Ministry of Transport and Communications

Future transport power sources

Executive summary

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Abstract

On 17 January 2012 Minister of Transport Merja Kyllönen appointed a working group to explore alternative propulsion systems for the transport of the future. The task of the group was to examine – on the basis of the current modes of transport and their expected renewal rate – what forms of propulsion would be possible in Finland in the future, to what extent they could be used, and on what timetable they could be adopted. In addition, the working group was to issue recommendations on what measures should be taken.

The group's vision is that passenger car traffic, rail transport and boating will be almost entirely independent of oil in 2050. Liquid and gaseous biofuels should cover at least 70 per cent of the fuels used in heavy-goods transport by 2050, and electricity should have an equally large share in bus and delivery transport in urban areas. In aviation, biokerosine would replace 40 per cent of the current fuels and in shipping, the use of sustainable alternative fuels would contribute to the reduction of greenhouse gas emissions by 40-50 per cent. Transport in airport and port terminals would be nearly emission-free as early as 2030.

To achieve the goal for private motoring, the working group proposes that an interim target be set whereby all new private cars registered in 2030 should be capable of using alternative fuels. In addition, energy-efficiency needs to improve by nearly 50 per cent from the 2013 level. As far as maritime transport is concerned, the LNG Action Plan must be implemented by as early as 2020.

On the basis of its study, the working group puts forward recommendations for measures to be implemented by 2020 and indicators for monitoring the implementation.

The task assigned to the expert group ‘Future Transport Power Sources’, set up by Minister for Transport and Communications Merja Kyllönen on 17 January 2012, was to determine, based on the existing fleet of transport vehicles and their projected rate of replacement, what kinds of power source options will be available in Finland in the future, and the extent of the potential availability, as well as to outline a timetable required for the switch-over. The expert group was also tasked with making recommendations for implementation measures. The expert group was chaired by Chief Counsellor, Director of Unit Silja Ruokola from the ministry's Transport Policy Department, and the members represented 27 different organisations and corporations. As part of its work, the expert group also issued more extensive background studies on the alternative power source options for shipping and aviation. The expert group delivered the final report to the Ministry on 8 May 2013.

The expert group proposed that the Ministry adopt the following target state for the year 2050:

The targets for the year 2050 as defined by 'Future Transport Power Sources’:

1. Rail transport output is, by 2050, almost entirely electricity-powered.
2. Passenger vehicle transport is, by 2050, almost entirely emissions-free.
   a. Passenger vehicles registered in 2020 comply with the low-emissions standards (<95g/km[1]), or are capable of using alternative fuels or power sources.
   b. All passenger vehicles registered in 2030 are capable of using alternative fuels or power sources.
3. Terminal traffic in aerodromes and ports is, by 2030, almost entirely emissions-free.
4. Recreational boating is almost entirely emissions-free by 2050.
5. As a combined effect of the use of biofuels and other measures, the GHG emissions from shipping are reduced by 40% in 2050, as targeted by the EU, supported by the separate LNG Action Plan and improved energy efficiency.
6. In aviation, the portion of sustainable alternative jet fuel meets the target set by the EU, being 40% at a minimum.
7. The portion of biofuels consumed in heavy road transport is at least 70% in 2050. The portion of electricity used in urban bus and delivery transport is of the same order.
8. In 2050, the major part of the bio-fuels in use is either liquefied 2nd generation biofuel or biogas. In 2030, the effective reduction in emissions afforded by the use of biofuels is at least 60%. The increasing proportion of electricity used for transport purposes is generated without creating emissions.
9. By 2020, Finland will have established a distribution infrastructure for alternative power sources.
10. Finland will have production capacity for sustainably produced biofuel, covering all domestic demand.

[1] The determination of the target level is to comply with the definition of the average limit value for new passenger vehicles as adopted by the Parliament and the Council after the Commission proposal (COM(2012) 393) amending Regulation (EC) No 443/2009.

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1 Introduction

The transport sector is almost entirely dependent on oil. Apart from electricity-powered rail traffic and biofuels used in road traffic, nearly all energy sources used in traffic are hydrocarbon fuels refined from raw oil. The most commonly used transport fuels include petrol, diesel fuel, light and heavy fuel oils, and flight fuel (kerosene). In recent years, a given amount of biofuel ingredients produced from renewable raw materials has been added into petrol and diesel fuel. In addition, natural gas, and liquefied gas in very limited amounts, are used as transport fuels to some extent. International airline operators have been active in experimenting with kerosene containing bio-based components.

During the transition period, no single alternative power source or fuel alone can meet the energy needs. Therefore, clearly defined interim goals and measures are necessary to reduce the dependency on oil in transport and the associated emissions. The measures undertaken to reduce transport needs and to improve the efficiency of logistics are supportive of these goals, but, in the end, the key to success is how to integrate and schedule the technological readiness of the equipment and the vehicles with the quantitative and regional availability of the required power sources, as well as the capability to make the decisions required to switch over to entirely new technologies.

2 Why are new transport power sources needed?

In the opinion of the expert group, the mitigation of climate change requires a radical reduction in CO_2 emissions from transport, a goal attainable only through gradually abandoning fossil fuels in domestic transport to a minimum by 2050. Alternative transport power sources and sustainably produced renewable fuels create the preconditions for the entire society's sustainable growth and welfare. The motives underlying the ambitious roadmap set for the alternative fuels are the direct economic and societal benefits, improved trade balance, the potential provided by the green economy, and the positive effects of distributed fuel production on a regional level.

Finland has committed itself to the reduction of greenhouse gas emissions at international, national, and EU levels. According to the portion allocated to Finland under the EU-level emissions reduction targets, Finland must reduce emissions from traffic by 16 per cent from the 2005 level by 2020. Meeting this target value means that the emissions from domestic traffic in Finland may not exceed approximately 11.4 million metric tonnes in 2020.

The long-term target set by EU is to reduce greenhouse gas emissions from traffic (including air traffic) by 60 per cent from the 1990 level. The target set in the Finnish Climate Policy Initiative Report[2] is to cut greenhouse gas emissions from traffic by 80 per cent from the 1990 level by 2050. Over the long run, to accomplish this requires, in practical terms, switching over to emissions-free passenger road traffic and a significant reduction of emissions in other traffic sectors. Because of the slow replacement rate of the existing vehicle fleet, automotive emissions must experience a very significant reduction already in the decades in the run up to the year 2050.
The growth pressures on logistics costs can be alleviated by improving the energy-efficiency of transport. In a market economy, the various power source options can gain popularity only if the price of the alternative power sources is competitive in holistic terms. For example, in air traffic, fuel costs account for 30% of the operating expenditure. As investments in new equipment and a new transport fleet are costly, the

[2] The foresight report outlines long-term climate and energy policy: Towards a thriving low-carbon Finland (http://vnk.fi/julkaisut/listaus/julkaisu/fi.jsp?oid=273273)

future availability of the new fuel types must be based on sufficient predictability and reliability of supply.

The impact of fuels on the Finnish trade balance is EUR 4 billion per annum. On the European level, transport fuels generate an outflow of capital to oil-producing countries outside Europe, amounting to over EUR 100 billion annually. Due to the increase in the oil price, in 2012 import prices increased more steeply than export prices, thus deteriorating the terms of trade and increasing the trade deficit.

The export value of Finnish clean-technology products is approximately EUR 12 billion, accounting for nearly 20% of the total exports. A solid national commitment to resolving climate issues in all sectors thus also establishes a foundation for the potential provided by sustainable business. Ambitious national goals create a thriving domestic market for clean-technology innovations, which in turn enhances our competitive edge and improves the relative position of Finnish companies on the international markets.

3 Alternative transport power sources

The popularity and use of alternative fuels are partly restricted by their availability and price, but partly also by a number of technical features. Certain fuel options require specifically designed vehicles and distribution infrastructures, whereas the product features of some alternatives restrict their use in combination with other power components.

The suitability of potential power sources and fuels also varies according to the intended operating site. For example, in urban areas and within agglomerations, liquid forms of gaseous fuels, as well as electricity, are feasible alternative options.

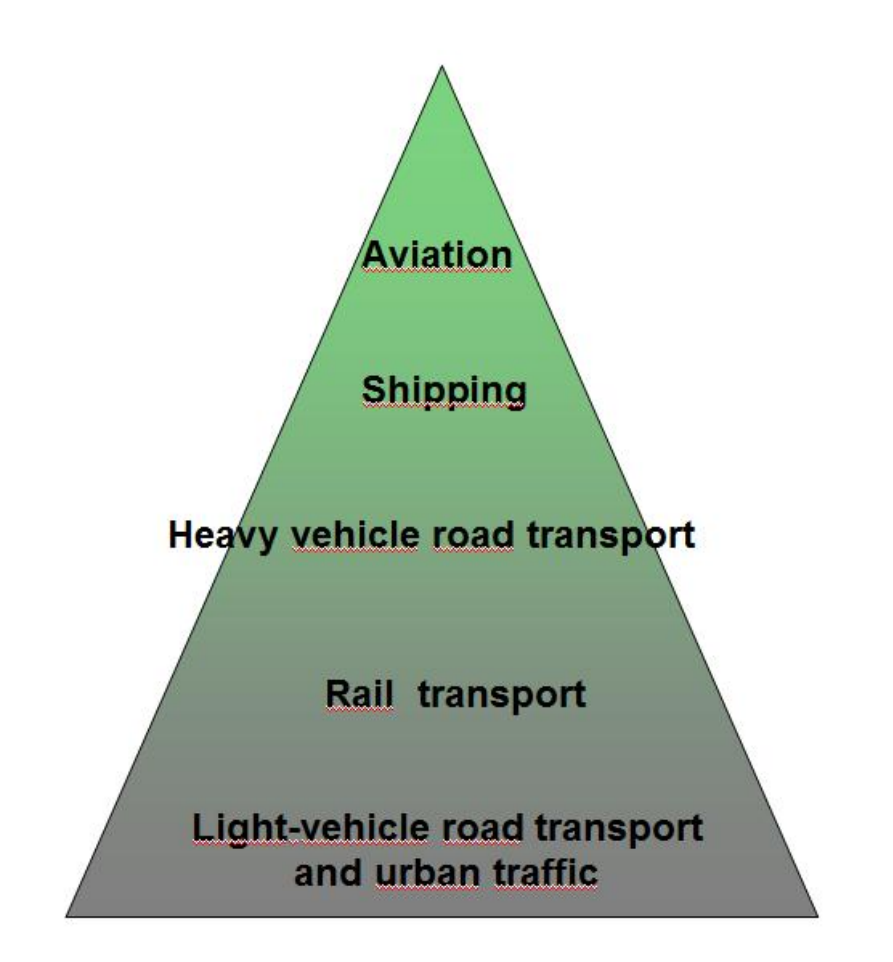
In long-distance road-transport vehicles, ships, and aircraft, high energy density is vital, and thus fuels in gaseous form or electricity (batteries) cannot be used except in exceptional cases. Methane (natural or biogas) can be liquefied in order to increase energy density, that is, by producing liquefied natural gas (LNG) and liquefied biogas (LBG). Safety issues, such as gases heavier than air or toxicity, can prevent the use of a given alternative fuel in certain solutions.

In the opinion of the expert group, the following alternative fuels and power sources are domestically the most preferable alternative fuels and power sources for the various modes of transport.

	Biofuels	Electricity	To be noted
Heavy road vehicles	Liquefied (ethanol, biodiesel fuel) and gaseous (biogas and hydrogen) fuels to replace diesel fuel	Vehicle hybridisation, overhead contact lines (buses); in urban traffic also electric vehicle batteries	▪ Battery capacity a limiting factor ▪ High initial investment in equipment ▪ Availability of fuel also critical for cross-border traffic. ▪ Regional production also domestically
Light road vehicles and urban delivery transport	Liquefied (ethanol, biodiesel) and gaseous (biogas and hydrogen) 2nd generation biofuels to replace fossil fuels; Dual-fuel vehicles	Initially, a solution especially for urban areas. Rechargeable hybrid vehicles to form the major part of the vehicle fleet; Fuel cell vehicles	▪ Recharging network ▪ Availability of gas ▪ Also regional fuel production (ethanol, biogas, hydrogen) ▪ The supply of ethanol or gas-powered vehicles and fuel cell vehicles dependent on the manufacturers
Rail traffic	Biocomponents and biogas to replace diesel fuel	Electrification to be extended on the sections with the highest transport output	▪ Transporting heavy freight by rail increases potential for emissions reduction
Seaborne transport	Bio-based fuels and natural and biogas to replace fossil fuel (LNG, LBG)	Connection to shore grid at ports	▪ Transition to natural gas enables meeting air-quality targets more readily ▪ Availability of LNG at ports must be regionally comprehensive ▪ Oil-based fuel cannot be totally eliminated
Air transport	Biokerosene to replace fossil flight fuel	Ground operations	▪ Portion of biokerosene may not exceed 50% of fuel content ▪ Domestic production ▪ The effect of distribution at aerodromes on emissions reduction exceeds many times over the emissions produced domestically

Internal hierarchy among power sources and fuels

In the opinion of the expert group, a hierarchy must be established regarding the different modes of transport and their respective fuel usage needs based on the technical limitations, availability, and effective impact of the alternative fuels. In such prioritisation, the highest hierarchical position is reserved for those modes of transport where the availability of sustainable alternatives is the most limited in technical or qualitative terms. In these modes of transport, fossil fuels can be substituted only partially. For the modes of transport at the bottom of the hierarchy, there is a wider range of alternatives for fossil fuels, and their price or technical deployment issues do not pose limits to a more extensive fuel substitution. At the lowermost level of the hierarchy, the effective impact on the reportable climate emissions is also the greatest (Figure 3.1).



(Figure 3.1) The prioritisation of the fuel usage needs of the different modes of transport represented hierarchically

Fuel-specific characteristics

The so-called first generation biofuels are products that are manufactured using raw materials suitable for human consumption. Such products include, for example, ethanol based on staple corn, maize, or sugar beet, as well as biodiesel fuel based on oil plants. The base material used in the second and later generation biofuels does not compete with the cultivation area required for food production. The calculations used to

grade biofuels favour energy derived from waste materials and leftovers, as well as from the cellulose and lignocelluloses of plants other than food plants.
The simplest alternative in employing renewable energy in heavy diesel equipment is to use renewable diesel fuel that is compatible with the existing equipment.

The term 'biodiesel fuel' refers to traditional fuel produced from fatty acid methyl esters (FAME) [with a fixed mixing ratio]. Renewable diesel fuel refers to biocomponents of the 'drop-in´ type, which do not present any actual limits to the fuel contents. Such paraffin diesel fuels can be produced either through Fischer-Tropsch synthesis or by hydrotreatment of fatty acids (hydrotreated vegetable oil, HVO). In the case of the Fischer-Tropsch method, solid biomass can be used as raw material to produce renewable fuel. The alternative is commonly referred to as biomass-to-liquids (BTL).

The range of gases suitable for engine fuel use is rather wide. Second only to ethanol, natural gas is the most commonly used alternative fuel globally. So-called dual-fuel gas-powered engines use two fuel types simultaneously: a small amount of diesel fuel is used for ignition, while methane (biogas or natural gas) is the main power source. In vehicle use, methane is usually natural or biogas compressed to 200 bar (compressed natural gas CNG; compressed biogas CBG). As for the vehicle itself, it is does not matter whether natural or biogas is used. Biogas is available from dedicated biogas plants or by feeding purified biogas into the natural gas supply network.

Methane can also be liquefied to increase energy density (liquefied natural gas LNG; liquefied biogas LBG). The LNG technology is already in commercial use in trucks, ships, and locomotives. LGN is not suitable for uses in which inactive or stand-by periods are long. The NOx emissions restrictions entering into effect have significantly increased interest in the use of LGN as fuel in shipping.

Apart from electricity, hydrogen is the only energy carrier that enables carbon dioxide-free travel, provided that no fossil energy is used in the production. Hydrogen will be used especially in fuel cell vehicles. A fuel cell vehicle is a sub-type of electric car, since the vehicle runs on electricity. In principle, the storage of energy in hydrogen form is easier than in batteries.

Electricity has been traditionally used to power trams and railways, for example. In these solutions, energy is not stored in the vehicle, but, instead, the electricity is supplied via the overhead power lines. The technology based on overhead lines is also used in trolley-buses, and its application to heavy transport vehicles has also been under consideration.

The challenges facing electric cars are primarily associated with the technologies used to store electricity, meaning electric cars powered by batteries. The greatest challenges, however, are related to the high purchasing price and limited operating range of full-hybrid vehicles.

Despite the cold operating conditions, there are two factors in Finland that encourage the deployment of electric cars: relatively low-coal electricity production (approx. CO_2/kWh) and block-heater outlets that could be modified under certain conditions and with some minor changes for the slow charging of electric cars. Sufficiency of electricity supply is not a restricting factor, either. A variety of different technological solutions and business models are being developed for the fast recharging of electric cars. A further requirement is a publicly accessible fast recharging infrastructure, and a directive ensuring the minimum coverage of such a network is currently being drafted at EU level. Electricity is an alternative power source especially for road traffic, and it can be used, in addition to passenger cars, to substitute the fuel needs of urban delivery transport.

In practice, the standards adopted for biokerosene permit mixing two types of [paraffin] biokerosene with fossil flight fuel used in commercial jet engines: synthetic kerosene based on the Fischer–Tropsch (FT) method and synthetic kerosene based on hydrogenated vegetal oils or hydroprocessed animal-source esters and fatty acids (HEVA/HVO). At present, both these components can be mixed up to 50% with the fossil-based kerosene used in the existing engines. Due to the international nature of air traffic, the deployment of biokerosene is hampered by varying regulations in different countries and continents.

4 Factors influencing more extensive adoption of the alternative power source options

Extensive deployment of alternative fuels is highly dependent on the strategies adopted by the EU regarding especially the regulations and restrictions governing energy production, project funding, and the standards applicable to the means of transport and fuels. Lobbying at EU level must be active and must enable the implementation of the roadmap for the new power sources, based on the nationally justified starting points. A strong commitment expressed by the EU also promotes taking global action to reduce emissions, especially from aviation and shipping, without compromising regional competitivity. The compatibility of vehicles and other means of transport with the best available fuels must be secured well in advance.

The proposal for a directive on the deployment of alternative fuels submitted by the Commission on 24 January 2012[3] requires the member states to undertake the following measures to build up a trans-European alternative fuels distribution infrastructure:

> Electricity – a minimum number of recharging points, equipped with a standard plug-in (Type-2), for electric cars are to be put in place in the EU states by 2020 so that electric cars can be recharged all across Europe;
> Hydrogen – common technical specifications for the refuelling points, fuel hoses, and other relevant components are to be determined, and the refuelling points existing in 14 member states are to be linked with one another into a territory-wide network;
> Liquefied natural gas (LNG) – the member states shall ensure that LGN refuelling points are provided in all 139 maritime ports of the TEN-T Core Network by 31 December 2020 and in all inland ports of the TEN-T Core Network by 31 December 2025, and that the distance between the truck refuelling points for the TEN-T Core Network may not exceed 400 km by 31 December 2020.
> Compressed natural gas (CNG) – a sufficient number of publicly available refuelling points are available, with maximum distances of 150 km, to allow Union-wide circulation by 31 December 2020.

The obligations relevant to Finland are depicted in Table 4.2. The technical specifications designed to ensure the intercompatibility of the alternative fuels distribution infrastructure and cross-border transport operability within the EU are to be completed by 2015. Furthermore, with respect to liquefied fuels, the refuelling points, distribution equipment, and vehicle manuals must carry uniform markings indicating the compatibility of the vehicles and the fuels.

[3] Proposal for a directive of the European Parliament and of the Council on the deployment of alternative fuels infrastructure
http://www.europarl.europa.eu/RegData/docs_autres_institutions/commission_europeenne/com/2013/0018/COM_COM(2013)0018_EN.pdf

Table 4.2 Quantitative targets set for Finland in the directive.

	Basis for target-setting	Quantitative target
EV recharging points	2 items per EV estimated to be in use in 2020; of which 10% to be publicly accessible recharging points	71 000 Publicly accessible: 7 000
GNG refuelling points	At 150 km distances	60
LGN maritime refuelling points	TEN-T Core Network ports	3 (Kotka/Hamina, Helsinki, and Turku/Naantali)
LGN road-transport refuelling points	At 400 km distances within the TEN-T Core Network	6
Hydrogen	At 150 km distances between existing refuelling points	6

The EU cannot accomplish by its own measures alone the targets set for future power sources. Especially the challenges facing shipping and aviation are global, but also the automotive industry worldwide requires that the production of alternative fuels and the associated demand meet to a greater extent. The increasing energy consumption in the emergent countries and the availability of fuels must also be factored in.

Figure 4.3 illustrates how the reduction in traffic-related carbon dioxide emissions could be accomplished by 2050 (the measures are arranged based on the order of significance):

- Efficient vehicles
- Low-carbon fuels and energy forms
- Shift to efficient modes of travel and transportation
- Avoidance of unnecessary travel

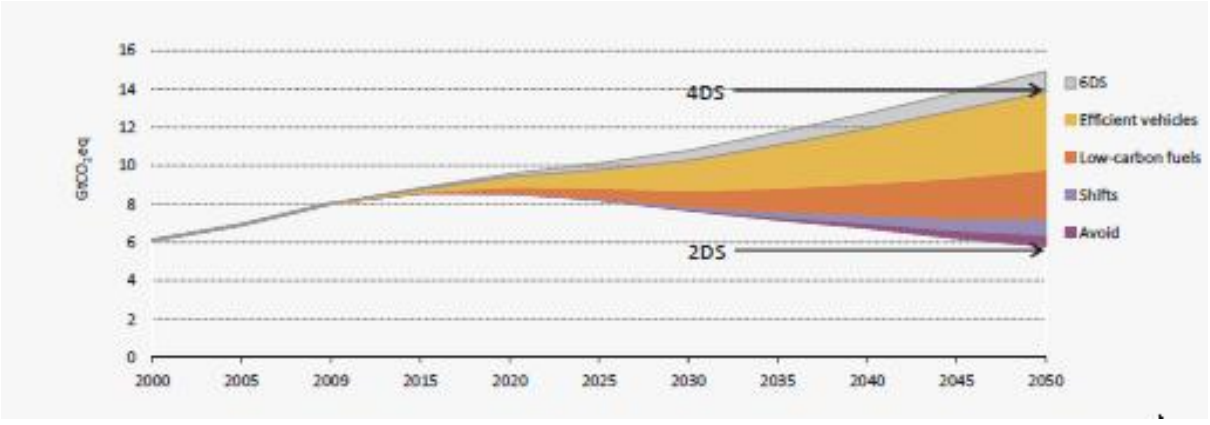


Figure 4.3 Measures to be undertaken to accomplish the emissions reduction by 2050 (ETP 2012)

Figure 4.4 provides a projection of the distribution of power sources per transport mode in 2050. For the entire transport sector, biofuels would account for 27%, electricity for 13%, and hydrogen for 7%. The distribution of biofuel consumption would be as follows:

- Road passenger traffic 37%
- Road freight transport and aviation, each 26%
- Shipping 11%

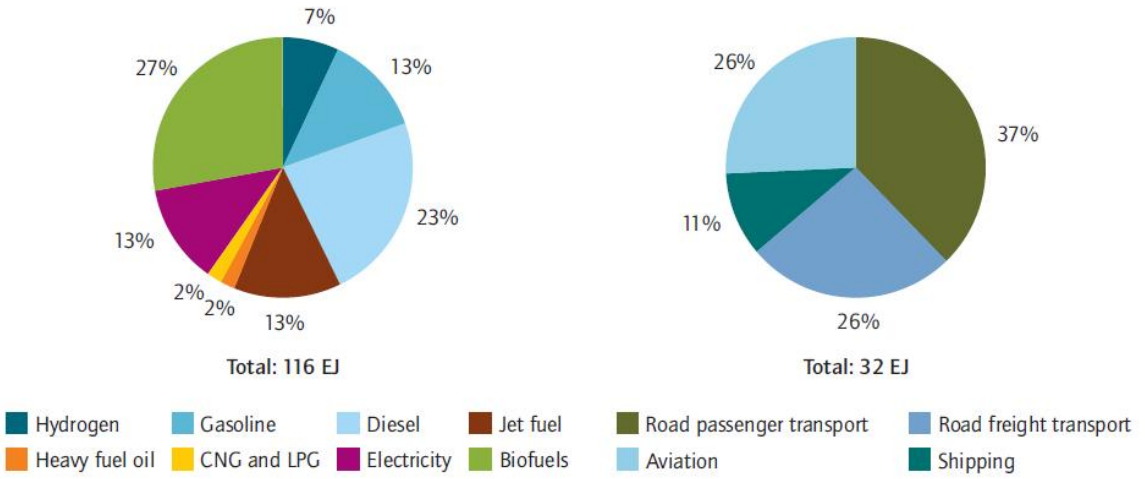


Figure 4.4 Estimated distribution of power sources and biofuels in 2050 (Biofuels Roadmap 2011)

National guidance instruments

To promote the use of biofuels and to meet, by 2020, the share of transport running on renewable energy, as required by the EU, Finland enacted the Act on the Biofuels Distribution Infrastructure (1420/2010). According to the distribution obligation laid down in the law, the portion of biofuel components in the energy content of transport fuels used in otto and diesel engines must be at 20 per cent by 2020. The second generation biofuels receive extra benefit from the fact that their consumption quantity is multiplied by two in the calculations for the distribution obligation. For these reasons, the intention is to meet the target mainly by means of the biofuels to which the so-called double inclusion is applied.

Meeting the distribution obligation by 2020 does not necessarily require any special transport vehicles, because the 20% share is attainable using existing equipment. In such a case, however, the use of biofuels would weigh heavily on diesel vehicles. A more balanced allocation can be reached if fuel types of a high ethanol ratio are used, such as E85 fuel (85% ethanol and 15% petrol). Such fuels, however, require vehicles adapted for their use, meaning the so-called flexi-fuel-vehicles (FFV).

Road-transport taxation consists of the purchase tax levied upon vehicle registration, the annual vehicle usage tax, and the fuel fee on transport fuels. The taxes on transport are thus focused on the purchase and the potential and effective use of the vehicle. All tax forms levied on transport have been entirely revised since 2007 so that they all are currently based on environmental considerations. Of the total tax revenue from transport, nearly EUR 5 billion in all, approximately 60% is collected through fuel fees, that is, for the effective use of the vehicle.

The purchase tax and the annual usage tax are determined based on the nominal carbon dioxide emission value measured for the vehicle. The emissions-based vehicle tax was

introduced in 2008, and the average carbon dioxide emissions of new passenger cars registered in Finland has decreased by 18% since that time. The basic component of the the annual usage tax was amended in 2010 into an emissions-based tax.

In addition, the transport fuel fees were based on environmental considerations in connection with the overall reform of energy taxation at the beginning of 2011. The fuel fee is determined by the energy content of the fuel, the nominal carbon dioxide emissions produced in combustion, and the local emissions. The staggering of the power source tax associated with the fuel fee entered into effect at the beginning of 2012. With the staggering scheme, electric cars, rechargeable electric cars, and gas-powered vehicles were assigned to dedicated power source tax levels, which are lower than the general power source tax.

Figure 4.5 indicates that, by virtue of the structure the Finnish emissions-based transport taxation (vehicle tax, usage tax, and fuel fee), the total taxes levied on an electric car over a period of ten years is around EUR 15,000 to 17,000 lower in comparison with vehicles equipped with an internal combustion engine. The corresponding tax advantage for rechargeable hybrid vehicles is around EUR 12,000 to 15,000.

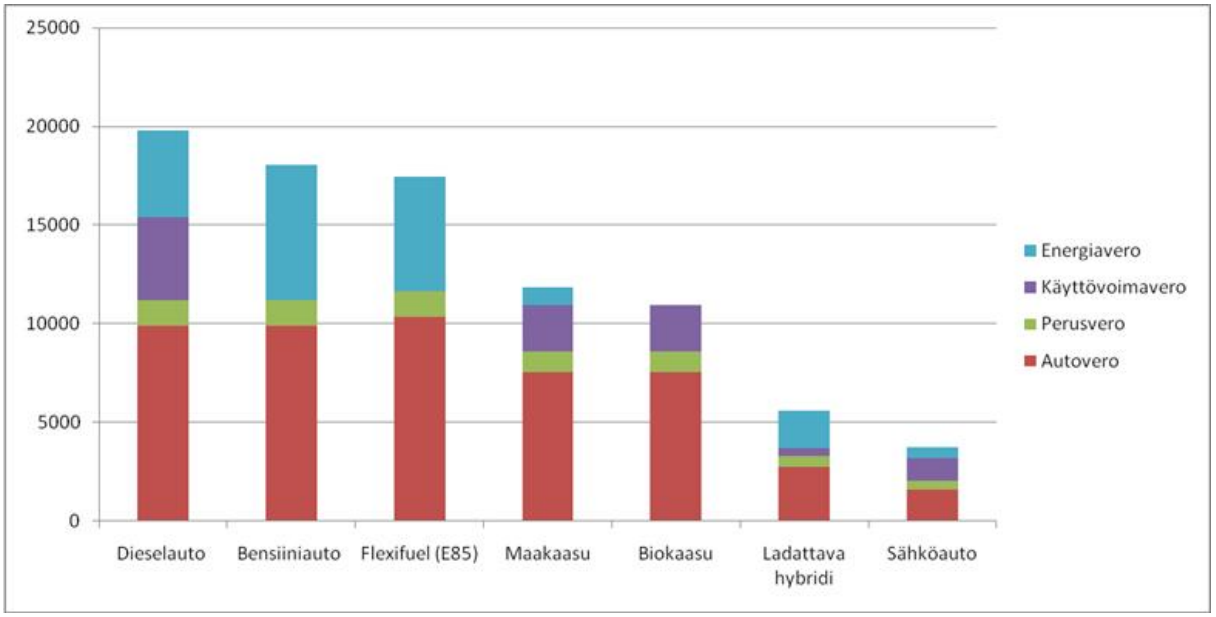


Figure 4.5 Total tax burden for a vehicle of different power source options over a period of ten years (Ministry of Finance 2012) (x-axis from left to right: Diesel oil, Petrol, Flexi-fuel (E85), Natural gas, Biogas, Rechargeable hybrid, Electric vehicle; different taxes from top to bottom: fuel fee, power source tax, usage tax, purchase tax)

Heavy goods vehicles are subject to the fuel fee for diesel fuel (as all diesel-driven vehicles) and to the power source tax under the so-called Euro-vignette directive. No power source tax is levied on buses. No purchase tax or usage tax is levied on buses and heavy goods vehicles. Vans are subject to the purchase tax, the usage tax, and the power source tax.

Shipping and aviation fuels are exempt from tax in accordance with international treaties and the EU Energy Tax Directive.

Investment subsidies are awarded for biofuel production as part of the energy subsidy scheme, which amounts to EUR 45 million per annum. Biogas production for transport purposes is also eligible for investment subsidy. Vegetable-oil based projects using

staple crops are excluded from the scope of the energy subsidy scheme. EUR 7 billion of the total energy subsidies is reserved for pilot and demonstration projects related to innovative biofuel technologies. In addition, in 2012, a one-time allocation of EUR 1000 million was reserved for subsidising second generation demonstration facilities.

The EU also provides funding through various channels to projects on renewable energy. Under the first call for proposals under the NER 300 funding programme, EUR 1.5 billion was awarded for innovative low-carbon technologies. The second call for proposals is currently under way, and the amount of funding to be awarded amounts to around one billion euros, depending on the price development of the emissions trading rights. Transport-related projects are also funded through the TEN-T funding scheme. Funding is available especially for the development of the LNG infrastructure at ports and for creating an electricity recharging network for road transport. Since 2008, the EU has awarded more than EUR 5 billion to research and demonstration projects on clean-technology road vehicles alone. The major part of such funding has been allocated to the R&D activities of the automotive industry and to pilot projects associated with road transport solutions.

Providing consumers with information on transport fuels

The key factor for a more extensive adoption of the new power source alternatives is their acceptance among end-consumers, especially in passenger road transport, where the number of users is high. Advice on choosing a new car, as well as comparison information on the different power sources, is available, for example, in the Eco-Motoring section of the website maintained by the Finnish Transport Safety Agency (TraFi) (www.trafi.fi/ekoautoilu). This section also incorporates a calculator for comparing new vehicle models on the market, based on fuel consumption and carbon dioxide emissions. In addition to the consumption and emissions values of the vehicles, the database contains the vehicles' technical specifications. The calculator enables the inclusion of the information for multiple vehicles for comparison at the same time.

The website section maintained by Motiva, ‘Choose Your Car Wisely’ (www.valitseautoviisaasti.fi), provides comprehensive information on the mobility and travel options afforded by the different modes of transport, based on ample comparison data. This section contains a compilation of information on the energy sources and the associated environmental impacts, safety matters, costs, and availability in Finland.

Uniform labelling is being prepared at EU level to enable the identification of the various fuels at all refuelling points throughout Europe. The launch of E10 petrol onto the market brought to the forefront of public awareness the compatibility of the vehicles and the new fuels for the first time. The website E10 (www.e10bensiini.fi) is a comprehensive databank, based on information provided by the manufacturers, covering all vehicles that can use E10 petrol.

Fuel distribution operators maintain online information on the refuelling points and, for example, the RE85 map template maintained by a private party is publicly available on the Internet. The North Carelian Transport Biogas Network provides on its website (www.liikennebiokaasu.fi) information on transport biogases. The site also contains information on all available biogas-vehicle makes and models for all modes of transport. Gasum Ltd also provides information on gas refuelling points. A database of EV recharging points is maintained in connection with the Electric Traffic Project by the Finnish Funding Agency for Technology and Innovation (TEKES). A mobile application for browsing the recharging points can be downloaded from the website (www.sahkoinenliikenne.fi).

5 Fuel and energy amounts in Finland

In spite of the reduction in emissions, the increase of energy consumption in transport has not yet been stopped. In the opinion of the expert group, future efforts must be focused both on improving energy-efficiency and promoting the use of such renewable transport fuels that yield the optimal reduction in emissions. In the estimate of the expert group, refinery capacity does not present an obstacle to a large-scale increase in the production of renewable fuels. Special attention, however, should be paid to the sustainability of the raw materials base and the transport distances. The initial investments in the refineries require sufficient subsidies both through the existing funding mechanisms and in the form of a predictable and stable regulatory framework.

Because of the reportable emissions reduction targets agreed to by Finland, to mitigate climate change and the wide range of instruments in the transport sector, the dependency on oil in transport must be considered both based on calculations and from a wider perspective of societal responsibility. Not all atmospheric emissions caused by Finnish travel, consumer behaviour, and transport for trade and commerce are factored into the official calculation of the Finnish atmospheric emissions, because only the share of domestic transport is included in the calculation. The potential available for reducing the emissions from aviation and shipping is significant, if the share of the traffic to and from Finland is included in the calculation, a factor that is currently excluded from the official calculations.

In the choice of practical methods and instruments, the benefits from distributed energy production to the regional economies, self-sufficiency of energy production, maintaining the operating preconditions of industry, and job creation must also be considered. The recommendations issued by the expert group are drafted in such a way that, despite the exclusions applicable to the calculation, fossil fuels will have been replaced, by 2050, by other energy sources in the most cost-efficient way, with the greatest benefit to society.

In Finland, the share of biofuels in the liquefied road transport fuels accounted for 6% of the energy content of the fuels in 2011, calculated according to the formula provided in the Act on the Fuels Distribution Infrastructure (1420/2010), amounting to approximately 240 ktoe. In addition, approximately 5 ktoe of methane (natural gas) was used in road transport in 2011, which is 0.1 percent of the total energy content of the transport fuels.

Biocomponents to replace diesel oil, natural gas, and jet fuel can be used in existing vehicles and other means of transport without any modification of the equipment. In shipping, the first passenger ship using LNG was introduced at the beginning of 2013. By the end of 2012, the number of passenger cars powered by alternative energy was as follows: 2,443 ethanol-powered (E85) FFV-vehicles, 834 gas-powered vehicles, 109 EV-vehicles, and 152 rechargeable hybrid vehicles (www.trafi.fi 2013). 131 gas-powered heavy vehicles (buses and trucks) were in use. The relative increase in the number of alternative-energy vehicles is high, whereas the total number of vehicles has not increased as targeted.

Projected carbon dioxide and energy amounts for 2020-2050

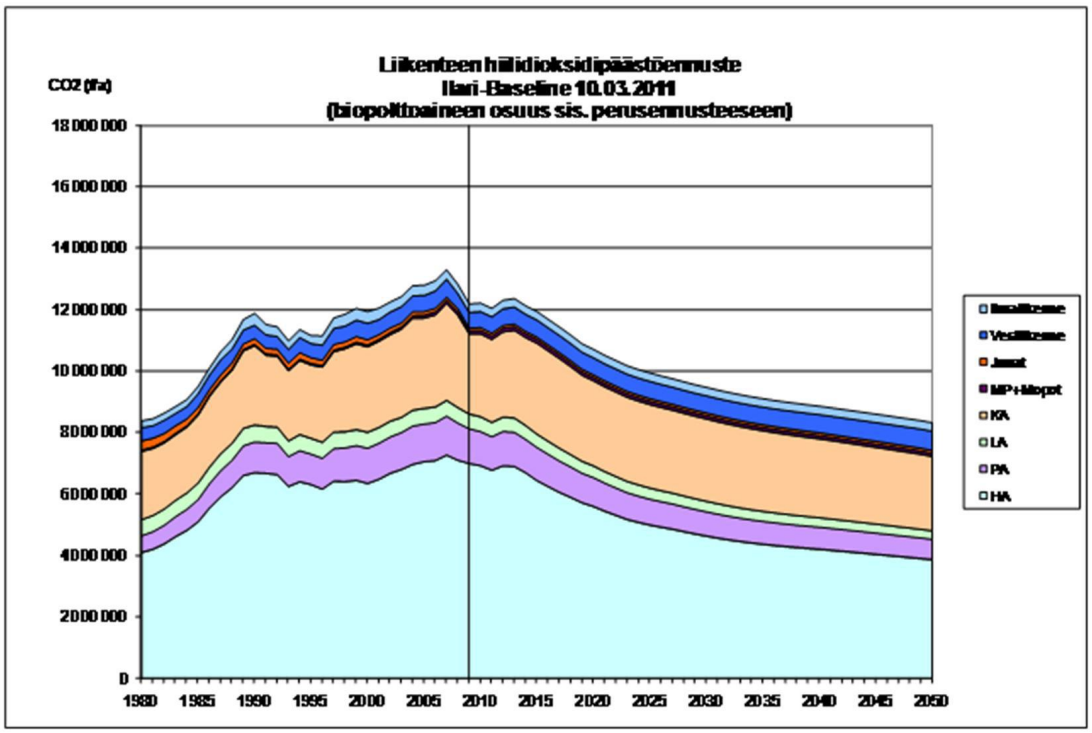


Figure 5.2 Baseline projection for transport-related carbon dioxide emissions (tons)up to 2050 (ILARI), presented by mode of transport (the portion of biofuels is included in the projection). (Jääskeläinen 2012) (transport modes from top to bottom: domestic aviation, domestic shipping, rail transport, motorcycles and mopeds, heavy goods vehicles, buses, vans, passenger vehicles)

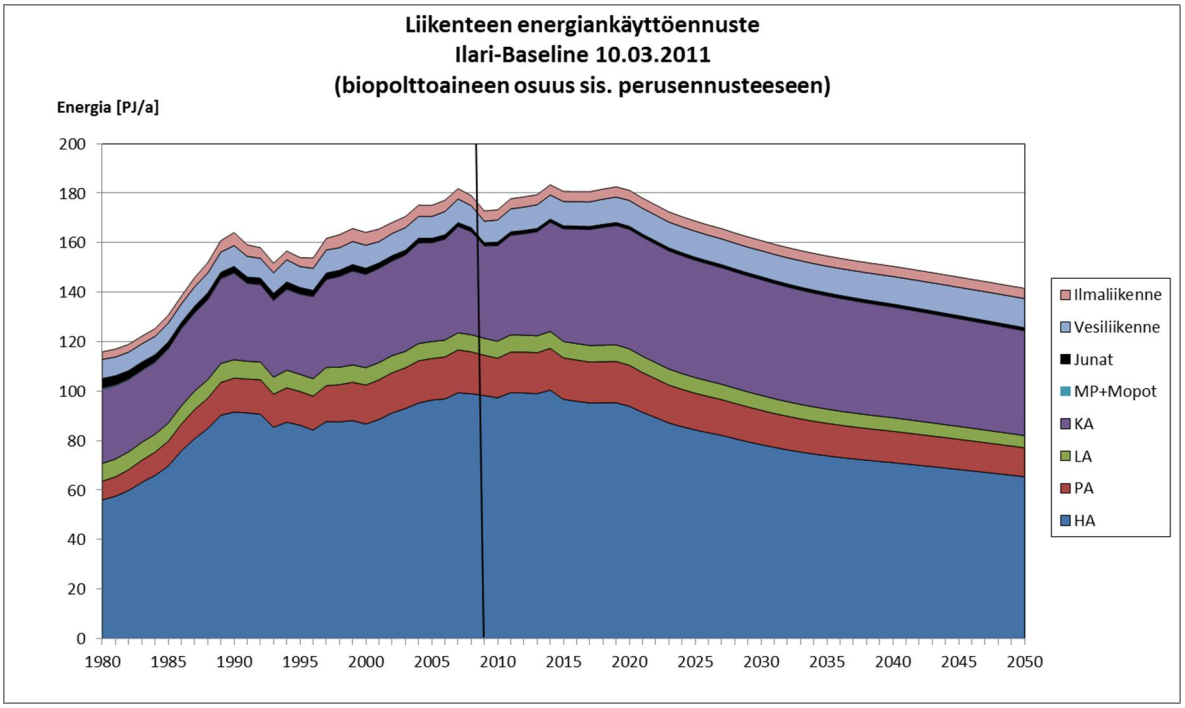


Figure 5.3 Baseline projection for transport-related energy consumption (PJ/a) up to 2050, presented by mode of transport. (transport modes from top to bottom: domestic aviation, domestic shipping, rail transport, motorcycles and mopeds (not visible in the chart), heavy goods vehicles (purple), buses, vans, passenger vehicles)

Production volumes of energy in 2020

The capacity of existing plants, combined with those for which an investment decision has already been made, enable obtaining a bio-fuel share of 13.5% in factual terms and a bio-fuel share of 19% in nominal terms. Hence, with the existing capacity and investment decisions, the target state set for 2020 is rather easy to reach. Any 'additional options' would increase the factual share to 19% and the nominal share to 29%.

According to the information available to the expert group, there are six production plants for transport biogas in operation in 2012, with an output of 10 GWh. There are 17 projects under way for new plants, to be ready for production by 2016. Of this total of 23 plants, 15 plants will operate independently of the natural gas pipeline infrastructure and will serve regional needs and so be capable of meeting the needs of regional public transport and electricity production. In March 2013, there are 18 publicly accessible gas refuelling points. Nearly all of these points supply both natural and biogas. In addition to the above, there are a number of private gas-vehicle refuelling points. Gasum Ltd intends to expand, within the catchment area of the natural gas pipeline network, its existing publicly accessible infrastructure to 30 refuelling points by 2020. At such time, the coverage of the network can be considered rather comprehensive in terms of the vehicle fleet. Hence, the availability of natural and biogas does not present an obstacle to a large-scale increase in the deployment of gas-powered vehicles. Natural gas, however, is currently used as a transport fuel on a rather modest scale. Natural gas is primarily used for industrial purposes and in the production of district heating and electricity.

If the terminal projects aimed at increasing the use of LNG are implemented, significant volumes of LNG will become available for both waterborne and road traffic. Using LNG as a power source for means of transport requires new investments both in the fuels infrastructure and in the vehicles. If the LNG terminals at the ports were to be implemented throughout Europe, this would also increase competition in the gas supply business and so be reflected in the price of gas.

Seven facilities are currently producing waste-based ethanol in Finland (15 million litres). There are plans to increase the number of plants to 50, with a total production capacity of 300 million litres, in line with the development of the vehicle fleet in use. Due to the slow adoption rate of the FFVs, part of the waste-based ethanol is used as bio-components in E5 and E10 petrol fuels for vehicles other than the FFVs.

At the moment, only three companies produce sustainable alternative jet fuel for aviation purposes on a commercial scale. The companies are: Neste Oil in Finland, Dynamic Fuels in the USA, and, to a minor extent, Honeywell-UOP. Neste Oil produces aviation fuel from both traditional and renewable raw materials in the Porvoo refinery.

6 Environmental and atmospheric impact of alternative power sources

In the opinion of the expert group, increasing the share of second generation biofuels and the increased use of emissions-free electricity support the reduction of transport-related atmospheric emissions and, over the long term, take into account the impact produced by the best available technologies and the fuel alternatives throughout their entire life-cycle. Therefore, these power sources should have priority in the determination of the guidance instruments. Optimal effective impact and cost-efficiency can be obtained when special attention is paid to the sustainability and continuous improvement of the raw materials base of biofuels. As potential additional benefits, domestic production has a positive effect on business and employment opportunities, the national security of supply, and the trade balance.

Emissions are generated both at the source of the fuel supply chain (well-to-tank (WTT) or, more commonly, the so-called upstream emissions) and by end-use (tank-to-wheel (TTW) or, more commonly, vehicle emissions). In the case of oil products, the source point of the supply chain includes, for example, oil production, transport of raw oil, oil refinery activities, and the transport and delivery of the end-products.

The use of electricity in vehicles, as well as the use of hydrogen in fuel cell vehicles, does not produce emissions. Apart from being emissions-free, such technologies have the benefit of a low noise level in comparison with internal combustion engines. In road traffic, however, silent vehicles may sometimes be a hazard for pedestrians.

In all cases, the engine combustion reaction produces CO_2, regardless of whether fossil fuel or biofuel is used (with the exception of hydrogen). The total emissions impact of the entire fuel chain is determined based on the emissions generated in production and on whether fossil or renewable fuel is being used.

According to international agreements, the use of biofuels is considered to be carbon-neutral in the calculation of transport-related CO_2-emissions, meaning that CO_2 emissions = 0. This is based on the notion that the amount of carbon bound up by the growth of biomass is equivalent to the amount of carbon released through combustion and so returned to the ecological cycle.

In an ideal world, the entire production chain of biofuels should be CO_2-neutral. This means that all energy used in the production chain is either renewable or carbon-neutral, no inorganic fertilisers are used in the production of biomass, and no other GHG emissions are released in the production of mass, including nitrous oxides (N_2O).

In practical terms, no biofuel is entirely free of GHG emissions. The best available biofuels, however, enable a significant reduction in the emissions.

In recent times, the rationality of using staple-crop-based biofuels has been discussed in rather lively terms, including on international fora. In a directive proposal[4] submitted in October 2012, the Commission proposed that the share of staple-crop-based biofuels be limited to 5% in the calculation of the 10% bio-component target level set for the purposes of meeting the obligations under the renewable fuels infrastructure. This new proposal would, in practice, favour algae-based fuels and fuels derived from actual waste raw materials. The instrument is designed to promote the development of so-called

[4] COM(2012) 595 of 17 October 2012; A proposal for a Directive of the European Parliament and of the Council amending Directive 98/70/EC relating to the quality of petrol and diesel fuels and amending Directive 2009/28/EC on the promotion of the use of energy from renewable sources.

second generation fuels derived from raw materials, which are not used for human consumption and do not increase the negative effects of land use.

Although the increasing use of electricity in transport signifies an increase in the consumption of electricity, in the EU emissions rights trading scheme, the electrification of transport does not increase the emissions falling within the scope of scheme. This means that the electrification of transport is taken fully into account when calculating the reduction in transport-related emissions, provided that electricity is used to replace fossil fuels.

7 Energy consumption and emissions according to the target state proposed by the expert group

For the purposes of ensuring that, in combination with other measures, the reduction target of 80% set for the transport-related CO_2-emissions will be attainable, the expert group considered the target levels required to replace the use of fossil fuels by sustainable biofuels under the projected baseline scenario in the different modes of transport by 2050.

- Light-vehicle road transport and aviation 40%. Furthermore, the use of electricity in passenger car traffic should be equal to at least 30% of the present passenger transport output, while the rest of the projected energy needs of passenger transport would be covered by improved energy-efficiency.
- Heavy-vehicle road transport and railway diesel traction 70%.
- In shipping, the targeted reduction in GHG emissions is 40%, of which the switch-over to using liquefied methane, combined with improved energy-efficiency, would cover a significant portion.
- In addition to passenger transport, terminal traffic at ports and aerodromes, as well as in recreational boating and rail traffic, would be nearly emissions-free as a result of the use of electricity

When commencing their work, the members of the expert group on Future Power Sources outlined and assessed a realistic development path for a more popular adoption of the alternative fuels replacing fossil fuels. The assessments, as well as the energy consumption and emissions issues addressed in Chapter 5, indicated that the existing measures are not adequate to ensure a positive development path. For the purposes of supporting target-setting, a number of calculations were carried out, whereby the sufficiency of the target state could be evaluated.

The targeted reduction of 60% in transport-related CO_2-emissions is equal to 5 million tonnes, for which the projected usage volumes would suffice. Instead, the reduction target of 80% would mean cutting CO_2-emissions to 2.4 tonnes. This cannot be achieved by biofuels alone, and would require increased use of electricity or a significant improvement in energy-efficiency.

The target for emissions-free passenger-car transport necessitates, in any case, an improvement in energy-efficiency. Such an improvement can be accomplished partly through the switch-over to the use of electricity, due to the better efficiency ratio, and partly through developing further the engine technologies suitable for biofuels. Under the baseline scenario, the share of heavy-vehicle road transport in the total consumption increases significantly by 2050. The high nominal share (70%) allocated to biofuels in the replacement scheme can be reduced, if an equal nominal reduction is implemented by improving the energy-efficiency of transport or by increasing the use of electricity.

The figures provided in the official calculations do not include the overall impact of shipping traffic from abroad to Finnish ports or the associated potential for reducing

emissions. For this reason, the national measures undertaken to reduce CO_2-emissions should be based on the general reduction target of 40% presented in the White Paper and on the international requirements about to enter into effect to reduce harmful emissions. By the deployment of LNG, CO_2-emissions can be reduced by 25%, while simultaneously obtaining significant reductions in sulphur and NOx emissions.

Similarly, increasing the share of bio-kerosene in domestic aviation to 40% is not considered to have any greater significance regarding the nationally reportable emissions (effective impact of 1.3% on transport-related CO_2 emissions). For Finland, however, the CO_2 emissions reportable under the EU aviation emissions trading scheme amounted to a total of 2.9 million tonnes. Increasing the share of bio-components to 40% would have significance in this respect. Making bio-kerosene available at Finnish aerodromes increases the potential to reduce emissions to an even greater extent.

8 Challenges and opportunities regarding increased use of different power sources

At a general level, the following framework conditions can be identified for the suitability of the different power sources for transport and for the various modes of transport:

- security of energy supply and long-term availability
- environmental impacts
- reduction potential for CO_2 emissions
- energy-efficiency
- cost-effectiveness
- economic aspects and the creation of market demand
- regional availability and production volumes
- effects on other sectors, effects on other modes of transport
- consumer approval and serviceability
- societal and ecological sustainability viewed from a wide perspective

The promotion of the new power sources and how the individual framework conditions are emphasised depends largely on the development stage and circumstances in the different countries. In Finland, the policies to be adopted for increasing the use of the new power sources must be based on our own starting points. In Finland, for example, the availability of biomass resources does not constitute an obstacle to increased use of biomass-based fuels. In contrast, in many European countries, the territorial coverage of the natural gas pipeline infrastructure is far more extensive, and more readily convertible to transport use, than in Finland. In such countries, the most effective way to implement transport powered by natural gas is to establish transport corridors that are linked to the trunk road network and supported by regional fuel production.

In the determination of the feasibility and cost-effectiveness of the proposed measures, the low population density, long distances, and cold climate conditions in Finland must be considered. The fuels must be available according to the regional needs, and the serviceability of the fuels distribution infrastructure and the means of transport must be ensured in all weather conditions. Real-time information provided on the availability of fuels and the reliability of service may be a factor in increasing confidence among the users of the new fuels and power sources. In practice, all nationally implemented solutions must be adaptable to international frameworks and the global markets for both raw materials and means of transport. A general challenge, arising from the wide range of alternatives, is to establish, as the basic starting point for an increasing adoption of the new power sources, the freedom of choice among consumers and the market-driven nature of the transition period, while retaining a technology-neutral approach in the

assessment of the potential advantages and disadvantages of all the new power sources and in any associated taxation or subsidy instruments that may be required.

It is quite evident that nearly emissions-free road transport is, over the long term, a prerequisite for a low-emissions societal structure. As the replacement rate of the existing vehicle fleet is very slow, the number of carbon dioxide-free vehicles must increase significantly in the near future. We must also recognise that there are a great number of potential users and markets competing for the sustainable Finnish biomass. When the availability of sustainable biofuels decreases, the limited resources must be primarily allocated to securing aviation and heavy-vehicle road transport, so as to maintain the competition position of Finland.

Appendix 1

Measures recommended to accomplish the target state by 2020

Production and distribution of energy and biofuels

- To exercise influence at EU level so that the deployment of the second generation is encouraged effectively in such a way that the attainment of domestic climate targets is not compromised. (Ministry of the Environment; Ministry of Employment and the Economy)
- To ensure that, in the economic guidance instruments related to transport, the environmental and climate-related factors are considered in compliance with the existing policy principles. To set the main focus in the guidance of travel and mobility on the environmentally most sustainable modes and fuels, in compliance with the priority hierarchy confirmed by the expert group. (Ministry of Transport and Communications; Ministry of Finance)
- To support the formation of innovation concentrations in areas that have the required resources and expertise relevant to biofuels. (Ministry of Employment and the Economy)
- To develop, for the purposes of long-term research and a new kind of collaboration, funding instruments designed to ensure the availability of expertise and production infrastructure, in order to secure the capacity of the next generation fuels.
- The available subsidies should also be awarded to demonstration projects designed to increase the share of second generation biofuels or those associated with transport running on emissions-free electricity. (Ministry of Employment and the Economy; Ministry of Transport and Communications)
- To investigate what advantages and disadvantages would result from enacting, for the gas sector, a similar fuels distribution infrastructure obligation as currently governs the distributors of liquid biofuels. (Ministry of Employment and the Economy)
- To ensure that the general guidance instruments for energy policy and taxation are aligned, so as to secure low-carbon transport. (Ministry of Employment and the Economy; Ministry of Finance)
- To issue plans on the territorial scope of the distribution infrastructure of the alternative power sources, to establish sufficient coverage in a cost-effective way, and to ensure implementation to an extent not feasible in a market-driven way. (Ministry of Transport and Communications; The Finnish Transport Agency, ports; operators)
- To ensure that the infrastructure of the new power sources incorporates connectivity to intelligent systems, especially regarding electricity distribution, as well as other services. To make every effort to establish compatible charging and payment practices within the distribution of the various new fuels introduced. (Service providers)
- To take into account the new power sources in the operations of the public sector, in compliance with the policy principle of the Council of State under preparation on the environmental impacts of public procurements. To issue recommendations and schedules for increased use of the new power sources in vehicle and vessel procurement.

Rail transport

- To continue the electrification of railway lines and to investigate how to promote the implementation of the electrification projects of the rail sections earlier than previously planned. (The Finnish Transport Agency)

Aviation

- To establish a collaboration network between the government administration and the business sector, tasked with actively monitoring national and international activities to promote the deployment of sustainable alternative jet fuel and with issuing proposals for measures. (Ministry of Transport and Communications)
- To exercise influence to promote the production and deployment of sustainably produced alternative jet fuel within EU research programmes. (Representatives of Ministries and Agencies)
- To promote actively on international fora (ICAO, EU, and ECAC) the deployment of sustainable alternative jet fuel and the adoption of global sustainability criteria. (Representatives of Ministries and Agencies)
- To promote awareness of Finnish expertise and of sustainably produced alternative jet fuel and its adoption in the Nordic Countries and worldwide. To support collaboration between airline operators to promote the use of sustainable alternative jet fuel, and to develop Helsinki-Vantaa Airport into a 'bio-hub'.
- To investigate the possibility to use and allocate the auction revenue from the aviation emissions trading scheme for the reduction of emissions from aviation and to develop a concept, taking competition considerations into account, for ensuring as effectively as possible that such auction revenue is used to support the increase of sustainably produced domestic alternative jet fuel, for example, in the form of subsidies awarded for the production and transport of renewable raw materials or as R&D funding for the development of raw materials production or production technologies. (Ministry of Transport and Communications, Ministry of Employment and the Economy, and Ministry of Finance in collaboration)
- To produce information for consumers on the measures aimed at reducing emissions from aviation and on how the raw materials of sustainable alternative jet fuel satisfy internationally adopted sustainability criteria set for fuels. (Neste Oil Ltd, Finnish airline operators, and airport operator Finavia Plc in collaboration)

Road transport

- Measures related to the development of the fuels distribution infrastructure:
  - To ensure that the recharging infrastructure for electric cars is implemented, for example by means of building regulations and zoning.
  - To investigate the need for and feasibility of implementation of gas infrastructure serving heavy-vehicle road transport in Finland.
  - To ensure that the infrastructure of the new power sources uses information and communications technologies, implemented in the best available way, especially regarding the production and the power grid of electricity. Information and communications technologies are to be used in the services supporting the distribution.
- Exercising influence on automotive technology:
  - To exercise influence at EU level to adopt uniform standards and policies.
  - To investigate what advantages and disadvantages the conversion of vehicles would present. The investigation is to cover all of the technologies (conversion into electric, flexi-fuel, or gas-powered vehicles).
  - To continue the research activities related to automotive technologies, from the environmental, safety, and serviceability perspectives.
  - To promote the use of electric and hybrid-powered utility vehicles and mobile work equipment in industry, logistics hubs, and mines, with the intention of switching over to such equipment entirely by 2030.
- Exercising influence on the demand for the new power sources:
  - To make every effort to promote the alternative power sources in a technology-neutral way, through extensive measures.
  - To develop informative guidance relevant to the new power sources.

- To develop, over the long term, economic guidance for transport so that it will be responsive to the targets set in the energy, environmental, and transport policies, as well as to the needs of the state finances.
- To consider the new power sources in public procurements. To issue recommendations and schedules for increased use of alternative power sources within the public sector.

Shipping

- Promotion of clean shipping:
  - To promote clean-technology projects and energy-efficiency in ship building, and in the planning and preparation of marine engines, including the emissions reduction technologies related to the use of heavy diesel oil, and to exercise influence on sufficient input with respect to such technologies in EU research programmes, including the development of the use of solar, wind, and wave energy.
  - To establish a collaboration network between the government administration, the business sector, and research institutions, tasked with actively monitoring national and international activities to promote the deployment of alternative vessel fuels and new power sources, as well as promoting emissions reduction technologies related to the use of heavy diesel oils, and with issuing proposals for measures (by means of the virtual research centre FIntrip).
- Promotion of the deployment of LNG in shipping:
  - To investigate the need for and feasibility of the implementation of gas infrastructure serving shipping in Finland, and to promote its implementation based on the LNG action plan.
  - To investigate the use of financial incentives in the building of the LNG infrastructure and in the acquisition of LNG-powered vessels, for example in the form of investment subsidies and public guarantees in connection with vessel acquisitions, with the intention of including the required appropriations in the state budget for 2014.
  - To promote actively on international fora (IMO, EU, and HELCOM) the deployment of LNG as a shipping fuel, including the construction of the LNG infrastructure and the preparation of LNG regulations and advisories, especially regarding LNG bunkering.
- To assess and review, by the end of 2013, the potential to develop domestic biofuels for shipping, especially regarding inland waterborne traffic and in the archipelagos.
- To promote increased use of shore-grid electricity during port visits, taking into account the impact of alternative fuels, and to exercise influence on the uniformity of international connection standards.
- To promote the target to switch over to emissions-free boats in inland waterborne traffic by 2030.
- To promote the development of the intelligent network application, distributed electricity production (biomass), and the storage of electricity through increasing the power output capacity of the major ports.