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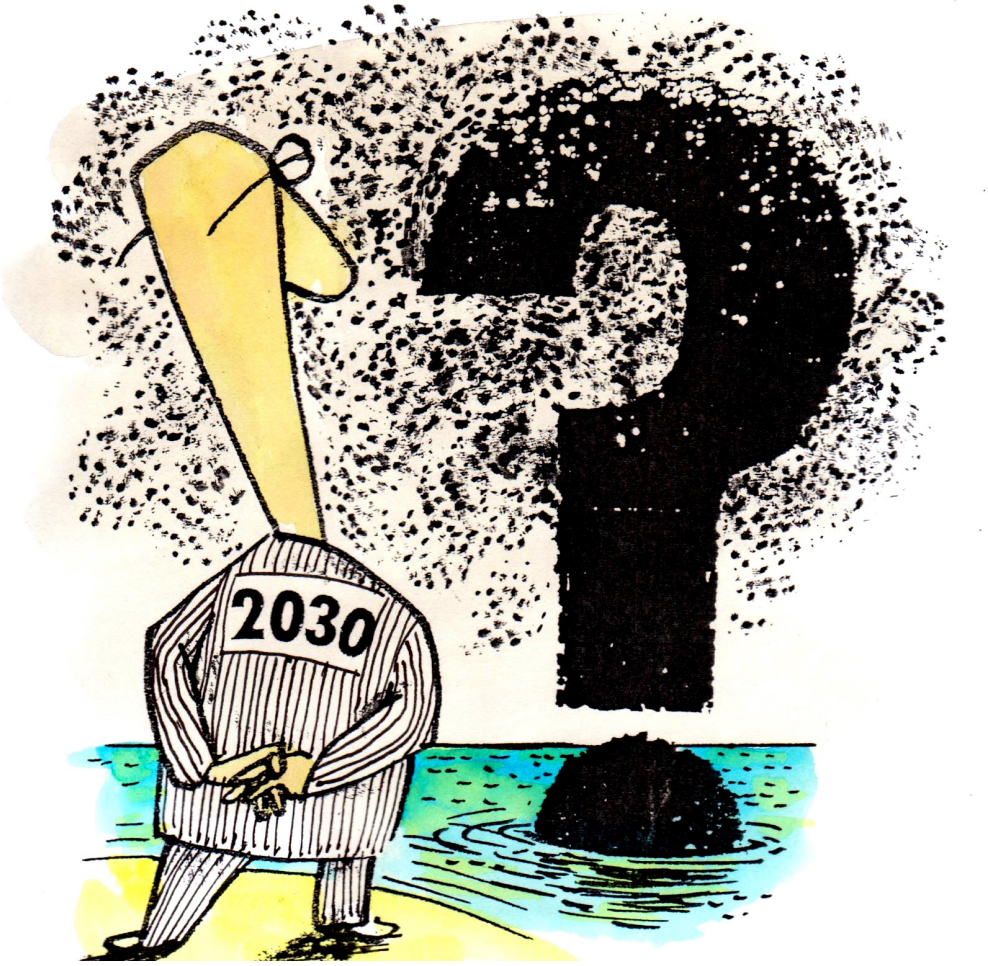
What will it take to phase out greenhouse gas emissions from road traffic in the Nordic-Baltic region by 2030–2035?

by Mats-Ola Larsson



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What will it take to phase out greenhouse gas emissions from road traffic in the Nordic-Baltic region by 2030-2035

What will it take to phase out greenhouse gas emissions from road traffic in the Nordic-Baltic region by 2030–2035?

Discussion paper by Mats-Ola Larsson

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Contents

Summary

This report was produced with support from AirClim – the Air Pollution and Climate Secretariat. It describes a conceivable scenario in which the climate impact of road traffic in the Nordic and Baltic countries is reduced to almost zero by the year 2035.

Strong measures will be needed if the Nordic and Baltic countries are to reduce emissions from road traffic quickly and radically. The socio-economic cost of replacing fossil fuels with fossil-free technology on a large scale is in many cases higher in the transport sector than in electricity generation, industry and heating. The reason it is important to phase out road traffic emissions before less expensive measures have been fully implemented in other sectors is that the transition would otherwise take too long if the aim is to help the world meet the 1.5°C goal.

The report describes the following measures that will be required in order to phase out the climate impact of road traffic by 2035.

- Greenhouse gas emissions from all new vehicles sold up to 2035 must fall sharply. Vehicles need to consume less energy than today.
- The majority of lightweight vehicles and heavy buses that are sold after 2035 need to have a high degree of electrification. Some heavy vehicles also need to be electrified.
- The fossil carbon content of fuel needs to be steadily reduced, so that greenhouse gas emissions fall sharply.
- After 2035, fuels must have net greenhouse gas emissions that are close to zero. A large proportion of these fuels must be able to be used in conventional diesel and petrol engines.
- Local rules and instruments are needed to accelerate the phasing out of vehicles with high fuel consumption, especially those that produce high emissions of pollutants that harm health and the environment.
- Regulations and support are needed to accelerate the expansion of charging points and refuelling facilities for new fuels, possibly combined with electric highways or inductive charging.
- Economic instruments are needed to dampen the growth of road traffic and make it more profitable to distribute goods with a high load factor and low emissions.
- Goods need to be distributed more efficiently in cities with the help of transport planning and improved traffic management.

If measures such as these are implemented promptly and consistently it will be possible to reduce greenhouse gas emissions from road traffic to zero by 2035. All the technologies already exist and are in use, but new fuels and vehicles need to be developed commercially. There are effective instruments and legislative opportunities in all the relevant countries. Several of the most effective measures must be decided jointly at EU level, or at least internationally. This means that strong political decisions are needed, and it is difficult to assess what social impacts may arise.

1. The task

This report describes the technical and political measures that would be needed to completely or almost completely phase out greenhouse gas emissions from road traffic in the Nordic and Baltic countries sometime during the period 2030–2035. For ease of reading this is written throughout the report as "by 2035", meaning that emissions must be reduced to almost zero during this period. The report covers Iceland, Sweden, Norway, Denmark, Finland, Estonia, Latvia and Lithuania. The task was to describe the measures that will be needed to achieve such a transition in these countries.

The report was written by Mats-Ola Larsson at IVL Swedish Environmental Research Institute. The work was carried out in spring 2017, with support from Reinhold Pape at the Air Pollution and Climate Secretariat (www.airclim.org), who commissioned this report as the basis for an information publication.

2. Limitations and explanations

IVL has not made any estimates of emissions, costs or likely reductions. Technologies and instruments have not been analysed specifically for the countries examined. Instead, the report should be seen as an outline of the types of decisions that need to be taken if road traffic is to become fossil-free within a couple of decades. The investigation is based on technologies and instruments that are relevant in Western European environmental policy. The automotive industry and the fuel industry are international markets. Much of the legislation is international and is often EU-governed.

The target period of 2030–2035 was chosen by the Air Pollution and Climate Secretariat. The secretariat wants to stress that the western world has a responsibility to phase out its emissions of climate gases rapidly enough so that temperature rise due to human action can be stabilised at 1.5°C above pre-industrial level, in compliance with the Paris agreement.

The Air Pollution and Climate Secretariat has also commissioned a report from another consultant on how fossil emissions from the energy sector and from industrial production in the Nordic and Baltic countries can be phased out during the same period. In this report we therefore assume that electricity generation and industrial production in the region will be fossil-free by 2035.

Some terms that are used in the report are defined below.

Emissions: The report refers only to greenhouse gas emissions. For ease of reading, the term "emissions" is occasionally used by itself, and refers in such cases to greenhouse gases.

Net emissions: This term is used to encompass greenhouse gas emissions from fuel that arise throughout the processes of extraction, cultivation, manufacturing, processing and transportation, incineration or re-use, including any reduction in climate impact through recycling and the like, or emissions from infrastructure, manufacture of vehicles and the like.

Almost zero emissions: A vehicle or fuel that produces very low greenhouse gas emissions compared with current technologies, up to a maximum of 10 percent.

Greenhouse gases: Emissions or discharges of fossil carbon dioxide, methane, nitrous oxide and other gases covered by the UN Climate Convention.

3. Transition is difficult, but achievable

It is more difficult to make road transport fossil-free than, for example, the energy sector and some sectors of manufacturing. It will require many coordinated international decisions and the active involvement of many industrial and economic stakeholders. Organisations and individuals require training and new skills in order to reach new decisions. Large global companies and organisations may lose out as result of the transition, and some may therefore try to delay measures, while future winners do not yet have the same economic resources and influence on jobs and at national level[1].

Millions of individuals, companies and organisations buy new vehicles every year. Vehicle owners often want to minimise risks and prefer existing vehicle technologies that they are familiar with and feel able to assess technically and financially. Vehicle manufacturers and fuel distributors need to be able to sell new and unfamiliar technologies on a large scale within a short period of time. This means that strong incentives and clear signals from government, the automotive industry and fuel distributors are needed to achieve the transition to fossil-free transport as rapidly as outlined in this report.

Misconceptions make it difficult to introduce economic instruments, however. One common misconception is that economic instruments have no effect on transport. Measures that are often challenged include road wear charges for commercial vehicles, parking fees, various taxes on vehicles and fuels as well as congestion charges. Many believe that the only effect of economic instruments is that vehicle owners lose money. Their argument is that there is a clear need for transport, and that need will be satisfied regardless of price. In fact, there is convincing scientific evidence that price actually does influence demand[2]. Flexible environmental taxes and charges can have a strong influence and be very cost effective. Some instruments can also be used to redistribute money from high-income earners (who on average drive more) to low-income earners (who use public transport more and may benefit if revenue is spent there). Nevertheless, misconceptions make it difficult and unpopular to use certain instruments.

Another problem is that the socio-economic cost of replacing fossil fuels with fossil-free technology on a large scale is usually higher in the transport sector than in electricity generation, industry and heating. Reducing emissions by switching to alternative vehicle technologies and fuels can be much more costly than other means of cutting emissions. This makes it especially important to use

1 Styrning mot nollutsläpp 2050 – LETS 2050 Slutrapport. LETS-rapport 2013

2 Andersson, M. et al. 2012: Ekonomiska styrmedel och dess påverkan på den individuella vägtrafiken med motorfordon – en kunskapsöversikt. Centre For Transport Studies, TKH.

methods that are as cost-effective as possible. The reason it is important to start phasing out road traffic emissions before other less expensive measures are fully implemented is that the transition will otherwise take too long, due to long lead times and the time needed to replace all road vehicles. If the Nordic and Baltic countries want to lead the way and contribute to a rapid and radical reduction of emissions in the western world, strong measures will be needed in all sectors, including the transport sector.

4. National variations

Road traffic in the eight countries accounts for between 10 and 30 percent of greenhouse gas emissions from each country. See table 1.

Table 1. **Greenhouse gas emissions in the Nordic and Baltic coutries, 2014 (figures are rounded).**

	Million tons CO_2-equivalents	Percentage from road traffic
Denmark	54	22 %
Estonia	21	10 %
Finland	61	17 %
Iceland	5	17 %
Latvia	12	24 %
Lithuania	19	24 %
Norway	53	19 %
Sweden	57	31 %

Sources: Norway; Norska SSB. Others: https://www.eea.europa.eu/data-and-maps/data/national-emissions-reported-to-the-unfccc-and-to-the-eu-greenhouse-gas-monitoring-mechanism-12

Biofuels account for about five percent of the energy supply for road traffic in the EU. See Table 2. Among the Nordic and Baltic countries, Sweden and Finland have the highest share, with about 20 percent biofuels, while Iceland and Estonia have less than one percent. Some fuels are double-counted in the EU figures and the actual consumption is slightly lower. The table shows the share of renewable fuels in 2014. Since then the use of biofuels has increased in some countries, especially HVO.

Table 2. **Percentage of renewable fuels used intrasport sector 2014.**

	Percentage of biofuel
Finland	21.6
Sweden	19.2
Denmark	5.8
Norway	4.8
Lithuania	4.2
Latvia	3.2
Iceland	0.6
Estonia	0.2
EU-28	5.9

Source: http://ec.europa.eu/eurostat/statistics-explained/index.php/Renewable_energy_statistics#Transport

Commercially available electric vehicles currently account for just a few percent of global sales. See Table 3. Overall there were a couple of million plug-in electric cars in the world at the end of 2016. A third of these were sold that year, which shows that electric cars are growing very rapidly. Norway stands out in the world as the country that has invested most in promoting electric vehicles, as can be seen in Table 3. There, 29 percent of new vehicles registered in 2016 were electric. In Sweden the corresponding figure was 4 percent and in the rest of Nordic and Baltic countries it was 1 percent or lower.

Table 3. **Number of cars, electric cars and plug-in hybrids (figures are rounded).**

	Millions of cars on road 2014	Newly registered cars 2016	Newly registered electric cars & plug-in hybrids	Percentage of new car sales	Newly regist-ered electric cars	Percentage of new car sales
Denmark	2.3	223 000	2 063	0.9 %	1 373	0.6 %
Estonia	0.5	23 000	35	0.2 %	35	0.2 %
Finland	2.6	119 000	1 431	1.2 %	223	0.2 %
Iceland	n/a	18 000	n/a	n/a	n/a	n/a
Latvia	n/a	16 000	43	0.3 %	25	0.2 %
Lithuania	1.2	20 000	64	0.3 %	64	0.3 %
Norway	n/a	155 000	44 908	29 %	24 222	16 %
Sweden	4.6	372 000	13 221	3.6 %	2 945	0.8 %

Source: Cars on road: http://www.acea.be/uploads/statistic_documents/ACEA_PARC_2014_v4.pdf. Newly registered cars: http://www.acea.be/statistics/tag/category/consolidated-figures. Rest: http://www.acea.be/press-releases/article/alternative-fuel-vehicle-registrations-1.2-in-fourth-quarter-of-2016-4.1-in

In most Nordic and Baltic countries, new cars have higher reported carbon dioxide emissions than the EU average, and these figures are highest in the Baltic countries. See Table 4. Norway's low emissions are due to the fact that a third of the cars sold are electric cars and plug-in hybrids. New cars in Denmark also have much lower carbon dioxide emissions than the EU average, despite the fact that less than one percent are plug-in vehicles. Instead, this country has a vehicle sales tax system that encourages buyers to choose small cars with low fuel consumption.

According to manufacturers' figures, carbon dioxide emissions from new vehicles fall by three to five percent each year in the EU. Even if emissions do not fall as much in real life, the effect is that the vehicles are using less energy. This is mainly due to EU-wide rules which mean that car manufacturers must achieve average emissions of 95 grams per km by 2021.

Table 4. **Carbon dioxide emissions from new cars in 2015. Average value for new cars sold, based on manufacturers' emission figures.**

	CO_2, grams per km
Estonia	137.2
Lithuania	137.1
Latvia	130.0
Finland	126.3
Sweden	126.3
EU 27/28	119.6
Denmark	106.2
Norway*	99
Iceland	n/a

*Sources: http://www.acea.be/statistics/article/new-car-co2-emissions. *; European vehicle market statistics Pocketbook 2015/16. ICCT.*

The level of car ownership varies widely in the Nordic and Baltic countries. See Table 5. Car ownership in each country is mainly influenced by income levels, economic instruments that apply to vehicles and travel, labour market structure and the proportion of the population that lives in urban areas.

Table 5. **Number of cars per thousand inhabitants, 2015.**

	Population (rounded figures)	Cars per 1000 inhabitants
Iceland**	300 000	671
Finland	5 500 000	590
Estonia	1 300 000	514
Norway	5 200 000	501
EU 27 *	-	495
Sweden	9 800 000	474
Lithuania	2 900 000	431
Denmark*	5 700 000	420
Latvia	2 000 000	345

Sources: Population; http://apps.who.int/gho/data/node.main.POP107?lang=en. Car ownership; http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=road_eqs_carhab&lang=en.

** = http://ec.europa.eu/eurostat/statistics-explained/images/e/eb/Figure_2_Number_of_passenger_cars_per_1000_inhabitants%2C_2015.png (estimated from graph, no precise figures given).*

*** = https://www.statice.is/media/49863/icelandinfigures2016.pdf (refers to 2014).*

The proportion of people who travel by public transport varies considerably between countries. See Table 6. Once again, these figures are influenced by income levels, economic instruments, labour markets and the proportion of the population that lives in urban areas.

Table 6. **Passenger transport broken down by means of travel, 2014 (percent).**

	Car	Train	Bus	Total by public transport
Denmark	80.0	10.1	9.9	20.0
Latvia	81.0	4.1	14.9	19.0
Estonia	81.6	1.9	16.5	18.4
EU 27/28	83.3	7.6	9.1	16.7
Sweden	84.7	8.9	6.4	15.3
Finland	85.2	5.0	9.8	14.8
Lithuania	88.2	1.0	10.8	11.8
Iceland *	88.5	0.0	11.5	11.5
Norway	89.7	4.9	5.4	10.3

Source: http://ec.europa.eu/eurostat/statistics-explained/index.php/Passenger_transport_statistics.

** = https://www.eea.europa.eu/downloads/341402c4628c4720a40fb8a4466e-6e9f/1479205824/transport.pdf (refers to 2012).*

The share of freight transported by road varies considerably between the countries. See Table 7. The distribution of freight transport is affected by the countries' infrastructure, economic instruments, socioeconomic factors and industrial organisation.

Table 7. **Freight transport broken down by means of transport, 2015 (percent).**

	Train	Inland waterways	Road
Denmark	10.6	-	89.4
Norway	12.9	-	87.1
EU 27/28	18.3	6.4	75.3
Finland	27.0	0.4	72.6
Sweden	29.4	-	70.6
Estonia	52.4	-	47.6
Lithuania	65.9	0.0	34.1
Latvia	79.8	-	20.2
Iceland	n/a	n/a	n/a

Source: http://ec.europa.eu/eurostat/statistics-explained/index.php/Freight_transport_statistics_-_modal_split.

5. Measures for reducing emissions

This section describes some of the key measures that would be required to reduce greenhouse gas emissions from road traffic to almost zero by 2035. There are several ways to reduce emissions and they will all be needed. Renewable fuels need to replace fossil fuels, vehicles need to use less energy per kilometre and more of them need to run on electricity, and growth in travel and transportation must be stabilised or reversed.

Electric vehicles

Electric cars are currently more expensive to buy and therefore have higher capital costs than conventional cars. Most plug-in electric vehicles are hybrids that also have an internal combustion engine. Many forecasts indicate that the use of lightweight electric vehicles will increase rapidly[3].

Cars that get electricity from fuel cells and are refuelled with hydrogen have not made a commercial breakthrough yet, but there are one or two models on sale. There is no existing infrastructure for filling up with hydrogen in the Nordic or Baltic countries, but some smaller projects are underway. Research and development on the use of hydrogen as a fuel is supported by the EU. The fuel infrastructure directive mentions hydrogen as a possibility, but there are no binding requirements for the member states to build more refuelling stations.

3 Slowik, P.; Pavlenko, N. och Lutsey, N. 2016: Assessment of next-generation electric vehicle technologies. ICCT White paper.

According to one assessment up to half the cars, light commercial vehicles and buses that are sold in Europe in 2030 could be electric and 10–20 percent of transport could be electric-powered, assuming that strong incentives are introduced[4]. Other studies have reached similar conclusions. The proportion of electric vehicles would continue to rise beyond this date, according to current forecasts, but it is hard to know for sure how electrification will develop, since it depends on political factors and technological development spanning several decades. It is however clear that coordinated incentives will be needed if the electric share is to grow rapidly over the next 5–10 years.

One example of the shift to fully electric or hybrid power in the automotive industry is Volvo Cars. The company has announced that all new models launched from 2019 will have some form of electrification. By this date all its cars will be mild hybrids, electric hybrids, plug-in hybrids or fully electric cars[5].

A large share of city bus traffic could be electrified by 2035. The switch to electric power is likely to be quickest here. Bus traffic is often subsidised and public transport users have good reasons to make demands for electric vehicles, since they benefit city residents. Battery electric and plug-in hybrid buses are commercially available and the number is growing rapidly. Trolley buses have also been using parallel technology for many decades. Traffic systems and infrastructure are relatively easy to adapt for electrical operation.

The distribution of freight in cities using medium-weight commercial vehicles can to some extent be influenced by local regulations and procurement requirements. Green zones can, for example, be used to speed up electrification.

Electric highways and fuel cells for heavy vehicles

There is currently no commercially available technology for driving long-distance heavy commercial vehicles with electricity. Existing battery technology is not yet good enough. A more likely option is that heavy vehicles will be powered by fuel cells, and such technology is being tested in heavy vehicles but is not yet at the commercial stage. Long-distance road haulage could also be powered by electrified roads, rather like train and trolley buses. Electric vehicles could draw power from cables above or at the side of the road, buried in the roadway, or by using inductive technology in which vehicles are charged electromagnetically instead of requiring physical contact between the cable and vehicle. Several trials are underway with electric highways in Sweden and Germany, for example.

Coordinated investment is required to implement any of these technologies. In view of the long lead times and the many infrastructure changes that are needed, coupled with the fact that it is more expensive than conventional technology, electric propulsion is unlikely to account for the majority of long-distance road haulage needs by 2035.

4 Berggren, C., Kågeson, P. 2017: Speeding up European Electro-Mobility. How to electrify half of new car sales by 2030. Report for Transport and Environment.

5 http://www.mynewsdesk.com/se/volvo_personbilar/pressreleases/volvo-cars-elektrifierar-hela-sitt-modellprogram-2050358

Emissions during the manufacture and scrapping of vehicles

Greenhouse gas emissions will also need to be reduced during the manufacture of vehicles if road transport is to become emission-free. Emissions are produced during the extraction and processing of materials and the manufacture of vehicles. If materials are recycled from scrapped vehicles this reduces the climate impact during the next stage, when the materials are used to build new vehicles or other products.

When life cycle analyses are carried out on automotive manufacturing many assumptions are made about materials, industrial processes, power generation, percentage recovery and so on. These studies therefore yield widely varying results. In general, it can be said that emissions from vehicle manufacturing and recycling account for roughly one-fifth of the climate impact that occurs during the lifetime of a car that covers 15,000 km annually for 15 years using current fossil fuels. Such calculations generally make an allowance for materials that are recycled, in other words emissions from such processes are not counted against the vehicle. Greenhouse gas emissions are reported in some references to be about 4–5 tonnes of carbon dioxide equivalents per car, but other studies give different results.

More materials are required to build a heavy vehicle, which leads to higher emissions. But heavy vehicles cover long distances, so emissions from manufacturing are still a smaller share of the total climate impact of current heavy vehicles that run on fossil fuels.

A large part of the climate impact during the manufacture of vehicles depends on how the electricity that is used in production was generated. This climate impact will gradually decline as global electricity generation switches to renewables.

Emissions from the manufacture of batteries and fuel cells

The lithium batteries in a modern electric car weigh several hundred kilograms and consist of various metals, plastics and electrolytes. The climate impact of battery manufacturing with current levels of recycling is in the range of 150–200 kg per kWh of battery, but various figures are given in the literature and the variation is large[6]. An average modern electric car has a battery capacity of 20–40 kWh, while the largest models have up to 100 kWh. This means that emissions from the production of batteries may be around 5 tonnes of carbon dioxide equivalents for a car with a small battery and up to 15–20 tons for the largest batteries based on current technology. This is equivalent to emissions from the extraction and use of fuel for about 3–8 years of driving for a modern fossil-fuel car. Emissions in the manufacturing of other parts of an electric car are somewhat lower, but the overall climate impact of materials and production is still greater for electric cars than for ordinary fossil-fuel cars.

6 Romare, M.; Dahllöf, L. 2017: The Life Cycle Energy Consumption and Greenhouse Gas Emissions from Lithium-Ion Batteries. IVL report C 243

The amount that emissions are reduced if a fossil-fuel car is replaced by an electric car depends on how far the vehicle is driven, how the battery is manufactured, how long the battery lasts, and which parts will be recycled. Batteries for electric cars are believed to last the entire life of the car. The technology exists for recycling or reusing electric vehicle batteries, but there is no commercial market since recycling is not profitable at today's prices, so new incentives are needed.

Life cycle analyses on fuel cell production give similar values for greenhouse gas emissions. Fuel cells for vehicles are not yet commercially available, so it is difficult to assess how high emissions would be in mass production using the current materials and energy mix in the relevant countries.

As in the manufacture of vehicles themselves, the climate impact during the manufacture of batteries depends on how the electricity that is used in production was generated. This climate impact will fall as global electricity generation switches to renewables. It can be speeded up through international regulation, but measures taken by producers and purchasers to reduce energy consumption in production can also play a big role.

More energy-efficient vehicles

The EU has introduced increasingly stringent requirements to persuade vehicle manufacturers to produce cars and light commercial vehicles with lower fuel consumption, measured as carbon dioxide emissions per kilometre. The energy consumption figures for newly manufactured vehicles fall by several percent each year. In practice, however, there is a growing gap between emissions in real life and the test cycles that manufacturers use. Emissions are not falling nearly as fast in reality[7]. The regulatory framework for certifying cars will however be revised to reduce the actual energy consumption. Manufacturers will also be required to declare energy consumption figures for heavy vehicles within a few years, which they do not have to do at present.

The EU is likely to continue to demand lower average consumption for newly manufactured vehicles. Manufacturers can meet such requirements through a combination of building smaller and lighter vehicles, smaller and more efficient engines, reducing energy losses and air resistance, and by selling more hybrids and electric cars.

Conventional vehicles after 2035

Vehicles can be used for several decades. Most passenger cars and commercial vehicles have an economic life of 15–20 years. So even if all newly manufactured vehicles became fossil-free from 2035 onwards, there would still be many used cars with internal combustion engines on the roads.

7 Tietge, U. et al. 2016: From laboratory to road. A 2016 update of official and "real-world" fuel consumption and CO2 values for passenger cars in Europe. TNO och ICCT

It is vital that the energy consumption of newly manufactured vehicles continues to decrease until 2035 if emissions from vehicles in the Nordic and Baltic countries are to have a reasonable chance of reaching zero by 2035. The less fuel these vehicles need, the easier it is to supply them with sustainable fuels.

It is theoretically possible to phase out the use of vehicles early. But scrapping or banning a large number of vehicles that have significant economic value, such as vehicles that are five to ten years old, would require broad political support and be very costly. This means that for a few years after 2035 some journeys will still be made by internal combustion vehicles, for purely technical and economic reasons, although considerable efforts should be made to reduce this proportion.

One possibility, however, is to ban or scrap the oldest or most polluting vehicles early. Getting rid of vehicles that have the highest emissions of harmful pollutants could have major social benefits, especially in cities and urban areas. The current green zones in many European cities have broad support, and these systems can be extended. It is also possible to introduce temporary scrappage premiums to remove a small group of highly polluting vehicles. This form of regulation could be applied on a large scale in the Nordic and Baltic countries, and could be based on the climate impact of individual vehicles.

Biofuels

Since it is not possible to phase out all internal combustion vehicles by 2035, it will be necessary to use fuel that does not produce any significant greenhouse gas emissions.

The most widely available biofuels over the next few decades will be crop-based. But cellulose-based fuels are also growing in importance, such as alcohols and synthetic petrol or diesel. Vegetable and animal oils will be used to produce synthetic diesel. Biogas can be used in diesel and petrol engines, but there is a limited supply of raw material. Biogas has the greatest potential for urban and long-distance vehicles.

It is possible to increase the use of biofuels significantly. The Nordic and Baltic countries might even be able to replace the entire volume of fossil fuels used today with biofuels if they impose sufficiently high subsidies or reduction requirements on fuels. But this would make it necessary to import some of the fuel. Because there is a limited supply of biofuels, and they can be used all over the world, this will be something of a zero-sum game. If a very large proportion of biofuels are used by a few countries, less will be available to other countries. If the measures taken in the Nordic and Baltic countries are to be scalable throughout Europe or globally, biofuels cannot be the only solution for reducing emissions to near zero. On the other hand, countries in northern European may well have a higher share of cellulose-based fuels than many other countries, since they have large areas of forest and a strong forest industry that could collaborate in the form of energy combines.

In general it can be said that the biofuels that are in large-scale use today reduce

climate impact by 40–80 percent, but the actual values vary widely. Emissions can be very low if biofuels are produced from residues from the forest industry, while fuel made from new palm oil crops can produce such high emissions that it would take decades of production to compensate for the large amount of methane that is released when wetlands are drained.

It is also important that biofuels are produced without threatening biodiversity. Global demand for bio crops is rising as the population grows and economic resources increase. It is not possible to greatly increase global use without competing with other needs or threatening biodiversity, although there is the possibility of producing biofuel in fields that are currently unused or unfit for agriculture.

Many commentators consider that a maximum of 10–30 percent of current global fossil fuel usage could be replaced with biofuels if we are to meet reasonable environmental, biodiversity, and social considerations[8,9]. Even this would require major changes in the fuel markets.

New energy sources

Hydrogen and electricity will grow rapidly as alternative energy sources. It is not currently possible to predict which of the two will be more important. Battery electric vehicles are closer to market breakthrough at present, but the automotive industry is also investing heavily in fuel cell vehicles.

Electrofuels are manmade hydrocarbons, such as methane or methanol, that are produced from carbon dioxide and water by using electricity as an energy source. The technology is established, but there is still no large-scale commercial production. In a future of international restrictions and taxes on carbon dioxide emissions, electrofuels could be profitable. If carbon dioxide is separated out during the combustion of biomass, it could be used to produce electrofuels and improve the efficiency of biomass production at the same time. If demand for liquid fuels remains high, while environmental requirements become stricter, electrofuels could become more significant in a few decades.

Fuel distribution

Fuel stations, charging points and fuel distribution form a well-established distribution network that takes a long time to change. Existing infrastructure and investments give existing technology a strong lead. This makes it economically risky to introduce new technologies such as fast chargers or hydrogen. Widespread availability of a specific charging technology or fuel is needed to make it attractive to vehicle users, and a large number of vehicles are needed to persuade the fuel industry to build new infrastructure. The countries therefore need to introduce rules and give clear signals to convince commercial fuel suppliers to invest in new infrastructure.

8 How much bioenergy can Europe produce without harming the environment? EEA Report No 7/2006.

9 Diaz-Chavez, R. A. 2009: Sustainability analysis of biofuels production and use. Imperial College London.

Electricity generation and process emissions

It is also important that electricity that is used to drive vehicles does not give rise to greenhouse gas emissions. This requires a sustainable transition in electricity generation in the Nordic and Baltic countries by 2035. Such technologies are commercially available and are growing steadily, but they require political support in order to take over completely. In this report we assume that electricity production in the Nordic and Baltic countries is fossil-free by 2035.

Similarly, vehicle and battery production facilities must be supplied with electricity that does not produce greenhouse gas emissions. Production is spread all over the world and many manufacturers are based in Asia. The Nordic and Baltic countries have limited opportunities to influence the climate impact that occurs when vehicles and batteries are manufactured in other countries. To speed up the transition, requirements must be placed on manufacturers and importers to phase out fossil fuels in their production processes. It may be possible to introduce regulations, economic incentives on car purchases or differentiated vehicle taxes within the EU or Nordic and Baltic countries that also target emissions during vehicle manufacturing.

Travel and freight transport

It will be difficult to obtain sufficient amounts of biofuels that have acceptable environmental performance and do not contribute to deforestation or harm biodiversity. The availability of zero-carbon electricity will also be limited in the next decade, and electrification takes time. Technological measures are not enough; the countries also need to reduce the need for road transport and increase the proportion of rail-based transport, support public transport, cycling and rail travel, and improve freight logistics.

6. The transition has begun

Most countries in the Nordic and Baltic countries have large areas of forest. This means there is good potential to produce cellulose-based fuels in the regions, such as HVO and ethanol or synthetic diesel and petrol. In Sweden, HVO is produced from tall oil and in Finland there is a large plant for producing HVO from plant and animal fats. Ethanol and synthetic petrol are also produced from wood products in the region.

All the countries have sea borders. This provides good opportunities to increase the use of wind power and wave power to produce electricity, hydrogen or electrofuels for vehicles. Iceland also has unique resources for generating geothermal energy. There is potential to increase the use of sea transport for passengers and freight. Shipping clearly faces the same challenges of using fossil fuels as road transport today, but because energy consumption per unit of freight unit is lower on average, a shift to shipping will facilitate the use of renewables by reducing the demand for fuel.

In Sweden, various technologies are being evaluated for electric highways that could continuously supply vehicles with electricity from cables. Sweden also has a large automotive industry with the resources to develop new vehicle technologies.

In Iceland, several projects are underway to test hydrogen and fuel cell vehicles.

Norway has incentives that have increased the use of electric cars to the highest level in the world. Sweden also has strong incentives for electric cars. Vehicle taxation in Denmark is designed to stimulate the purchase of fuel-efficient cars.

Norway and Iceland are not members of the EU. This gives them the ability to make more independent decisions and to lead the way in areas where the EU has difficulty reaching rapid or far-reaching decisions. Conversely, EU member countries can benefit from the advantages of a common regulatory framework.

Estonia and Latvia have a high proportion of public transport. In Latvia and Lithuania, car ownership is low and a high proportion of freight is carried by rail. In Denmark, cycling is a popular means of travel in many urban areas.

These are a few examples of national conditions that could facilitate the phasing out of fossil fuels. There are many other examples in individual countries that can help others to introduce measures that speed up the transition to zero-carbon road transport.

Table 8. **Examples of national conditions that facilitate the phasing out of fossil fuels for road transport.**

Country	Main characteristic
Denmark	Incentives to encourage the purchase of energy-efficient cars High proportion of cycling
Estonia	High level of public transport
Finland	Production of renewable fuels, e.g. HVO
Iceland	Geothermal power Experience with hydrogen as vehicle fuel
Latvia	High level of public transport Low car ownership
Lithuania	Low car ownership
Norway	Strong incentives to promote electric car sales
Sweden	High proportion of biofuels Large automotive industry

7. A conceivable scenario

If the Nordic and Baltic countries are to reach zero emissions by 2035, emissions from all new vehicles sold up to then will have to fall sharply. Vehicles need to use less energy than they do today. Most new lightweight vehicles and buses sold after 2035 need to have a high degree of electrification, and the electrification of heavy vehicles has already begun. The energy consumption per km must be significantly lower for new and existing vehicles on the roads after 2035. A large part of the efficiency improvement must be achieved through hybridisation

and electrification. However, lighter materials, better aerodynamics, effective route planning, automatic eco-driving and other solutions will also play a big role.

The fossil carbon content of fuels needs to be steadily reduced so that net greenhouse gas emissions fall sharply. After 2035, fuels need to have net greenhouse gas emissions that are close to zero. It must be possible to use a large proportion of these fuels in conventional diesel and petrol engines. A market may appear for fuels such as DME, alcohol or biogas, and for vehicles that are modified to use them.

Local rules and instruments are needed to accelerate the phasing out of fuel-thirsty vehicles, especially those that produce high emissions of harmful pollutants.

Support and rules are needed to speed up the expansion of the charging point network and outlets for new fuels, possibly including the building of electric highways or inductive charging facilities.

Economic instruments are needed to dampen the growth of road traffic and make it more profitable to transport goods at a high load factor and with low emissions. The efficiency of goods distribution in cities needs to be improved through transport planning and better traffic management.

If such measures are implemented promptly and consistently, it will be possible to reduce emissions of greenhouse gases from road traffic to zero by 2035. All the technologies are known and in use today, but new fuels and vehicles need to be developed commercially. There are effective instruments and legal opportunities in all the countries concerned. Several of the most effective measures must be decided jointly at EU level, or at least internationally. Strong political decisions are therefore needed, and it is difficult to assess what social impacts may arise. The table below shows approximately what percentage of the decrease toward zero that different actions could contribute.

Table 9. **Potential for reducing emissions of greenhouse gases from road transport by 2035 compared to current emissions, if powerful instruments are applied. The figures should be seen as general estimates of the reduction potential.**

Measure	Maximum possible reduction
Efficiency improvements to conventional vehicles	40–50 %
Transition to electric vehicles combined with renewable electricity generation	20–30 %
Switch to biofuels	20–30 %
Minimising transport needs, instruments to improve transport efficiency	10–20 %

Freely taken from: Fossilfrihet på väg. SOU 2013:84

8. What decisions are needed and who needs to take them

It is not possible to formulate in advance a model that the Nordic and Baltic countries can follow to reduce emissions to zero. This section describes the key political decisions that are needed to phase out emissions by 2035, and where these decisions could be taken. It is not possible pin down when the various measures need to be introduced, what effect they will have and which combination of decisions would be most likely to achieve the goal. The analysis below should be seen as an outline of the decisions which, if taken together, could reduce emissions from road traffic to almost zero by 2035.

International requirements for vehicles

Individual countries cannot introduce technical requirements for vehicles on their own. This would probably be seen as a barrier to trade. EU-wide action will be needed to regulate emissions from newly manufactured vehicles to a level close to zero.

- Current EU requirements for CO_2 emissions from cars and light commercial vehicles apply until 2025. One possible way to ensure that emissions from vehicles approach zero would be to set new targets for carbon dioxide emissions in grams per km, with a final target close to zero grams in 2035. For plug-in hybrids, emission requirements need to be formulated so that they also apply when these vehicles use their internal combustion engines.
- There are no rules yet for carbon emissions from heavy vehicles, but an international regulatory framework is on the way. One way of reducing emissions from heavy vehicles to almost zero in the EU could be a progressive tightening of requirements for such vehicles to almost zero grams of carbon dioxide emissions by 2035.
- EU requirements may need to be supplemented with corresponding requirements for new engine types that are not currently regulated.
- An alternative or complementary measure to carbon dioxide requirements would be to require that the proportion of electric vehicles is gradually increased. The EU or individual countries could require automotive manufacturers to gradually increase the share of plug-in vehicles they sell each year, with penalties or other sanctions if these requirements are not met. Such requirements could be introduced for both light and heavy vehicles.
- It would in principle be possible to introduce rules of this type. They would radically change the automotive and fuel industries. If zero-emission vehicles are the only way to continue selling their products, the industry will try to develop them. However, in view of the technical uncertainties and costs for rapid retooling, this type of decision would probably be considered a step too far. It would require strong political commitment and detailed impact assessments to implement such changes. The most viable route is probably to continue tightening requirements, while allowing a certain proportion of internal combustion engines to remain on the road in 2035, most likely in heavy vehicles. Regulations for vehicles and for fuels are interdependent, see below.

Manufacturing and materials

- The EU Ecodesign Directive or equivalent legislation could be supplemented with requirements to reduce the climate impact of the key materials used in vehicles that are manufactured and imported into the EU. Alternatively, vehicle emission legislation would need to be supplemented with limits on emissions during manufacturing. It is however uncertain whether this is permitted under international trade regulations and whether it is possible to monitor emissions during manufacturing.
- It is especially important to require reductions in emissions during the production of electric vehicles, otherwise there is a risk that increased use of batteries and fuel cells will drive up emissions from automotive manufacturing.
- EU legislation on vehicle and battery recycling needs to be formulated so that a larger proportion of materials are recycled, and economic instruments need to be introduced so that recovered materials are recycled in a way that significantly reduces climate impact.

National instruments for new vehicles

Vehicle sales can also be influenced nationally by taxes, subsidies and local regulations.

- Countries and cities can set up green zones with zero emission requirements. Such zones can have a large impact locally by making it more attractive for organisations and individuals to choose emission-free cars, commercial vehicles and buses to access these zones.
- Some countries charge taxes on the sale of new vehicles. These taxes can be differentiated to benefit low-emission vehicles and disadvantage high-emission vehicles. This type of sales tax on vehicles can have a major impact on the supply and pricing of vehicles.
- Annual vehicle tax and taxes on car benefits and the like can be differentiated to favour vehicles with low emissions. If taxation is clearly differentiated for at least the first few years, it will affect new sales.

Existing vehicles

Many of the vehicles that are bought over the next decade will be will still be driveable after 2035. Instruments are therefore needed to reduce the use of such vehicles or control their use to favour fuel-efficient models over fuel-thirsty models.

- It is probably not practical or politically viable to scrap most existing internal combustion vehicles by 2035. The only realistic possibility is to continue driving them with fuels that have very low climate impact.
- The countries could introduce tax rules that reduce the economic life of old vehicles, for example by raising annual vehicle taxes on old or fuel-thirsty vehicles. As older vehicles are often owned by companies and individuals with limited financial resources, such measures may need to be combined with compensatory measures of some kind.
- Taxes on car benefits and the like can also be differentiated for slightly older vehicles so that they favour low-emission vehicles. These are clearly vehicles that are already in use, but taxes affect their used values and thus how long they remain in use. High taxes on old vehicles increase the rate of scrappage.

Fuels

If the fuels used in the Nordic and Baltic countries after 2035 are to have close to zero emissions, this will require political decisions. The fuel market is also harmonised within the EU, but this is an area where individual member states have greater opportunities to control consumption by means of national taxes and regulations.

- The EU Fuel Quality Directive and Renewable Energy Directive regulate the level of greenhouse gas emissions permitted during the production of fuel that is sold in the EU. In principle it would be possible for the EU to introduce gradually tighter requirements to reduce lifecycle emissions to almost zero by 2035. Fuel suppliers would then have to switch raw materials and processes to enable the continued sale of fuel for existing internal combustion vehicles, while ensuring that fuels do not give rise to net emissions of climate gases.
- An alternative to common EU requirements is that individual countries make a reduction commitment that compels fuel suppliers in the country to develop fuels that gradually reduce climate impact. Such systems are already being introduced, although no country has yet set the requirements at zero emissions.
- The EU Renewable Energy Directive needs to be supplemented with stricter requirements for the sustainability of fuel, energy efficiency, nature conservation and perhaps even social factors. The current requirements are inadequate to prevent ecological and social damage. At the same time, the EU needs to introduce similar requirements for fossil fuels. These will naturally be phased out, but if lower requirements are set for fossil alternatives they will be economically favoured, which will result in a slower transition to renewables. The EU directive also needs to clearly address the issue of indirect land use for growing raw materials for biofuel production.
- There is a need to revise EU rules on the taxation of fuels. Member states must be permitted to set different national taxes for fuels based on their impact on the climate and environment, to make it easier to phase out fossil fuels. Current competition rules prevent states from giving tax advantages to renewable alternatives.

Electricity generation

The electricity that is used to manufacture vehicles and materials, and to drive vehicles, must be emission-free by 2035.

The organisation that commissioned this report has commissioned a sub-report to show how electricity generation can be phased out over the same period. This aspect is therefore not covered here.

Infrastructure for electricity, hydrogen and the like

The Nordic and Baltic countries need to stimulate the expansion of electricity, hydrogen and the like. Rules on infrastructure for fuels and electricity are mainly national in scope.

- The countries may need to introduce grants or rules that promote the expansion of public fast-charging points, hydrogen refuelling, DME or other new fuels. It would for example be possible to require fuel distributors to provide such fuels.
- Cities and countries can support the creation of infrastructure for charging, hydrogen refuelling or the like in response to increased demand. For example, investments in infrastructure could be procured in a similar way to rail and electricity networks if operators do not invest sufficiently on commercial terms.
- The EU Alternative Fuels Infrastructure Directive could contribute to the transition. The directive requires that member states have a plan for the expansion of certain fuels. This directive could be extended. Iceland, which is not a member, could introduce corresponding rules independently.
- Standards would probably need to be developed for conductive and inductive charging, for both vehicles and infrastructure.

Reducing demand for road transport

It does not make economical or technical sense to phase out the climate impact of road traffic by 2035 by technical measures alone. It also requires changes in infrastructure, city planning and transport patterns to make the transition possible at reasonable cost. Changes in the transport system can also provide other social benefits, such as lower energy demand, lower infrastructure costs, less noise and emissions of hazardous substances, more attractive urban areas, reduced impact on valuable nature and lower energy consumption.

- The EU needs to direct its economic support for infrastructure in such a way that it does not lead to more road traffic. Aid should not be used for major investments in motorways and new transport corridors that make road traffic more competitive.
- The expansion of roads and suburbs needs to focus on reducing demand for road transport and instead make it easier to walk, cycle or use public transport. For example, in congested suburbs, it may be effective to prioritise bus and cycle lanes. In residential areas, it can be effective to reduce the speed limit to 30 kph to improve traffic safety and make the environment more attractive to cyclists and pedestrians. Investment plans need to be designed to reduce car travel and increase the share of sustainable journeys.
- Economic instruments need to reduce the proportion of journeys made by cars and commercial vehicles. Examples include municipal parking fees, road charges, mileage taxes and congestion charges.
- New construction and urban planning need to focus on reducing dependency on cars. Important issues include the availability of parking spaces, access to public transport and goods deliveries to homes and offices.
- Cities can speed up the electrification of freight delivery and public transport by using procurement and local road regulations to encourage electrification.
- The countries can offer support to local government. Examples include the urban environment agreements in Norway and Sweden, where the state helps to finance public transport and cycling initiatives if local governments take measures to counter growth in road transport.
- The countries need to increase support for research, development and innovation in sustainable transport and sustainable urban planning.

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