growth until 2040. [18]

The Swedish Transport Administration expects, in its "business as usual" scenario 2018, an increase in transport up to 2040 [18]. The increase is partly due to a larger population, higher employment rates and a positive real income development [19]. When it comes to regional transport (shorter than 100 km), car driving is believed to account for the largest increase in terms of passenger kilometers. Trains and other rail traffic are expected to increase by about 50 percent. Also, for long-distance journeys (more than 100 km), trains are assumed to increase by about 50 percent. Long-distance car transport is believed to increase by about one-third to 2040. Freight transport is expected to increase a lot both at sea and on road and rail. For shipping, transports are believed to almost double.

#### 3.2.1.1 Different possibilities for the future development

In 2016, the Swedish Transport Administration was commissioned to report which instruments and measures were required to reduce the transport sector's GHG emissions by 60 and 80 percent by 2030 (compared with 2010). The Swedish Transport Administration presented four different scenarios to reflect the uncertainty and illustrate the outcome for some of the different options [20]. The Swedish Transport Administration's reasoning applies only to domestic transport.

1. In the first scenario, an emission reduction of 60 percent was described, which could largely be achieved by means of energy efficiency, electrification and increased use of biofuels. No extensive changes to the transport infrastructure were required. To achieve a 60 percent reduction according to scenario 1, the Swedish Transport Administration estimated that 14 TWh of biofuels and electricity were needed. Efficiency and electric propulsion reduce the climate impact per vehicle kilometer [21].
2. In the second scenario, the target was an emission reduction of 80 percent. An assumption was made about a good biofuel supply at a low price, as well as that the biofuels would be fully utilized. No extensive changes to the transport infrastructure were required. For the 80 percent reduction, the second scenario requires 29 TWh of biofuels. However, according to the Swedish Transport Administration, achieving an 80% reduction in emissions by means of efficiency and biofuels would probably require Sweden to become a net importer of biofuels. According to the Swedish Transport Administration, the scenario could be difficult for other countries to follow and could also lead to higher biofuel prices [21].
3. In the third scenario, the target was also an emission reduction of 80 percent. Travel and transport were expected to decrease, and interest was directed towards measures to redirect to public transport and to other modes of transportation. Increased use of biofuels or electrification was not the focus [21].
4. In a fourth and final scenario, it was assumed that neither investment in increased biofuel production or structural changes in society were implemented. Instead, emissions reductions would be achieved through reduced travel and fewer transports. In the third and fourth scenario, the Swedish Transport Administration considered that 17 TWh of biofuels were needed [21].

### 3.2.2 The expected demand for non-fossil fuels

Researchers at SLU and Lund University of Technology have calculated the need for biofuels in 2030. According to the researchers, the biofuel requirement will depend on a balance between structural changes, investments in infrastructure and technical solutions [22]. Their estimate is that the need will be 13–24 TWh of biofuels in 2030 in order for Sweden to be able to reach the goal with 70 percent lower GHG emissions. They finally settle in the assessment 20 TWh. The researchers believe that in addition to biofuels in the future, we will need to reduce transport work, use vehicles with higher efficiency and thus use less fuel or use vehicles that run on electricity [22].

Another Swedish research report estimates that 80 percent of the European passenger car fleet must be electrified 2050 for the EU to meet its targets, see section 4.1.1 below. This would in turn require that 4 percent of the new car sales in 2020 consist of electric vehicles, 20 percent in 2025 and that half of the new car sales consist of electric cars in 2030. With this development, electric cars would constitute 14 percent of the total car fleet in the EU 2030. According to this study, the electricity to these vehicles would correspond to 4 percent of the expected electricity demand in EU 2030 [23].

The action potentials presented in the FFF-study, mentioned in section 3.1.2, are deemed to be technically-economical reasonable by that study and realizable within the current timeframe provided instruments of various kinds are implemented [8]. The use of biofuels was expected to increase compared to the time of the writing of the report and correspond to 20 and 15 TWh per year around 2030 in scenarios A and B, respectively, and 13 respectively 20 TWh per year around 2050 in scenarios A and B. The decrease of biofuels between 2030 and 2050 in scenario A (high emission reduction) depend on lower total transport needs and higher proportion of electrification

in 2050. The increased need for biofuel around 2030 and 2050 roughly doubled compared to the use at the time of writing [10].

The Swedish Royal Academy of Engineering Sciences (IVA) estimates that in Sweden, 10-16 TWh of electricity will be needed for transport after 2030. This would correspond to approximately 8 percent of the total electricity use in Sweden [24].

In one of their reports, the Nordic energy authorities (Föreningen Norden) report that total demand for aviation fuels in Sweden will stabilize after 2025 and that the proportion of renewable fuels will increase. According to them, the same pattern will be seen in the Nordic region as a whole [25].

In 2019 a governmental inquiry was presented about bio jet fuel [9]. Table 2 shows the Inquiry's estimated results for total volume of bio-jet fuel to achieve the reduction obligation levels, and total amount of energy. For the sake of comparison, in total approximately 2 TWh of fuels for domestic flights and 11 TWh for international flights are currently used (2019). The use of biofuels for the road traffic sector was approximately 15 TWh in 2017.

Table 2. Reduction obligation translated into volumes of bio-jet fuel and estimated cost for the years 2021, 2025, and 2030.

	2021	2025	2030
Total volume of bio-jet fuel (m <sup>3</sup> )	13 500	70 000	424 000
Amount of energy (TWh)	0,1	0,7	4,1
Price of bio-jet fuel (SEK/litre)	18	14	12
Total additional cost of bio-jet fuel (SEK millions)	162	560	2 544

There is also an increased interest in biofuels from the shipping sector where the current trend is to shift to LNG (for longer distances). The UN agency for international shipping, IMO, has agreed to reduce GHG emissions from shipping by at least 50% by 2050 and to continue to phase out GHGs as soon as possible in this century.

In Sweden, the alternative fuels of interest for the shipping sector include HVO, FAME, biogas, methanol, ethanol and electricity [26]. There are examples of the use of low-blending of RME and electricity in commuter vessels and use of HVO in governmentally owned Swedish road ferries in Sweden [27]. There are also some recent initiatives for LBG and during 2018 two ships bunkered LBG in Sweden, Fure vinga of Furetanks (40 m<sup>3</sup> which corresponds to roughly 0.02 GWh) and Terntank (18 tons which corresponds to roughly 0.24 GWh) [28].

### 3.3 Amounts needed to meet the targets

Based on the scenarios previously presented from the Swedish Transport administration, outlined in detail in appendix A, a plausible forecast can be outlined. This forecast is on the usage of biofuels in Sweden and comprises the year 2030 (short term) and 2050 (long term), see table 3. Attempts have been made to further refine the contents of the table, e.g. in liquid and gaseous biofuels, but the results have been deemed too speculative for dissemination.



Table 3. Domestic energy usage of ART-fuels for transport, TWh, 2030 and 2050. Based on the sections of domestic potential usage of ART-fuels in Sweden and the scenarios made by the Swedish Transport Administration.

	Road		Working machines, shipping and aviation	
	2030	2050	2030	2050
<b>Biofuels</b>	10-15	10-15	20 <sup>(1)</sup>	n.a. <sup>(2)</sup>
<b>Electricity</b>	4,5	12	n.a. <sup>(2)</sup>	n.a. <sup>(2)</sup>

1: Whereof 4.1 TWh dedicated to aviation [9].

2: No suitable references have been located to make this assessment.

## 4 Review of the challenges and hurdles for the implementation of ART fuels in Sweden

### 4.1 Challenges for increased ART fuel usage in Sweden

#### 4.1.1 Different fuels have different strengths and weaknesses

Today new raw materials are used in established manufacturing methods for biofuels. This applies, for example, to residual products and lignocellulosic raw materials in the production of ethanol and biogas. Lignocellulose has also begun to be used for gasification and oils for hydration, e.g. HVO. Different raw materials give different yields in the form of energy or finished fuel. Sugar and starch-based raw materials generally give a high energy yield. However, these crops are often used as food or feed and will be limited as raw materials to fuels within the EU. Instead, waste and residual products are needed. Sweden has good access to waste and residual products in the form of residues from the forest, agricultural waste, manure, industrial waste and household waste. The fuels that are to a large extent produced from these raw materials are biogas and HVO. [21]

##### 4.1.1.1 Different fuels have different production costs.

Biogas from waste and ethanol from sugar cane has a relatively low production cost. Jet fuels and hydrogen gas are comparatively expensive to manufacture. The lowest cost for reducing emissions is obtained from biogas produced through the digestion of waste and from sugar cane-based ethanol, while biodiesel from e.g. oilseed rape has high emission reduction costs [21]. Börjesson et. al. has compiled a list on the estimated production costs for different biofuels in 2016, see table 4 [29].

Table 4. Estimated average production costs for biofuels expressed as SEK/l gasoline-equivalent [29].

Biofuel	SEK / 1 gasoline-equivalent
Fossil gasoline and diesel	4
EtOH from sugar-cane	5
EtOH from grain	7
FAME/RME	7
HVO from tall-oil	7
Biogas from waste	4
Biogas from grain	7
Biogas from manure	7

#### 4.1.1.2 The emissions vary with different raw materials.

From a life-cycle perspective, waste and residual products have the potential to provide large emission reductions in terms of GHG:s. The use of rapeseed or soy, on the other hand, gives lower emission reductions. If one calculates the emissions based on average values for the raw materials, HVO and biogas provide the lowest emissions of GHG:s. The origin of electricity is of great importance for emissions, both in the use of electric vehicles but also in the manufacture of vehicles and liquid / gaseous fuels.

The Swedish Energy Agency presents the emissions from fuels used in Sweden for different years, see figure 3 [31].

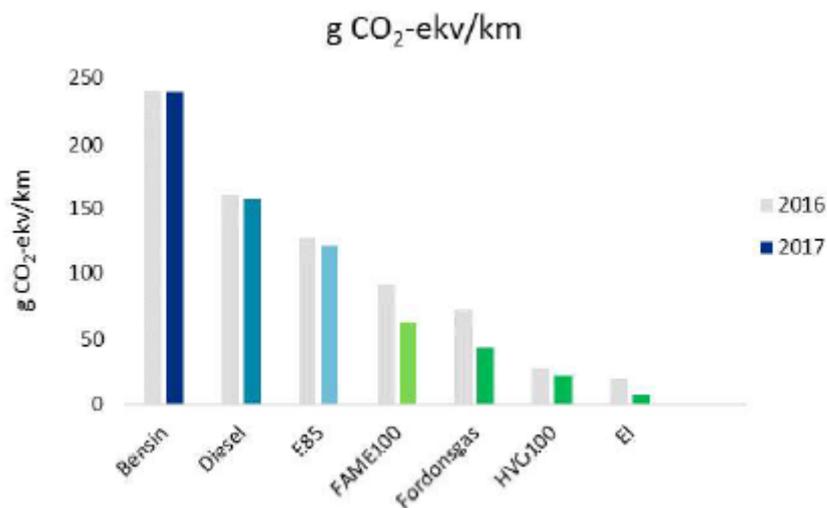


Figure 3. GHG emissions g CO<sub>2</sub>e/km from small private cars with the fuel-qualities of 2016 and 2017. Private cars are usually not certified for HVO<sup>100</sup> and FAME<sup>100</sup> but these biofuels are used in diesel-type engines for heavy vehicles [31].

## 4.1.2 Both liquid and gaseous biofuels and electricity will be needed

Sweden already has good access to fossil-free electricity compared to other countries. Electric vehicles are energy efficient - which means that the total amount of energy for transport decreases - and gives no emissions when driving. However, increased electrification of transport requires expansion of recharging infrastructure. Similarly, parts of the vehicle fleet need to be changed and the issue of electricity grid capacity need to be solved. The recycling or use of alternative materials must also be increased to ensure availability of metals and to prevent unsustainable social working conditions in the extraction of metals.

Liquid and gaseous biofuels will need to be used where their unique properties are necessary. Within the aviation and long-distance shipping industries, liquid and/or gaseous fuels will be the main alternatives for a long time. Other areas will also need liquid and gaseous propellants. The transport sector is partly characterized by inertia, and some vehicles will have to be refuelled with liquid fuel for many years to come. The need for biofuels can be greater for heavy vehicles than for passenger cars, as the latter may have easier to switch to electric drives. On the other hand, the turnover time is shorter for e.g. buses and trucks than for passenger cars. Particularly low-blend fuels (e.g. ethanol and FAME) and drop-in propellants (e.g. HVO and bio-gasoline) have many advantages: they do not require new vehicles, no new infrastructure for distribution and the blending in fossil fuels can be based on the current availability on different occasions. However, there is currently not enough drop-in fuels available. For some of the fuels, there is insufficient raw materials or resources and for others there are no raw materials that can be considered sustainable. In Sweden, the necessary infrastructure in the form of facilities for large-scale production is still lacking. Many of the biofuels are also more expensive to manufacture and therefore have difficulty competing with fossil fuels. [21]

## 4.1.3 Transports for the whole county

Fuel distributors may face problems to be able to supply a plethora of different (bio)fuels in the whole country. As the demand for conventional fuels may drop it may be harder for fuel suppliers to maintain profitability and to introduce an additional fuel in such circumstances may be perceived as a challenge. This reasoning is in favour for drop-in fuels. However, drop-in fuels alone will not be enough in the long-term when the emissions should be removed.

There may not be the same commercial interest in establishing an infrastructure for the distribution of biofuels in more sparsely populated parts of the country. The effects of higher fuel prices in general may also be more severe for people living in these areas. Electrification of road transport or distribution of clean biofuels will probably be faster to implement in densely populated areas than in more sparsely populated parts of the country, since in urban areas there is a larger possible market for these alternatives. PHEV or drop-in fuels allow for a gradual transition to biofuels in areas where it will take some time before there is an electricity or clean biofuels infrastructure. [21]

## 4.1.4 Investment cost and second-hand value play a role

Buying a car is a big investment. The second-hand value for any vehicle is affected by how they are perceived by the public, how they are described by the media, the fuel price, and how they are

affected by age, among other things. The second-hand value of fuel-flexible cars has fallen faster in recent years than for corresponding gasoline cars. The second-hand price for diesel cars could be affected by the discussions on a possible future ban on diesel. Biogas cars in some cases lack the flexibility in fuel selection that fuel-flexible cars offer, which can affect the second-hand value. Hence, it is often hard for the individual consumer to fore-cast the second-hand value of their car, and how it is affected by the choice of propellant. According to a survey by F3 (A Swedish Knowledge Centre for Renewable Transportation Fuels), a low secondary value has, among other things, been raised by the media as an argument against ethanol cars [32].

### 4.1.5 Sweden is part of an international vehicle market

Vehicle development is a global industry where profitability is based on long series that will pay development costs. Sweden cannot control which vehicle models are being developed, and an investment in fuels that requires specially adapted vehicles, as for some of the pure biofuels, presupposes that there are vehicle models internationally. Sweden can of course function as a test market for new vehicles and fuels, but then there must also be a potential international market [20] for dedicated vehicles. The cost for such an effort would be large however.

### 4.1.6 There is an inertia in the market

The demand for gasoline or replacement fuels for gasoline will be needed for a long time to come [2]. There is also some inertia regarding the private car market, and economic considerations alone are not always crucial. The Swedish Transport Administration points out that it was already profitable to buy a diesel car in Sweden during the first few years of the 21st century, but that it would take until the second half of the 00's before the market took off and then stimulated by additional instruments and incentives [20].

The aviation market is characterized by a large amount of inertia. Developing new aircraft models is very costly, the lead time for the development and production of new models is long and in addition, individual aircraft have a long lifetime (approximately 25-30 years) [33]. The same applies to ships and shipping which also have a long operational life-time, while the opposite often holds true for trucks [34].

### 4.1.7 Technical performance has influence

The operational range is a parameter for a possible choice of electric vehicle. A Swedish-German study shows that the reach requirement is 390 km for a household's first car and 220 km for a second car, which means that electric cars could be introduced as second cars while waiting for their operational range to increase [35]. A Swedish study shows that every other car in Sweden has a tow bar, which is high in an international perspective. Today, almost no electric cars allow for tow bars, and only some of the plug-in hybrids do so. For an increased use of electric vehicles, the Swedish Transport Administration believes that users either must adapt to new behaviors and services or that the manufacturers must make it possible to mount a trailer also on electric cars [20]. The Swedish Petroleum and Biofuels Institute (SPBI) has conducted a user survey that points to concerns about ethanol's possibly negative effects on the engine as an explanation why owners of fuel-flexible cars choose to refuel gasoline instead of ethanol [3].

## 4.1.8 Knowledge and information are important

Society's acceptance of new fuels is an important piece of the puzzle. One step in achieving this is that the consumer has access to clear and relevant information about the sustainability of fuels. The statutory origin marking of electricity already exists today, and the corresponding labeling for fuels will be introduced in Sweden from first of January Special conditions for pure biofuels

A Swedish study has studied barriers to vehicle systems that use high-ratio mixed and pure biofuels., the study showed that the two most important factors for ensuring the legitimacy of high-ratio biofuels are a competitive price in combination with sufficiently long-term policy instruments. If these are removed too quickly, it gives a political signal that they no longer believe in the fuel, and then an uncertainty spreads among all actors in this market [32]. A report on public procurement of environmental vehicles shows that financial incentives are not enough or that the vehicles are included in lists of cars that may be purchased. Instead, clear political goals and political backing combined with a clear incentive structure and information are examples of factors that are of great importance for a functioning green public procurement [36]. For more information on specific policy instruments, please see section 4.1.2, below. Moreover, pure biofuels often have different demands on separate infrastructure to reach the consumers and the incentives to establish such infrastructure needs to be considered for increased usage of pure biofuels, in contrast to drop-in biofuels.

## 4.1.9 Recharging infrastructure

The main part of the recharging of an electric vehicle is at home or at the final destination. But to enable good mobility and to build trust for electric vehicles, there is also a need for public stations for fast recharging. There is the possibility of state investment support for recharging infrastructure, and other regional and local climate measures, via Klimatklivet (see section 4.1.2.3 below for details) which is handled by the Swedish Environmental Protection Agency. Today, there are over 1,800 public recharging stations in Sweden equipped with just over 7,900 recharging points. More than 600 recharging stations of these are for fast recharging with direct current. The Swedish Energy Agency's analysis of existing recharging infrastructure, and recharging stations granted within Klimatklivet, shows that the infrastructure is considerably denser in southern Sweden than in the north, both for normal and fast recharging [37].

During the spring of 2018, the Swedish Transport Administration carried out a government commission to investigate how the lack of fast recharging along major roads can be remedied and also propose opportunities for the state to promote business models for expansion. The result of the investigation shows that it is mainly lacking fast recharging in Norrland's inland (the northern non-coastal regions of Sweden) but also in parts of Värmland, Gävleborg and Småland (all more southern but relatively remote locations). Proposals to remedy this are to either increase and target the investment support to these areas or that the state points out road sections and then carries out a reverse auction where players may offer to build fast recharging to the lowest state support. The investigation also found that the operating cost for fast recharging stations is significant and that some form of state support may also be needed there [37].

## 4.2 Analysis of current policies

### 4.2.1 Policies on the EU-level

#### 4.2.1.1 The renewable energy directive (REDI)

RED stipulates that Member States should achieve 10% renewable energy in the transport sector 2020 [38]. The directive further states that a maximum of 7% may come from crop-based fuels. Fuels produced from waste and residual products may be double counted against the target. From 2015, a non-binding target of 0.5% advanced fuel [39] was also introduced. Another important change introduced in 2015 was a reporting requirement regarding indirect land use changes from biofuels, ILUC. Advanced biofuels refer to fuels produced from raw materials listed in the Renewables Directive [39] and any other raw materials for fuels identified by each Member State as waste, residues, non-food cellulose or materials containing both cellulose and lignin.

RED includes sustainability criteria for biofuels and liquid biofuels. These have been implemented in Sweden via the Act on Sustainability Criteria for Biofuels and Liquid Biofuels [40]. The sustainability criteria [38, 39] mean, among other things, that:

- GHG emissions from biofuels in existing plants before October 5, 2015 need to lead to a reduction of 35% and at least 50% from 2018 (estimated value from a life cycle perspective). For plants taken / commissioned after 5 October 2017, a reduction corresponding to 60% applies.
- It is forbidden to cut down natural forest.
- It is forbidden to grow raw materials in natural and non-natural grasslands with high biodiversity, in wetlands and peatlands, and in areas with high carbon layers.

For the Swedish part, these criteria must be met for domestic players to be able to be granted tax reduction, have the right to obtain electricity certificates for their renewable electricity production and be included in a quota obligation system for biofuels, etc.

#### 4.2.1.2 The revised renewable energy directive (REDII)

[41]

The original renewable energy directive (2009/28/EC) establishes an overall policy for the production and promotion of energy from renewable sources in the EU. It requires the EU to fulfil at least 20% of its total energy needs with renewables by 2020 – to be achieved through the attainment of individual national targets. All EU countries must also ensure that at least 10% of their transport fuels come from renewable sources by 2020.

In December 2018, the revised renewable energy directive 2018/2001/EU entered into force, as part of the Clean energy for all Europeans package, aimed at keeping the EU a global leader in renewables and, more broadly, helping the EU to meet its emissions reduction commitments under the Paris Agreement. The new directive establishes a new binding renewable energy target for the EU for 2030 of at least 32%, with a clause for a possible upwards revision by 2023.

Under the new Governance regulation, which is also part of the Clean energy for all Europeans package, EU countries are required to draft 10-year National Energy & Climate Plans (NECPs) for 2021-2030, outlining how they will meet the new 2030 targets for renewable energy and for energy

efficiency. Member States needed to submit a draft NECP by 31 December 2018 and should be ready to submit the final plans to the European Commission by 31 December 2019. Most of the other new elements in the new directive need to be transposed into national law by Member States by 30 June 2021.

The Directive 2009/28/EC (REDI) specifies national renewable energy targets for 2020 for each country, taking into account its starting point and overall potential for renewables. These targets range from a low of 10% in Malta to a high of 49% in Sweden. EU countries set out how they plan to meet these 2020 targets and the general course of their renewable energy policy in national renewable energy action plans.

Biofuels and bioliquids are instrumental in helping EU countries meet their 10% renewables target in transport. The Renewable Energy Directive (in both of its versions) sets out biofuels sustainability criteria for all biofuels produced or consumed in the EU to ensure that they are produced in a sustainable and environmentally friendly manner. Companies can show they comply with the sustainability criteria through national systems or so-called voluntary schemes recognized by the European Commission.

In REDII the goals are set for the individual fuel suppliers and not (like in REDI) for the member states. The new targets and obligations in REDII include:

- A Union binding target of 32% by 2030
- Increase the share of RES supplied for heating and cooling by an indicative 1.3% as a yearly average for the periods 2021-2025 and 2026-2030
- Obligation on fuel suppliers to ensure the share of RES supplied for final consumption in the transport sector of at least 14% by 2030

#### 4.2.1.3 The fuel quality directive (FQD)

The FQD includes requirements for reduced GHG emissions for fuel suppliers for the energy they deliver for transport corresponding to 6% 2020 [38]. FQD also sets maximum permissible limits for the incorporation of biofuels. State aid rules and the Energy Tax Directive [42, 43] regulate the lowest tax levels for fuel. This limits the ability of individual Member States to promote renewable fuels through tax reductions or exemptions [44], see for example section 4.1.2 on Swedish policy instruments.

#### 4.2.1.4 Investment and research support

Investment and research support, e.g. within the framework of NER 300 and Horizon 2020, are distributed within the EU to promote renewable fuels. For example, the Swedish gasification project Bio2G, which was planned to be constructed on a commercial scale, was approved for support from NER 300. NER 300 can cover up to 50% of the investment [45]. Horizon 2020 is more focused on new technologies that require further research and development.

## 4.2.2 Swedish policies

This section discusses policy instruments directly aimed at, in one way or another, increase the usage of ART-fuels in Sweden. There are, however, also other policies in effect that influences for example the behavioural patterns of individuals, and that may relate or have some effect also on energy usage and consumption within the transport sector. Such policies are not explicitly discussed in this report.

#### 4.2.2.1 Fuel taxes and reduction obligation

**Fuel taxes** consist of CO<sub>2</sub> and energy taxes. CO<sub>2</sub> tax was introduced in 1991 and energy tax has been around since the 1950s. Fuel is also charged with VAT, 25% (on fuel cost and on fuel tax). The fuel taxes can be a powerful instrument. By taxing fossil fuels, tax revenues are obtained and incentives for renewable fuels are also created. The CO<sub>2</sub> tax is seen as the primary means of achieving Sweden's climate target by 2020 and the interim target until 2030 in a cost-effective way [51]. The tax is paid per kg of CO<sub>2</sub> emissions, and is calculated based on the content of fossil carbon in the fuel.

Pure biofuels and high-blends are currently exempt from CO<sub>2</sub> tax and for energy tax reductions or exemptions are granted. The reduction for biofuels is governed by EU state aid rules. If the reduction means that the production cost (including distribution and infrastructure) of a biofuel becomes lower than its fossil equivalent, illegal state aid is deemed to exist. The Swedish Energy Agency therefore checks this ratio twice a year and the government adjusts the tax reduction if necessary. Such adjustments have occurred on several occasions, which has created an uncertainty for market players [44]. Sweden has been approved by the EU Commission for tax exemptions for biofuels until 2020.

At the introduction of the reduction obligation on July 1, 2018, the tax system for low-blend biofuels and fossil fuels changed (see description below), while current systems will continue to apply for high-blend and pure biofuels. This is also proposed by the Swedish Energy Agency in a supporting report for the reduction obligation [55].

**The reduction obligation** specifies how much GHG emissions reductions that fuel distributors must achieve through incorporation of biofuels into gasoline and diesel. The duty does not cover gaseous fuels, high-blends or pure biofuels. The emission reductions specified separately for gasoline and diesel follow a reduction curve until 2030. For the years 2018-2020 there are certain levels for the duty and in 2030 an indicative reduction has been set at 40% [51]. The emission reductions indicated by the duty levels for the years 2018–2020 correspond to 2.6%, 2.6% and 4.2% for gasoline, respectively, and for diesel 19.3%, 20% and 21% respectively [51]. The Swedish Energy Agency is currently reviewing this system and will publish a report with conclusions in June 2019.

The reduction obligation can be seen as a retake of the quota obligation that was proposed but which was never introduced in Sweden due to of EU state aid rules. Two important differences can be seen between the reduction and quota obligations. First, the reduction obligation is expressed as reduced GHG emissions and not as a volume-based biofuel ratio. Secondly, low-blend biofuels will be subject to energy and CO<sub>2</sub> tax, regardless if they are sold within the system or not. [12]

If a distributor does not fulfill the reduction obligation, it is obliged to pay a reduction duty. The reduction duty is a maximum of SEK 7 / kg CO<sub>2</sub> equivalents. According to Furusjö et al. [30] the fee is high enough to create the intended incentives to fulfill the reduction obligation via blending-in of biofuels and not through payment of the fee. According to the Swedish Energy Agency no distributor has missed the obligation during the first 6 months of the scheme (May 2019).

In 2019 a governmental inquiry was presented about bio jet fuel [9]. This report suggests a reduction obligation scheme for jet fuel suppliers in Sweden. The reduction level will increase from the equivalent of approximately 1 volume percent in 2021 to the equivalent of approximately 30 volume percent in 2030. According to the report, the cost of meeting the obligation would initially be low and then rise, as a greater level of blending would be required. However, the cost increase would be curbed as biofuels are expected to become cheaper as supply increases and technology improves, and energy efficiency measures will continue, reducing the need for fuel.

#### 4.2.2.2 Policy instruments for the vehicle fleet

**Bonus-malus.** The bonus-malus instrument was adopted in 2017 and entered into force on 1 July 2018. Bonus-malus provides clear incentives for car buyers. Cars with low or no CO<sub>2</sub> emissions at the exhaust pipe receive a premium (bonus) and cars with higher emissions receive an increased vehicle tax (malus). Bonus is set at SEK 60,000 for cars with zero CO<sub>2</sub> emissions. The bonus decreases linearly to SEK 10,000 for cars that emit 60 g CO<sub>2</sub> / km. CNG/CBG cars are given a fixed bonus of SEK 10,000 [51]. In previous proposals for bonus-malus, gas cars ended up on the malus side, which sent unclear signals to the market [44]. Bonuses are paid six months after purchase to prevent subsidized cars being exported [51].

Malus is given during the car's first three years of use and is in relation to the car's estimated emissions per kilometer during mixed driving: SEK 82 / g CO<sub>2</sub> between 95 and 140 g CO<sub>2</sub> / km. For vehicles that emit more than 140 g CO<sub>2</sub> / km, malus corresponds to 107 SEK / g for every gram over 140. After the first three years, malus drops, and the amount corresponds to SEK 22 / g emitted per kilometer over a limit value of 111 g / km. For gas and ethanol vehicles, no increased vehicle tax is charged, but they pay SEK 11 / g, which is emitted per kilometer above the limit of 111 g / km [51].

**Incentives for environmental cars and super-environment cars.** In order to promote the sale of cars with a lower environmental impact, premiums and other incentives have been directed towards cars that meet the definition of what is called the environmental or super-environment car. The definition and incentives aimed at such cars have varied over time.

**The environmental car premium** was introduced in 2007. The premium that went to private individuals amounted to SEK 10,000 and applied during the period from 1 April 2007 to 30 June 2009. Demand was greater than expected (a total of nearly 169,000 cars) and more money than what was budgeted had to be added [6]. The definition of environmental car was passenger cars that had the following characteristics:

- Emissions of no more than 120 g CO<sub>2</sub> / km in case of mixed driving on gasoline or diesel-powered car, or gasoline / electric energy or diesel / electric energy and max. 5 mg particles / km for diesel
- Max consumption of 9.2 liters of gasoline / 100 km in case of mixed driving if the car is wholly or partly operated with other than gasoline / LPG (ethanol, ethanol / electricity)
- Max consumption of 9.7 m<sup>3</sup> gas / 100 km in case of mixed driving if the car is wholly or partly operated with other than gasoline / LPG (natural gas / biogas, natural gas / biogas / electricity)
- Max consumption of 37 kWh electric energy / 100 km for electric car belonging to Environmental Class El.

The environmental car premium was replaced in 2010 with a **vehicle tax exemption** for environmental cars, which meant that environmental cars (with the same definition as before) were exempted from vehicle tax for five years [46]. This applied retroactively from 1 July 2009–2012. In 2010 and 2011, 40% of the passenger cars that were registered were environmental cars (which corresponds to around 120,000 cars). This can be compared with the environmental car share of approximately 15% at the introduction of the environmental car premium in 2007 [6, 47].

As of January 1, 2013, new passenger cars, light trucks and light buses (the latter two categories mean an extension compared to earlier) were released from vehicle tax for five years if the vehicle's

CO<sub>2</sub> emissions during mixed driving do not exceed a calculated maximum CO<sub>2</sub> emission in relation to the service weight of the vehicle. Cars that can be driven by ethanol or gas fuel (in addition to LPG) may have a higher CO<sub>2</sub> emission in relation to the car's weight. The consumption of electric energy by electric cars and recharging hybrids must not exceed 37 kWh / 100 km. The reason why not only the fixed limit for CO<sub>2</sub> emissions or fuel consumption is lowered is that even heavier cars equipped with energy-efficient technology must be able to be covered by the tax exemption. This design is also considered to stimulate the purchase of cars equipped with the most energy-efficient technology regardless of the weight of the car [6].

A so-called **super environment car premium** was introduced in 2012. With a super-environment car, a passenger car was intended to emit a maximum of 50 g CO<sub>2</sub> / km during mixed driving ([48, 49] on super environment car premium). For private individuals, the super-environment car premium is SEK 40,000 per super-environment car and for legal entities the super-environment car premium amounts to an amount which per super-environment car corresponds to 35% of the price difference between the super-environment car and the nearest comparable car, however, a maximum of SEK 40,000 [Hansson and Grahn, 2013]. The super environmental car premium was aimed to be technology-independent, however in practice this was not the effect it actually had. It instead pushed matured technologies and electricity more than other technologies.

In 2018 a bonus-malus system was introduced, see description above, which builds on the control instruments targeted at environmental and super environment cars.

#### 4.2.2.3 Other policy instruments

According to the so-called **pumping act** [50], all points of sale of gasoline / diesel (above a certain volume from 2006) must also provide at least one renewable fuel. The Act led mainly to an increase in fuel stations for ethanol (E85) and was supplemented in 2006 with a contribution to sales outlets for fuel for investments in pumps other than ethanol [46]. This contribution primarily benefited an expansion of vehicle gas filling stations [6, 44]. In the referral round of this policy, all agencies and other referral bodies were skeptical to the proposed policy and the final implemented version of the policy was in many ways a political compromise. The intention was to implement this policy in conjunction with other complementing instruments to achieve a strong effect, however the only one left from that package today is this policy.

Various forms of **investment support** have also occurred. The climate investment program Klimp comprised just under two billion SEK 2003–2008 as support for climate investments that reduce GHG emissions. The money has gone to municipalities and other local actors. Almost 20% of the total funds disbursed went to the production and upgrading of biogas and an additional 8% went to biogas systems for vehicles (mainly gasoline stations and gas pipelines) and investments in gas vehicles [6].

**Klimatklivet** (The climate-stride) was introduced in 2015 and supports climate investment at local level for municipalities, companies and associations. For 2016–2018, SEK 600 million per year has been allocated. The investments will reduce GHG emissions and are awarded in competition based on their potential climate benefit. The support can be sought by both public and private organizations and has gone to e.g. biofuels and electrification of transport. For example, it has contributed to dedicated recharging points for electrical busses and approximately 9,000 new recharging points for electric cars [51].

**Public procurement** can also be a powerful instrument. At the national level, requirements are imposed on the authorities' purchasing and leasing of passenger cars. Between 2004 and 2009, 85%

of the total number of passenger cars that an authority purchased or entered into leasing agreements during a calendar year would be environmental cars, with some exceptions for emergency vehicles for example [52]. The authority would also ensure that the environmental cars that were able to run with alternative fuels were operated like that as far as possible. From February 2009, all passenger cars that an authority buys or enters into leasing agreements to be environmental cars (according to the current applicable definition) still with certain exceptions [6, 53]. However, all agencies do not fully follow these requirements and there are no clear penalties for not doing so.

At **local level**, in municipalities and county councils, various types of policy instruments exist to promote the introduction of renewable fuels. Public procurement through the county council for public transport has, for example, been a powerful instrument. In Stockholm and in several other counties, the entire public transport bus fleet is now fossil-free [54]. There is a premium in place for investments in electrical busses which have had effects on the buss-fleet in cities. Municipalities have also provided exemptions for environmental cars from parking and congestion charges. Moreover, local authorities have the possibility of implementing environmental zones in certain areas. Even though it has not been implemented anywhere yet, the environmental zone 3 has very strict demands for which vehicles may be used inside it. These exemptions have been gradually abolished as the number of environmental cars increased [44]. The effects are generally greater close to the implementation of such efforts and then tend to stabilize on a slightly higher level, although lower than before implementation.

## 4.2.3 Analysis of policy instruments

### 4.2.3.1 Evaluation of the policy instruments effect in different phases of development

A Swedish study from 2018 analyses different policy incentives in order to understand their effects on the development of biofuels, in which development phase they have effect and specifically, how the policies contribute to innovation, up-scaling and/or proliferation. The national biofuel use, and domestic production are briefly described, and it is commented whether the instruments seem to favor any particular type of fuel, e.g. biofuels with large climate benefit [12].

How the Swedish policy instruments affect different phases in the development of biofuels (research and development, demonstration, upscaling, and dissemination) are summarized in Table 5. The table also indicates whether any specific direction for development is pointed out with the means of control or what level of ambition / objective it corresponds to etc. Vision and objectives are here considered as a form of policy instruments.

Table 5. Compilation and analysis of policy instruments in Sweden. Green: Strong governance (The instrument has a direct and significant effect on development), Yellow: Weak governance (The instrument has an indirect and lesser effect on development), Orange: Weak / no governance, Red: No governance. Source: [12].

Policy instrument	Research and Development	Demonstration and Pilot plants	Scale-up	Dissemination
Reduction obligation. Indicative reduction of 40% to 2030	None	None	Strong	Strong, Mature technologies with high GHG-performance
CO <sub>2</sub> tax exemption and energy tax reduction for high-blend biofuels and biogas	None	None	Strong, Have resulted in up-scaling of HVO and biogas	Strong
National vision and target	Weak	Weak	Weak	Weak
Sustainability requirements	None	None	Weak, Development is focused to waste and residual from forest	Strong, Technologies that can be double-counted.
Public procurement of transport	Weak, some effects on buss development.	Weak / none	Weak	Weak, Towards mature technologies
Other R&D: The Ethanol programme, Demonstration support, etc.	Strong	Strong	None	None
Other policies for fuels: The Pump-act, Klimp, Klimatklivet, Urban environmental agreements.	None	None	Weak, Mostly related to biogas.	Strong, Towards mature technologies
Other policies for vehicles: Bonus-malus, super-environmental cars, etc.	None	None	None	Strong, Towards mature technologies and electricity



#### 4.2.3.2 Evaluation of policy instruments

Within this study a workshop has been performed together with experts and representatives from the two Swedish agencies responsible for policy incentive development, implementation and analysis directed towards ART-fuels; The Swedish Transport Administration and The Swedish Energy Agency. The results from this workshop are summarized in table 6 below and is an evaluation of recent implemented policy instruments in Sweden.

The evaluation is set up to elaborate on, and answer the questions:

- What have the motives been for the respective policy instrument?
  - Why was it introduced?
  - What goals motivated its introduction?
- What effects have been observed from the introduction of the respective policy instrument?
  - Has the intended goal been fulfilled?
  - Have other effects been observed?
    - Predicted
    - Not predicted
- What lessons can be learned from the introduction of the respective policy?

Table 6. Results from the evaluation of policy instruments carried out together with experts from the Swedish Transport Administration and the Swedish Energy Agency.

Policy instrument	Motives	Effect	Lessons learned
<b>The reduction obligation</b>	Long-term frame-work to reach a fossil-free vehicle fleet. The 70% reduction-target. The problem was previously the short-term tax exemptions.	Reduced climate impact from gasoline and diesel. No one has missed the level so far. Those who produce fuel have shifted the focus from high-mixed and pure biofuels to blending into gasoline and diesel. Has suppressed the willingness to invest for alternative fuels which imply a risk of not daring to invest in clean fuels. Increased prices at pump - probably as a result of suppliers taking height for the reduction obligation. Non-anticipated effect: volumes decreased towards the end of the year 2018. It is obvious that there is a roof.	Hard to profile when mandatory (both for producer and buyer). Difficult to go beyond legal requirements. Becoming similar to electricity. Annex IX in RED raw materials will be used due to their better performance.
<b>CO<sub>2</sub> tax exemption and energy tax reduction for high-blend biofuels and biogas</b>	Started as an exemption for pilot-plants, like a production support. Purpose to reduce emissions and promote domestic production of biofuels. Drifted towards general tax-exemption for biofuels. Connected to EU tax-regulations.	High effect on usage but low effect on domestic production. The question of over-compensation is difficult. Peculiar that it becomes bad with cheap biofuels. Capricious system.	EU view on tax exemption challenging. Another system may be needed. Hard to include high-blend and pure bio fuels in the reduction obligation. Has not affected production.
<b>Sustainability criteria</b>	Fulfil the requirements in RED to head off the worries of non-sustainable biofuels.	Represents a way to compare biofuels and a way to measure emissions from biofuels. Vacuums the market for residuals and wastes that are used for other purposes.	Unpredicted effects can arise that need to be adjusted for. The wording of the regulation effects the actions of the market to a large extent. Rapid and frequent changes make market-actor lose faith in the instrument.
<b>The Pump Act</b>	Make biofuels available at filling stations.	A lot of E85 pumps was installed. Few other biofuels benefitted (CNG). Low turn-over filling stations have gotten alleviations. Initially resulted in many biofuel pumps and vehicles, and large biofuel usage. Has significantly decreased over time. FFV (flexi fuel vehicles) now mainly run on gasoline.	In conjunction with complementary instruments, it was effective in rapidly increasing the number of pumps (E85). Despite technology-neutral policy instruments, it became a strong technology-driver. Driver for the cheapest solution. Instruments must be put in a context where (at least) vehicles, infrastructure and usage are included - and how it should be phased out. This was initially in place in Sweden (tax exemption on CO <sub>2</sub> tax, congestion tax, parking benefits etc) but these have been reviewed (locally, nationally and the EU).
<b>Investment support i.e. Lip, Klimp and</b>	Reduce emissions through investment support. Increase the pace of change.	The most cost-efficient solutions have been rewarded (Klimatklivet). This also means that mature solutions benefit more.	Less cost-effective than general CO <sub>2</sub> tax and therefore criticized. Difficult to support potential

Klimatklivet (the climate-stride)		long-term solutions (Klimatklivet)	
<b>Public procurement</b>	Public authorities and municipalities etc. have goals and public procurement is an effective way to execute them. Trickle-down of national climate targets	Dissemination of experiences between municipalities and other actors, including individuals. Economy, practical experience (e.g. gas refuelling). Spreads over time. Creates a market for biofuels.	Agree on common definitions e.g. environmental vehicle. Good driver early on to bring in new technology.
<b>Bonus-malus</b>	Accelerate the deployment of cars with lower CO <sub>2</sub> emissions, lower energy use and electrification. Fossil-independent vehicle fleet and later the 70% target for 2030.	First half of the year mainly increased registration of BEV. The fact that PHEV did not increase can be related to the introduction of WLTP. No effect on CO <sub>2</sub> emissions of non-rechargeable vehicles so far. Drives the introduction of new technology. Makes it easier to tighten EU requirements.	Malus seems to be too low as the effect on CO <sub>2</sub> emissions on non-rechargeable cars has not been realized. Risk for subsidizing car ownership. Make sure the cars remain in Sweden.
<b>Super environmental car premium</b>	Stimulate the introduction of rechargeable vehicles. Fossil-independent vehicle fleet.	The start of the introduction of electric cars and recharging hybrids. Also created medial debate that certainly stimulated the introduction. Impact on both individuals and organisations. Technology-neutral but the result nevertheless BEV and PHEV.	Supplementary support for recharging was missing.

## 4.3 Possible additional measures

### 4.3.1 Policy implications

Policy instruments for biofuels need to handle the competition against fossil fuels. The policy also needs to handle the potential technical risk of new innovative solutions e.g. cellulose-based fuels, so that these solutions are given adequate chances to develop. A combination of general policy instruments, such as a differentiated CO<sub>2</sub> tax, or a quota or reduction obligation, in combination with more specific instruments, for example an off-take agreement, which creates the conditions for a scale-up of immature technology. The alternative to combining different types of specific and general policy instruments is to force innovative solutions through large subsidies and separate quotas with high penalties. This is however not in accordance with EU-regulations be a expensive, system. [12]

In addition to the technological and oil price risks, politics naturally needs to deal with the political risk. In practice, this means that the systems that are implemented must apply to individual operators over at least a ten-year period [45]. Adjustments to individual quotas need to be made continuously, but the long-term goal must be fixed. The same applies to off-take guarantees where there is a need for long-term agreements for at least a ten-year period to ensure that investors get a return of their investment [45].

To ensure that the policy instruments that are introduced to stimulate biofuels really achieve the GHG reduction and climate benefits that are intended, control instruments must also be introduced. This is the reason for the sustainability criteria that exist today. Since sustainability covers both environmental, social, and economic aspects and that in many cases the impact cannot be generalized, this poses a challenge. [12]

A recent study investigates the legal possibilities that Sweden may have to ban vehicles propelled by fossil fuels in relation to what governance different authorities have over the Swedish vehicle fleet. In several countries within the EU and the EEA there are proposals that new sales of cars driven by fossil fuels should be banned from 2025, 2030 or 2040. This is presented in different ways in Denmark, the Netherlands, the UK, France and Norway. In Sweden, this is promised in the recent 2019 January agreement between the government, the Center Party and the Liberals. The conclusion from the Swedish study is that Sweden cannot decide on a ban on the sale of new gasoline and diesel-powered cars or fossil fuels. The analysis shows that Sweden, on the other hand, can impose higher climate requirements on fuel, as such space is provided in the EU regulation. [56]

This means that it may be possible to strengthen the Swedish reduction obligation so that in practice the result will be a phasing out of fossil fuels. But if the EU concludes that such a reduction obligation would constitute a trade barrier, then it is not possible. The existing legal obstacles are thus mainly EU rules. [56]

### 4.3.2 Prerequisites for efficient implication of policy and policy recommendations

Based on findings drawn from studying how different countries have tried to implement policy, a number of general prerequisites have been spotted that need to be fulfilled for an efficient mix of policies to be applied on biofuels [12]. This includes the following aspects:

- Long-term and high ambitions. Without clear and long-term climate ambitions with specific targets for total GHG reductions from the transport sector, all instruments and initiatives will risk becoming ineffective. A low set ratio thus risks becoming a ceiling in climate policy and a low carbon tax with many exceptions creates weak incentives for investments.
- National industrialization ambitions should be clarified. All types of industrialization ambitions should be clarified and not "hidden" in the general climate policy. If there are such goals, it will affect and place higher demands on which policy instruments are to be chosen.
- There is a need for a long-term policy instrument that acts as a general "engine" in climate policy. The literature often indicates that a high CO<sub>2</sub> tax is the best alternative but because of EU regulation and the political difficulties in raising taxes, most countries have opted for a quota or reduction obligation for the development of biofuels.
- A combination of policies is needed to lead to innovation and maximum climate benefit. The "engine" should therefore be supplemented, not replaced, with support systems with so that the mix consists of support (technology push), market-driving (technology pull) and system-wide instruments whose purpose is to adapt existing laws and regulations to meet the goals.
- Support for off-take via a price premium or a separate quota may be needed. In order to enable technologies with great potential in the long term, support for scaling up and disseminating new technologies may be needed, e.g. for demonstration facilities. It may also be necessary to supplement with a separate quota and / or off-take guarantees for particularly desirable solutions.

- All fuels should be treated according to a "polluter pay principle". Also, sustainability criteria should be designed for the long term and include as many aspects of sustainability as possible.
- The effect of a specific policy instrument can be very different depending on how it is implemented and which other instruments it interacts with. There is therefore a need to strengthen knowledge and research on implementation and design in combination with the need to strengthen the regulators' knowledge of the specific area.

### 4.3.3 Recommendations

The Swedish climate policy council have listed several specific recommendations on possible policies that may be implemented on different levels of society to achieve the desired effects on biofuel proliferation in Sweden [57]. The rationale behind these recommendations are specified in their recent report.

- Eliminate the exemptions in the carbon dioxide tax that remain for activities outside the trading system.
- Proactively work within the EU for tightening up the trading system and use cost-effective national instruments for reducing emissions from Swedish plants within the system.
- Introduce legislation that gives the government the right to verify the establishment of activities that counteract the possibilities of achieving the national climate goals.
- Decide on a timed action plan to reach fossil-free transport beyond the 2030 target.
- Make the transport policy objectives compatible with the climate goals.
- Strengthen regulations and processes for community planning that reduce car dependency.
- Consider different conditions and equalize negative distribution policy effects, for example between the city and rural areas.
- Prepare a reform of road traffic taxation based on increased electrification and use of autonomous vehicles, which at the same time promotes regional justice.
- Stop subsidizing car ownership, driving and parking.
- Strengthen the municipalities' mandate and tools to promote fossil-free transport.
- Accelerate electrification of road transport throughout Sweden.
- Establish a deadline for selling fossil fuels.
- Increased steering towards more climate-efficient vehicles.

## 5 Final remarks

Sweden has the potential of reaching the targets set for 2030 and 2045 but it requires substantial investments in production, infrastructure and policy, linked to increased ART-fuel implementation.

The policy system to be used for this implementation needs to be applied long term. The system also needs to be transparent and predictable both for the market and for the consumers. If this is not the case, and if rapid or frequent changes are made, market-actors may lose faith in the instruments. Many of the policies implemented this far have tended to promote mature technologies. If the goal is to also promote more novel solutions efforts towards this needs to be included in the design of the instruments. Instruments must be put in a context where (at least) vehicles, infrastructure and fuel usage are included - and how it should be phased out. Furthermore, the strength of the individual policies must be thoroughly analysed so that they have the postulated effects. Even so, unpredicted effects may still arise that need to be adjusted for along the way. Moreover, the cost-effectiveness of the instruments needs to be compared and considered before implementation so that the efforts are put where that can have the strongest effect.

The need for biofuels can be greater for e.g. heavy trucks than for passenger cars, as the latter may have easier to switch to electrification. On the other hand, the turnover time is shorter for e.g. buses and trucks than for passenger cars. Particularly low -blend fuels (e.g. ethanol and FAME) and drop-in fuels (e.g. HVO) have many advantages: they do not require new vehicles, no new infrastructure for distribution and the blending in fossil fuels can be based on the current availability on different occasions.

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# Appendix A - Scenarios

Based on the literature and given different assumptions, the potential production capacity of biofuels in Sweden is somewhere between 15 and 25 TWh in 2030 [2, 5-10]. The expected biofuel demand for domestic transport on the other hand is expected to be between 15 and 30 TWh in 2030 with 4 TWh for aviation [8-10, 20-28]. Biofuels will also be required in other areas, for example off-road vehicles and shipping.

The Swedish Energy Agency and The Swedish Transport Administration repeatedly publishes scenarios or prognosis for future biofuel production and demand in Sweden. New updated versions will be available from the latter in the fall/winter of 2019. The forecasts from The Swedish Transport Administration postulates achieving the target of 70% emission reduction from road transport. The most recent assessments from the agencies are presented in the sections below.

## Swedish Energy Agency

The Swedish Energy Agency have produced five different possible scenarios for the future ART-fuel usage in the Swedish transport sector, all based on current policies:

- Reference EU (Referens EU)
- Lower GDP (Lägre BNP)
- Lower fossil prices (Lägre fossilpriser)
- Higher electrification (Högre elektrifiering)
- Reduction obligation (reduktionsplikt)

Common for the scenarios is that the energy consumption drops until 2030 and then increases to 2050. This is largely due to a more efficient use of energy in the passenger car fleet which is counteracted by a parallel growing demand for transport. In the passenger car fleet, there is a transition from conventional gasoline cars to diesel cars, rechargeable cars, electric hybrids and gas cars. This means that the vehicle fleet will then be renewed when many older, fuel-efficient gasoline cars are phased out. It also means a transition from internal combustion engines to more energy efficient electric motors.

In the scenario Higher electrification, a faster and increased transition to electrified vehicle types takes place both in passenger and heavy transports. In this scenario, pure electric cars and recharging hybrids are listed for 20 percent of the total passenger car fleet by 2030 and increases to just over 70 percent by 2050, to compare with other scenarios where clean electric cars and recharging hybrids account for just over 10 percent by 2030 and just under 30 percent by 2050 [59].

The expected increase in demand for transport in the scenarios applies to both passenger transport and freight transport. On the person side, the number of passenger cars in traffic increases by two million to 2050. The passenger transport work in road traffic more than doubled in all scenarios. The total freight transport work is doubled in the Reference EU scenario, and the mileage for light trucks increases to about three times the base year's level. The increase is due to that the strong relationship that has existed historically between population growth, economic growth and the demand for transport is also assumed to apply in the future. The results are largely influenced by how economic development is assumed to look in the future.

Economic developments affect, among other things, car ownership, the willingness to travel

For passenger transport and demand for goods and services (in the form of freight transport). Both passenger and freight transport increase during the scenario years. At the same time, for passenger transport the transition of the vehicle fleet, results in a decreased energy use for passenger transport until 2050. The energy use of freight transport is increasing however, until 2050. This explains why we see a small reduction in energy use until 2030 which then changes to an increase to 2050.

Most of the energy use for shipping and aviation is done abroad. The total energy consumption for foreign shipping and foreign aviation, increase by between 3 and 4 TWh during scenario years. The use of aviation fuel in all scenarios consists solely of fossil fuel as the Swedish Energy Agency believes that current instruments do not affect the increased use of biofuels in aviation. In the scenario EU Reference, the demand more than doubles for domestic air travel from the reference year 2016 to 2050 as a consequence of a strong positive economic development. For foreign air travel, there is almost a doubling of demand up to 2050 as a consequence of population development and economic development. Foreign aviation accounts for just over three times as much energy use as domestic aviation. This means that, despite the percentage increase being lower for foreign aviation compared to domestic use, energy consumption nevertheless increases most in absolute terms for foreign aviation. Within shipping, the fuel distribution of diesel oil, fuel oil 1 and fuel oil 2–6 is the same in all scenarios, a fuel distribution that does not change significantly over the scenario years when there are no significant instruments that provide incentives for a reduction. The limit values for sulfur emissions from shipping can be managed by partly changing the fuel, but also by the fact that ships can install scrubbers and thereby reduce their particle and sulfur emissions. However, the pace of development of total energy use in shipping and aviation differs between the scenarios based on the different economic growth rates in the scenarios. A higher economic development gives higher demand for transport while lower economic development gives the opposite effect. This generates different total fuel usage for these two modes of transport, both domestic and foreign.

In all scenarios, the renewable share of the transport sector is expected to increase throughout the scenario period. This is mostly done within road transport and is partly due the reduction obligation. In the aviation and shipping sector an introduction of renewable fuels is not expected based on current policy instruments. The use of road traffic also increases in all scenarios as a consequence of increasing the demand for passenger transport. When designing the scenarios, there were no instruments that deal with clean and high levels biofuels after 2020, therefore a cautious development is assumed for these fuels after 2020 and the volumes of pure FAME and pure HVO will only increase marginally during the scenario years.

The Reference EU, Lower GDP and Lower Energy Prices scenarios all have about the same renewable share that increases from just over 20 percent at base year 2016 to just over 30 percent to 2030. The largest increase in these scenarios is from the base year to 2020 when reduction levels have been decided in the reduction obligation, which means that the mixing levels of biofuels in gasoline and diesel is increasing. After 2020, the increase is mainly in the form of increased electrification and hybridization of the vehicle fleet. The share of renewable electricity is based on the electricity mixture of the supply-side and its development over the scenario years.

The largest increase in the amount of renewable fuels in the reduction obligation scenario occurs from 2020 to 2030 when a reduction level of about 40 percent emission reduction for gasoline and diesel is assumed to be achieved to 2030. This emission reduction will contribute to the goal of 70 percent lower GHG emissions in the transport sector to 2030 [60]. Thereafter, the increase is made by electrification

and hybridization of the vehicle fleet. In 2030, the reduction obligation scenario reports a renewable share for domestic transport of just over 51 percent. Renewable share in the scenario Higher electrification increases exponentially as more rechargeable vehicles and hybrid vehicles replace fossil-driven vehicles. In this scenario, the renewable share is just over 32 percent in 2030. The greatest difference between the scenarios is in road traffic where different development routes for the fleet produces different results in the distribution of fuel and also different rates of efficiency. This can be seen in Figure 4 which shows the total energy use for the five different scenarios (Reference EU, Lower GDP, Lower energy prices, Higher electrification and Reduction obligation) distributed on different fuels. For the first three scenarios, the distribution between the different fuels are the same since the new car sales are identical. For the scenario Higher electrification, there is a lower total energy use in road traffic and a considerably higher electricity consumption than the other scenarios. Electricity usage in the Higher electrification scenario stands in 2050 for just under a quarter of the road traffic's energy use. The reduction obligation scenario displays a significantly higher use of biofuels than other scenarios, mainly in the form of a higher use of HVO.

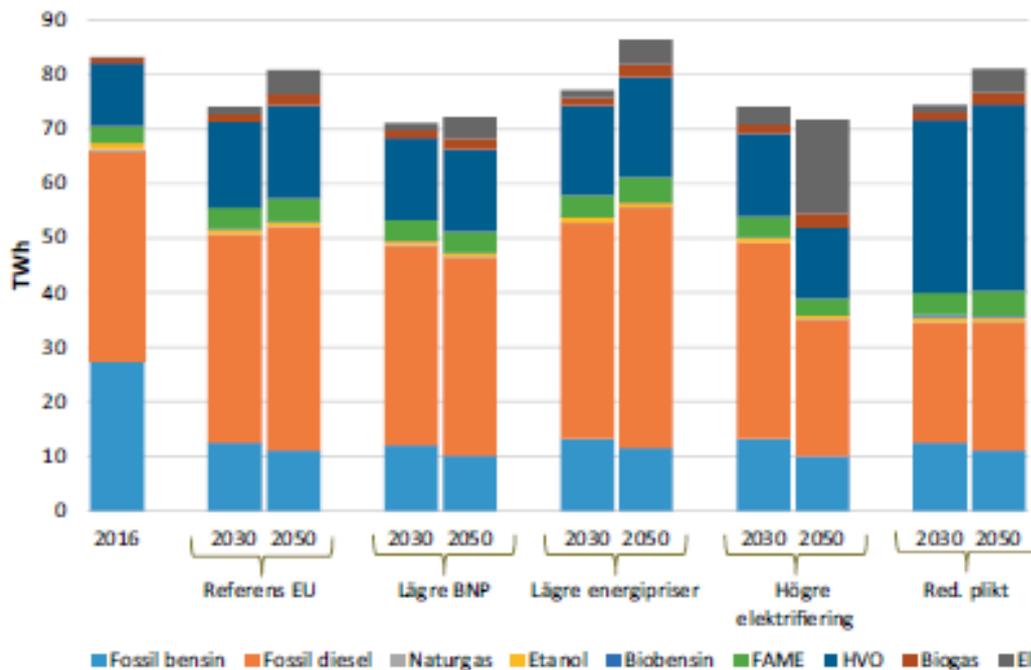


Figure 4. Energy usage for road transport. Distribution for all scenarios for 2030 and 2050 compared to the base year 2016, TWh.

## Swedish Transport Administration

The Swedish Transport Administration has identified three areas of action to reach the targets set for the Swedish transport sector in the future, namely:

- A transport efficient society
- More efficient vehicles and propulsion
- Transition to renewable energy

In their work on possible future scenarios [37, 61] the starting point is that the route chosen includes all these three areas of action. The reason is that the expected rapid transition requires multiple parallel measures for effects to vindicate. Moreover, to simultaneously pursue several tasks is a way to diversify and minimize risks. It is also important to pick a clear path that others may follow. Furthermore, given the facts that the resources needed for the transition are limited on a global scale e.g. raw materials for biofuels and batteries, vehicles and infrastructure, allowing a multitude of actions increases the chances for success. Finally, there are synergistic effects from the actions working in combination, primarily from a more transport efficient society.

### A transport efficient society – definition

According to the Swedish transport administration the target of a transport efficient society is defined as:

- 25-30 percent less passenger car traffic on a national level.
  - The decrease is primarily achieved in urban areas.
- Planning and development of buildings and transport systems aimed at decreased car usage
  - Densifying, central locations, close to public transport, mixed functions
  - Designed for walking, cycling, public transport, coordinated goods
  - Lower speed limits
  - Less space for parking and car related infrastructure
- Increased availability for travel-free options, walking, cycling and public transport
  - Doubled availability for public transport
  - Travel-free meetings
  - E-commerce
- The predicted increased need for transport of goods is covered by improved logistics, and shipping and railway.
- Increased coordination for decreased urban presence of trucks.
- Reliable railway system with increased capacity.
- Lowered costs and less time-consuming transshipment in docks and between trucks and rail.
- Longer and heavier trucks.

Policy incentives and measures to reach a transport efficient society according to this definition includes:

- Taxes on fuels
- Taxes on distance (kilometre-tax)
- Modified deduction for travel
- Parking fees



- Agreements on urban environment
- Environmental compensation for rail
- Eco-bonus for shipping
- Support for transshipping
- Planning

## More efficient vehicles and propulsion – definition

According to the Swedish transport administration more efficient vehicles and propulsion is defined as:

- 50 percent more efficient light vehicles compared to 2021.
  - Approx. 40-70 percent chargeable vehicles in new car sales
  - Approx. 15-30 percent of the vehicle fleet is electrified (including all cars)
- 30 percent more efficient heavy lorries compared to 2019.
  - Electrification of heavy transport lorries has a small potential until 2030 but significant possibilities beyond that, e.g. though electrical roads until 2045.
- 80-90 percent electrical city busses.
  - There is also large potential for city distribution vehicles.
- Lean driving, road design and lower speeds contributes with approximately 10-15 percent additional energy efficiency.

## Transition to renewable energy – definition

According to the Swedish transport administration transition to renewable energy is defined as:

- Vehicle efficiency measures, electrification and a transport efficient society makes the biofuels be enough for more
  - Less than half of the energy usage compared to 2010.
- Even so, it is challenging to meet demands for biofuels.
  - Sustainable Swedish production amounts to 15-30 TWh to 2030.
  - 10-15 TWh is needed for road transport.
  - Shipping, aviation and working machines together need more than 20 TWh.
- The current need for electricity in road transport is small compared to supply.
  - Swedish electricity production amounts to approximately 150 TWh.
  - 4-5 TWh is needed to 2030.
  - Long-term approximately 10-15 TWh.

Policy incentives and measures to reach a transition to renewable energy according to this definition includes:

- Reduction obligation
- Tax exemption pure biofuels
- Incentives for domestic Swedish production

## A scenario that combines all three actions

The Swedish transport administration have chosen to focus on a scenario that combines all three actions discussed above to reach the climate targets for 2030 and 2045. The projected effect on the GHG emissions of this scenario is showed in figure 5.

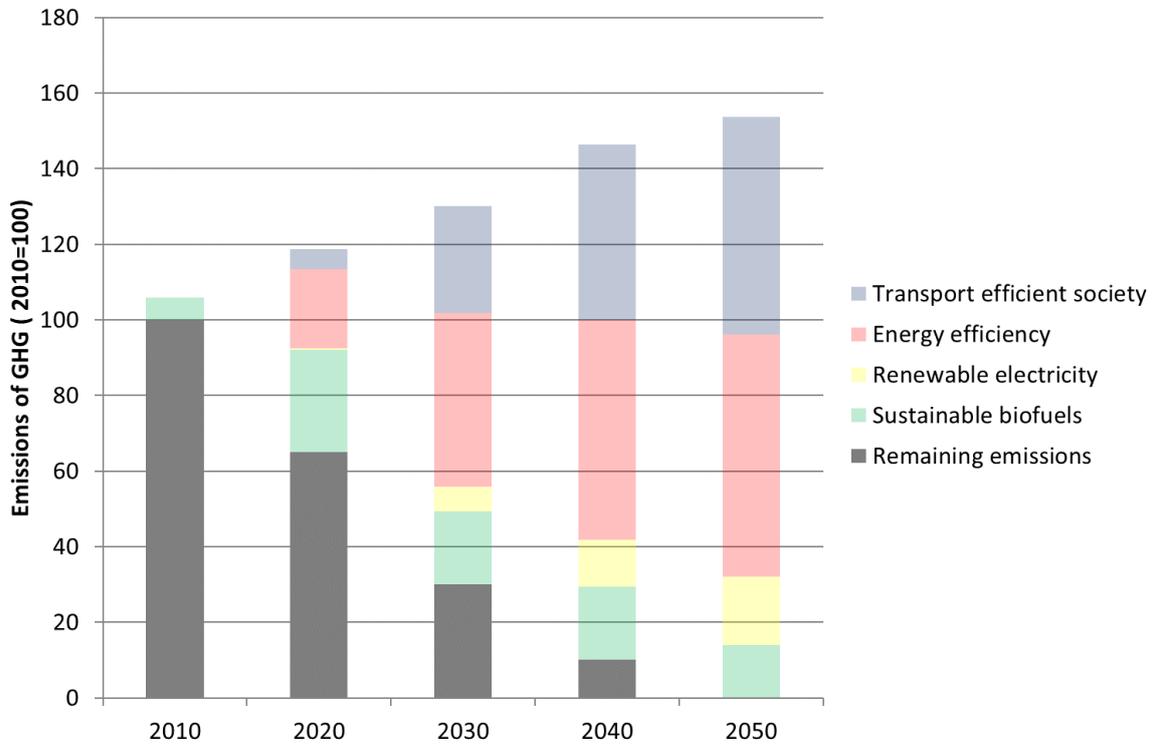


Figure 5. Emissions from Swedish road traffic in 2010, 2020, 2030, 2040 and 2050 (dark grey) and the impact from different measures (shown in different colours). The values are normalized and indexed against the reference year 2010 (100). Please note that emissions from biofuels are considerably lower than from fossil counterparts per mass-unit, hence values deducted from this graph cannot be directly translated to biofuel amounts.





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