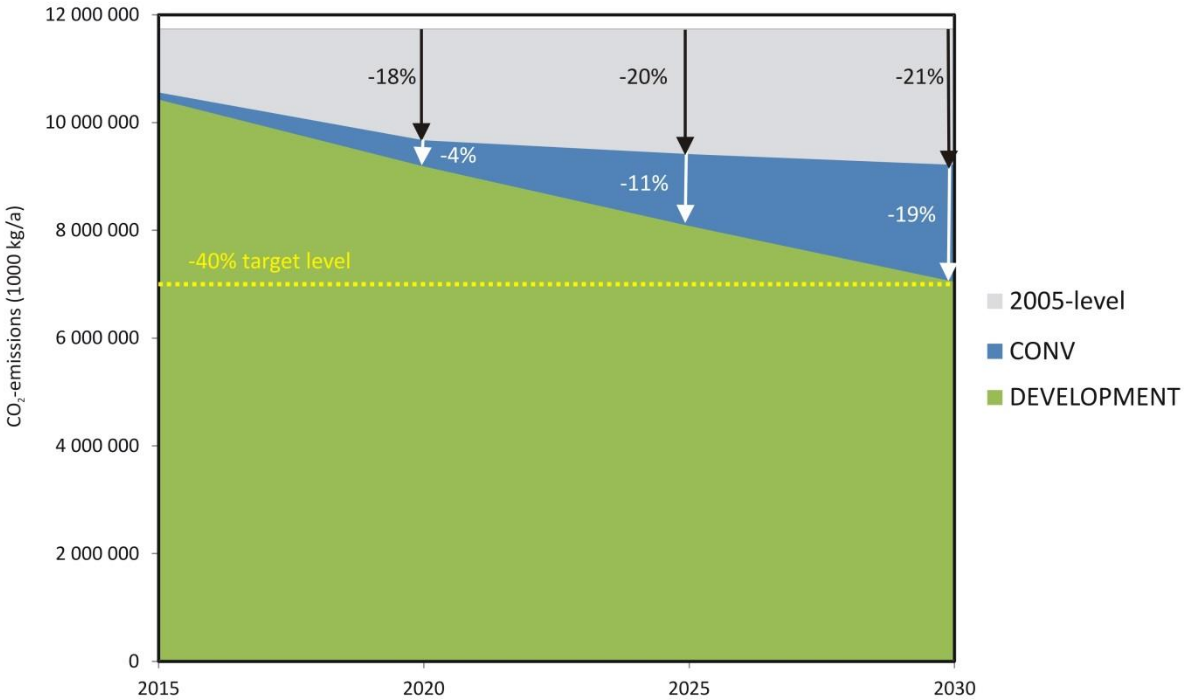

How to Reach 40% Reduction in Carbon Dioxide Emissions from Road Transport by 2030: Propulsion Options and their Impacts on the Economy

Authors: Nils-Olof Nylund[1], Saara Tamminen[2], Kai Sipilä[1], Juhani Laurikko[1], Esa Sipilä[3], Kari Mäkelä[1], Ilkka Hannula[1], Juha Honkatukia[2]

Confidentiality: Public

1) VTT Technical Research Centre of Finland
2) VATT Institute of Economic Research, Finland
3) Pöyry Oy

The main results and conclusions of the report are:

- The baseline scenario of implementing only current policy measures leads to a situation where CO_2 emissions from transport sector will be reduced by more than 20 per cent in 2030 compared to 2005.
- To reduce emissions further, it will be necessary to increase the use of low-carbon or carbon-neutral energy in transport.
- Based on the economic impacts, the most cost-efficient way to reduce emissions is to invest in the production and uptake of domestic, advanced drop-in biofuels. Their use will not require changes in the vehicle fleet or on the fuel distribution system.
- Biogas is also a relatively cost-efficient option for reducing transport related CO_2 emissions, but would require a significant increase in the number of gas-powered vehicles. However, it is not possible to set obligations for fleet renewal or powertrain choice.
- Major part of the raw material requirements for the new Finnish biofuel factories could be met with the domestic supply of wood and waste materials. With focused public investment supports, new technologies can be commercialised so that domestic production is competitive in comparison to imports.
- Because of the high price of electric cars at present, their large-scale uptake will not be cost-effective based on their impact on GDP until technology advancements bring down their price significantly.

English summary

1. General

In this study we assessed the impacts of biofuels and other alternative energy sources in transport on climate gas emissions and on the economy. The objectives were fine-tuned during the project to be in line with the EU 2030 framework for climate and energy policies introduced in early 2014. The new EU framework requires a 40 percent reduction in greenhouse gas (GHG) emissions compared to the 1990 level and an EU-wide binding target for renewable energy of at least 27%.[1] No specific, official target has been set for renewable energy or transport sector GHG emissions.

Following the research assignment, we identified options that would result in a 30 or 40% reduction in transport sector carbon dioxide (CO_2) emissions in Finland by 2030 compared to the reference year 2005, and the costs associated with each option. According to the impact assessment of the EU 2030 climate and energy policies for Finland[4] made by VTT and the

[1] 2030 climate and energy goals for a competitive, secure and low-carbon EU economy; Press Release, Brussels, 22 January 2014. http://europa.eu/rapid/press-release_IP-14-54_en.htm

Government Institute for Economic Research (VATT) for the Ministry of Employment and the Economy in the spring of 2014, emission reductions in the transport sector are the most challenging. They have significantly higher marginal costs than in the emission trading sectors.

CO_2 emissions from transport depend on distances driven, energy consumption and the carbon intensity of the used fuels. In the calculation of transport CO_2 emissions, biofuels, hydrogen and electricity are assumed to be carbon neutral. If vehicle-kilometres are considered unchangeable or locked, transport CO_2 emissions can be reduced by improved energy-efficiency or increased uptake of electric vehicles or biofuels. This report focuses on different technology and propulsion options. As such, it does not consider the impacts of possible public efforts to change the means and methods of transport or general improvements in the transport system.

VTT was responsible for drafting the fleet scenarios and calculating the emission and energy levels as well as the projected development of the car fleet in terms of technologies and costs. VTT also assessed the production potential and price developments of biofuels with Pöyry Oy. Consulting company Ramboll Oy evaluated the unit costs of the distribution infrastructure (Appendix 4). Government Institute for Economic Research (VATT) was responsible for analysing the economic impacts of the different fleet and energy scenarios.

2. Vehicle fleet and energy specifications

Certain assumptions were applied to the calculation of the vehicle fleet. Vehicle-kilometres follow the Nationwide Road Traffic Forecast 2030[2] by the Finnish Transport Agency (Liikennevirasto), published in the summer of 2014. According to the agency's forecast, transport volumes will keep rising until 2030. Therefore, the size of the vehicle fleet was expanded accordingly in this report. Vehicle fleet compositions were assessed with VTT's new ALIISA-model, which is a sub-model of VTT's LIISA calculation[3] model. The calculation model is based on the current vehicle fleet in Finland, vehicle sales figures, fleet renewal rate, vehicle-kilometres, fuel consumption and CO_2 emissions. The average renewal rate of the fleet was assumed to be about 6%, which means that the average age of the fleet remains practically unchanged at 11 years.

A baseline scenario was created to facilitate comparison of the results. It does not prioritise any alternative technology except for compatible biofuels, i.e. drop-in diesel components and a low-level ethanol blend (E10). Thus, most of the vehicles in the baseline scenario are standard vehicles powered by gasoline or diesel. In Finland, by 2020 the energy content of biofuels must account for 20% of the total energy content of the gasoline, diesel oil and biofuels delivered by the distributor for consumption according to the current distribution obligation[4]. However, at least some of the biofuels in use are falling into the regime of double counting. Therefore, in the calculations for the baseline scenario, it was assumed that the actual share of biofuels will increase to 15% by 2020 (same as the baseline assumption in the 2012 ILARI project[5]), and will remain steady at 15% until 2030. Because biofuels are considered as zero-emission fuels in the CO_2 balance for transport, it is expected that they will generate a 15% reduction in the transport sector CO_2 emissions between 2020 and 2030.

It was assumed that energy efficiency of the vehicle fleet will improve with the renewal of the fleet on average between 1.5 and 2% for passenger cars and 0.5% for other vehicle catego-

2 Jukka Ristikartano, Pekka Iikkanen, Juha Tervonen, Tuomo Lapp; Road Traffic Forecast 2030; Research reports of the Finnish Transport Agency 13/2014. Finnish Transport Agency, Helsinki 2014. http://www2.liikennevirasto.fi/julkaisut/pdf8/lts_2014-13_valtakunnallinen_tieliikenne-ennuste_web.pdf
3 The LIISA 2012 software for calculating exhaust gas emissions; http://lipasto.vtt.fi/liisa/
4 Act on the promotion of the use of biofuels for transport (1420/2010), Helsinki 2010.
5 Transport sector policy packages for climate change mitigation in Finland up to the year 2050. Baseline-scenario, Urban beat or Cornucopia?
http://www.lvm.fi/c/document_library/get_file?folderId=1986562&name=DLFE-17241.pdf&title=Julkaisuja 15-2012.

ries between 2015 and 2030. Given these prerequisites, in the **baseline scenario, CO_2 emissions will be reduced by some 21% from the 2005 level by 2030.** The use of biofuels and improved energy efficiency will reduce emissions, while growing vehicle-kilometres increase them.

Thus, additional measures are required to achieve a 30% or even 40% reduction in CO_2 emissions by 2030. This report does not assess the impact of methods such as influencing available means of transport or encouraging the renewal of the vehicle fleet (e.g. by tax schemes). The primary purpose of the report was to assess the impact of different propulsion solutions[6] on emissions, as well as the impact of each option on Finland's economy.

This report uses the following five main categories for vehicles: passenger cars, vans, buses, trucks and truck-trailer combinations. The following propulsion options were assessed for passenger cars: gasoline, diesel, high concentration ethanol (flexifuel/E85), gas (methane), plug-in hybrid electric vehicle (PHEV), battery electric vehicle (BEV) and hydrogen (fuel cell electric vehicle FCEV). Alternative propulsion systems were also assessed for other vehicle categories, but this assessment was restricted by a shortage of alternative solutions. For example, for truck-trailer combinations the only practical alternatives are liquid biofuels and liquefied natural gas (LNG).

It is very difficult to forecast the popularity and market shares of different propulsion options, in particular in the passenger car market. In terms of technology, the success potential of any new propulsion solution depends on many factors. The most important include:

1) Availability (= production);
2) Distribution system;
3) Compatibility with existing vehicle fleet; and
4) Price and consumer interest in the technology in question.

Any one of the first three factors can become a technical restriction for the use of the solution, but popularity in the market depends ultimately on the cost competitiveness and consumer interest on the technology. The prices of different vehicles depend on various factors, however, and public financial support systems can also have an effect on them. Further, the availability of different vehicle models can affect the popularity of each new technology.

In addition to the direct costs associated with each technology, it is necessary to assess the indirect impacts of the different options to obtain a view on the overall economic impacts e.g. on employment, current account balance and investments. This impact assessment is focused especially on analysing the overall economic impacts and not only the direct costs.

Alternative technologies were initially assessed one by one without consideration to possible restrictions. In the assessment, vehicle numbers were forced to a level by 2030 that would allow achieving a 40% reduction in emissions with that technology (i.e. an additional reduction of 20% in comparison to the baseline scenario). In the case of drop-in biofuels, the additional reduction is achievable without the introduction of new types of vehicles. However, it does require domestically produced or imported biofuels that are compatible with the existing vehicle fleet. While drop-in biofuels are already widely used in Finland, in particular in replacement of diesel fuels, they are less popular in Europe in comparison to 1G ethanol or FAME type of biodiesel. According to the proposed EU 2030 policy, 1G biofuels based on food crops can no longer get public support after 2020.

However, with the exception of the Drop-in scenario, none of the assessed technology scenarios are suitable for implementation as such. They would require vehicle volumes that are unattainable with standard sales volumes. Strong changes in demand typically re-

6 Propulsion = energy/fuel that powers the vehicle

quire economic incentives, which would create additional costs. This is why a small-scale uptake on a voluntary basis is more likely to be cost effective than strong and forced promotion of any individual technology.

The economic impacts of each technology scenario were analysed with the VATT's VATTAGE applied general equilibrium (AGE) model. The analyses were based on the separate estimates on vehicle and fuel volume changes, different types of additional costs and required investments that would allow each technology to reduce emissions by 40%. Therefore, the analyses provide comparable, scenario-specific overviews on the economic impacts of reducing carbon dioxide emissions. In principle, the most cost-efficient solution would deploy each technology option to the extent were the marginal costs of reducing CO_2 emissions are at the same for each option.

3. General scenario descriptions

Table 1 contains a list of the technology scenarios included in the impact assessment. The baseline scenario is abbreviated with CONV. It is mainly based on gasoline and diesel-powered vehicles and the existing distribution obligations and taxation. The baseline scenario reduces emissions by 21% by 2030 from the 2005 level. As in all scenarios, the emission reduction is primarily based on the use of biofuels according to the current distribution obligation (actual share of bioenergy 15%). In the other technology scenarios, further emission reductions were acquired by different additional measures to achieve a total reduction of 40%. The results of the technology scenarios are compared to the baseline scenario in order to analyse only their additional impact on top of the baseline scenario.

Table 1. Technology scenarios used in the impact assessment.

ABBREVIATION	DESCRIPTION
CONV	conventional gasoline and diesel vehicles only, emissions reduced by 21%
DROP-IN	CONV + drop-in fuels reduce emissions by 40%
FFV	maximised use of ethanol fuels E85 and ED95, emission reduced by 40%
CBG	maximised number of gas-powered vehicles, emissions reduced by 40%
PHEV	maximised number of plug-in hybrid vehicles, emissions reduced by 40%
BEV	maximised number of battery electric vehicles, emissions reduced by 40%
FCEV	maximised number of hydrogen fuel cell vehicles, emissions reduced by 40%
DEVELOPMENT	combination scenario, emissions reduced by 40%

Key assumptions for each scenario are presented in section 9 and the detailed the assessments of the direct costs to different parties in section 8 of the main report, but the most important key figures are also listed in Table 2.

Table 2. Key figures for the scenarios.

scenario	x-passen-ger cars* (#)	x-heavy vehicles* (#)	Main alternative propulsion option	Amount of alternative energy (ktoe/a)
CONV/DROP-IN	3 252 576	427 418	drop-in biofuels	1 130
FFV	1 547 861	116 391	ethanol	957
CBG	1 276 344	110 252	biogas	480
PHEV	1 473 574	56 660	electricity	328
BEV	1 128 205	39 518	electricity	418
FCEV	1 169 122	30 930	hydrogen	603
DEVELOPMENT/ BIO	3 102 651	423 225	drop-in biofuels	1 002
DEVELOPMENT/ CBG	50 000	7 200	biogas	50
DEVELOPMENT/ BEV	100 000	3 150	electricity	36
* "x" denotes the main alternative propulsion option on each scenario.				

4. The impact of the scenarios on the Finnish economy

In this study, the economic impacts of new fuel types and engine concepts are assessed based on their overall economic impacts in order to identify the most cost-optimal solution for the society as a whole. In addition to the main technology options, we created some sub-scenarios to take into account the diverging impacts of domestic versus imported fuels, investments and different cost assumptions. These are listed in Table 3. The table also specifies the main practical restrictions for each technology scenarios (i.e. the reason for the solid line to become a dotted one in chart 1). Table 3 displays also the achievable emission reduction of each scenario in reality.

There are nine technology scenarios in total. Their economic results are compared to the baseline scenario, where CO_2 emissions are already reduced by more than 20% from the 2005 level with the current distribution obligation and increased energy efficiency. Thus, the results of each technology scenario indicate the impact of reducing CO_2 emissions further to reach a 40% reduction by 2030 (i.e. the impacts of an additional 19% emission reduction compared to the baseline scenario). Comparison of the different scenarios' results is feasible, because they end in the same long-term reduction level in emissions.

Table 3. Technology scenarios in the economic impact assessment

#	ABBREVIATION	DESCRIPTION	MAIN RESTRICTION	POSSIBLE CO_2 REDUCTION CONSIDERING THE MAIN RESTRICTION
1	DROP-IN, imported	DROP-IN scenario, imported fuels	No restriction	40%
2	DROP-IN, investments	DROP-IN scenario, investments in domestic drop-in production	No restriction	40%
3	FFV, imported	FFV scenario, imported fuels	Number of FFV vehicles	about 9%
4	FFV, investments	FFV scenario, investments in domestic ethanol production	Number of FFV vehicles	about 9%
5	CBG	Biogas scenario	Number of gas-powered vehicles	about 10%
6	PHEV	PHEV scenario	Number of PHEV vehicles	about 12%
7	BEV, min.	BEV scenario, minimum costs of the charging infrastructure	Number of BEV vehicles	about 11%
8	BEV, max.	BEV scenario, maximum costs of the charging infrastructure	Number of BEV vehicles	about 11%
9	FCEV	FCEV scenario	Number of FCEV vehicles	about 10%

The calculations were made with VATT's VATTAGE model. It is a dynamic, applied general equilibrium (AGE) model. It was used as the assessment method in order to take in to consideration both the direct costs for all parties and the indirect impacts in the economy. Only by taking both of these views in to account, we can identify the best ways of reducing transport emissions from the whole society's point of view. Consumers and companies face direct costs/impacts in the scenarios in particular from the new types of vehicles and fuels. Further, firms will face the costs of additional investments in the fuel distribution infrastructure. In some scenarios it is also assumed that firms will invest in the production of new fuel types.

While the public sector supports these investments with public investment subsidies, **all scenarios are budget neutral for the public sector**. This means that if tax income falls or public spending increases significantly in a scenario, other commodity taxes will be increased. Otherwise some scenarios would results in major reduction in public tax income and an increase in the public-sector debt. Since the relative taxation of many new biofuels is currently lower than the taxation of fossil fuels, a need to increase overall commodity taxation arises in many scenarios. The main economic impact for the society as a whole is presented via the impact on value added (i.e. GPD). Effects on consumer demand and employment illustrate the main impacts on consumers. Changes in consumer demand and investments represent some of the main effects for firms.

Chart 1 illustrates the effects of each scenario on the GDP (value added) cumulative in comparison to the baseline scenario. The continuous lines indicate the parts where each scenario remains feasible based on the current technology uptake and projected advances. At the point where the line becomes dotted, each scenario becomes "out of bounds" due to the restriction specified in Table 3. In the hydrogen vehicle scenario (9. FCEV), it should be noted that there are no hydrogen vehicles in use before 2017 except for pilot cases. The diamond symbols in the chart indicate the years when each scenario has resulted in a 30 % reduction in CO_2 emissions compared to 2005.

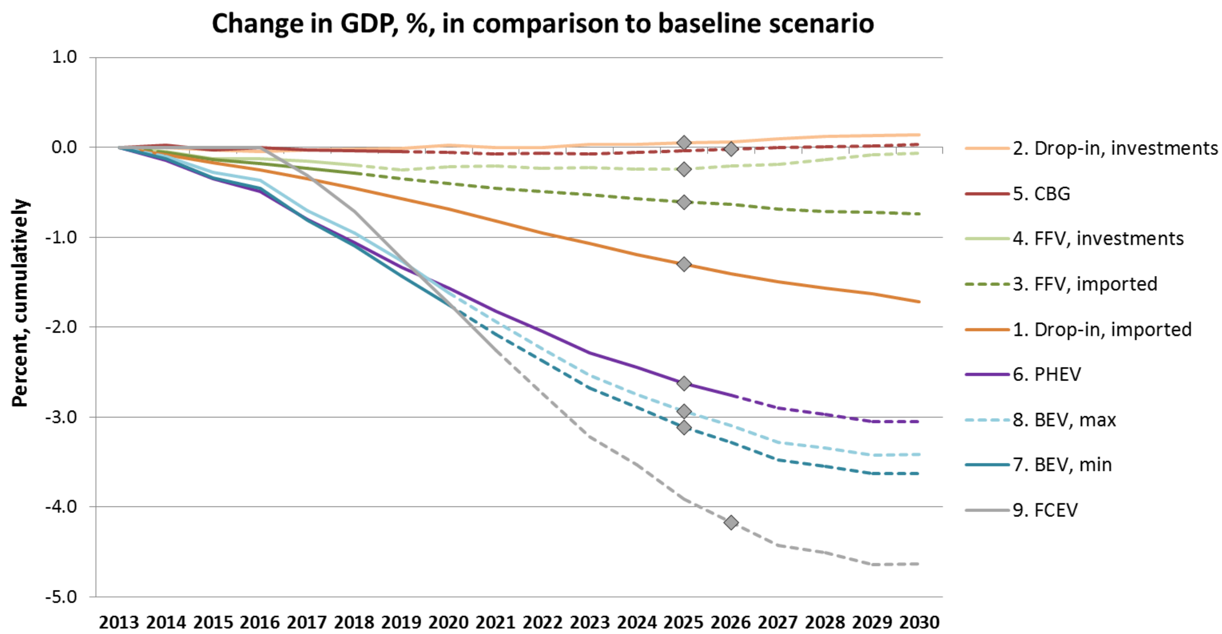

Chart 1: GDP effects of different scenarios[7] *(♦ =30 per cent reduction obtained).*

The value added (GDP) effects of the different scenarios vary greatly. Scenarios involving significant new investments in Finland, increased domestic production and no major changes on the average vehicle prices (scenarios 2, 4 and 5), decrease the GDP by a maximum of 0.2% at any year until 2030 in comparison to the baseline scenario. At the same time, the GDP will be several percentage points lower compared to the baseline in the scenarios where the average price of vehicles rises significantly, but domestic production less. For comparison, the real GDP is expected to increase cumulatively by some 40% from 2014 to 2030 in the baseline scenario. Based on the expected economic impacts, investing in domestic production of drop-in fuels and biogas seems the most cost-optimal solutions for reducing transport emissions. Finnish ethanol production appears to be also a relatively cost-efficient option.[8]

5. The DEVELOPMENT scenario

5.1 Initial considerations

This was the first wide-scale assessment of the overall impacts of different technology options on both CO_2 emissions and the Finnish economy. The calculations took into account both the current vehicle fleet in Finland and its evolution capability while also considering the Finnish economic structures. We have strong forestry and energy sectors, while our automotive industry is small and mostly produces heavy duty vehicles and working machinery.

[7] Dotted lines indicate an unlikely vehicle or fuel uptake taking into account the existing situation. Continuous lines implicate the extent to which each scenario remains likely.
[8] More detailed descriptions of economic impacts and some comparisons to previous results are presented in Chapter 9.

The following assumptions/views and previously presented results were taken in to account in the formulation of the DEVELOPMENT scenario. This final scenario is both technically possible and relatively cost-efficient based on the GDP impact:

A) Vehicle-kilometres follow the previously mentioned official projection. The share of each transport form remains unchanged, i.e. there is no shift from private to public transport or from road transport to rail transport (or vice versa).

B) Energy-efficiency improves as a result of technical developments and changes in the vehicle fleet.

C) The energy assortment requires changes, but long-distance freight traffic will continue to use combustion engines as its primary propulsion method in 2030. Diesel can be replaced by LNG to some extent, but first significant advancements are required in the technology. Electricity will not replace diesel (except in city buses), but mainly gasoline.

D) No individual technology option can result in a 40% or even 30% reduction in the total transport emissions apart from the drop-in biofuels due to many restricting factors (cost, fleet, fuel distribution). The best option is to deploy each option up-to the level where it is still rather cost-efficient. However, since the final costs depend also on the implementation schedule, it may be necessary to wait for a technology to mature before its wide-scale deployment. For example, the price of electric and hydrogen fuel cell vehicles is expected to drop in the future. Their cost-competitiveness and performance is expected to improve significantly after 2025.

E) The supply of gas-powered vehicles is at a reasonable level. Car manufacturers have an incentive to manufacture them. Due to the good hydrogen/coal ratio of methane, the CO_2 emission level in type approval is 20% lower than in similar gasoline vehicles. On the other hand, the production of FFV vehicles has narrowed down significantly as a result of the new Euro 6 emission limits[9]. Currently, there is only one model available in Finland that fulfils the latest requirements. The FFV technology provides no significant incentive for the manufacturers to produce them because their CO_2 levels are now significantly lower. Thus, it is uncertain whether the supply of FFV vehicles will increase in the future. Even though FFV vehicles are not significantly more expensive and the distribution of E85 fuel does not increase costs greatly, there may be no need to use FFV vehicles in Finland.

Ethanol can be also accounted as a drop-in fuel within the prerequisites of fuel standards. The current E10 fuel is already a sufficient “sink” for the domestic, sustainable ethanol production. Moreover, there are signs that fuel standard are likely to develop further by 2030 so that ethanol content of 20 or 25 per cent (E20, E25) will be allowed, creating an even larger pool for ethanol use, at least for new gasoline vehicles.

F) Electric vehicles remain expensive in comparison to traditional vehicles (with combustion engines). In addition, Finland does not manufacture electric passenger cars or lead the electric vehicles global technology developments (except for buses and machinery). Thus, any support measures to promote the use of electric vehicles are of limited benefit to our economy. Use of electricity would, however, reduce the import of oil. This is taken into consideration in the calculations. At the same time, a decrease in the Finnish oil demand is only expected to increase the export of Finnish oil refineries products and not affect the production level. Electric vehicles would primarily replace the use of gasoline, not diesel which is mostly used by freight transport. In terms of the reduction of total emissions, the contribution from the use of electric buses in Finnish city transport would be only 0.1%. Nevertheless, promising electric bus production is rising in Finland with potential for international success and exports.

[9] The Euro 6 type approval also includes the measurement of CO and HC emissions in -7ºC, and alcohol-powered vehicles struggle to perform in the cold.

G) Finland is one of the global leaders in biorefineries and the development of the related technologies. According to the economic impact analyses, investments in this sector will have a positive impact on our economy due to the increase in production, job creation and technology exports. Refined bio-based products manufactured from indigenous raw materials would reduce import oils and mostly replace diesel fuel consumption. Demand of liquid biofuels is expected to remain steady even if their use in road traffic would fall, because ships and air planes will also need renewable fuels in the future. Furthermore, under certain conditions, it is possible to convert biorefineries into chemical factories that produce other products than fuels.

H) If some political targets will be set for the volume of different car types, they should be smartly calculated, either based on the overall economic impacts or the volume of reasonably priced fuel options.

5.2 Description of the DEVELOPMENT scenario and its vehicle and energy volumes

Based on the economic impact assessments, it is possible to find cost-optimal paths to reach the 2030 emission targets. The following section describes the optimum combination of new technologies and technology developments up to 2030.

As regards the targeted reduction of 40% in GHG emissions by 2030, it was already stated that the baseline scenario will reduce the emissions about 20% from the 2005 level. This means that a further reduction of some 20% is required by 2030, or biofuel equivalent of some 800 ktoe/a. Major part of this reduction should result from increased use of drop-in fuels based on the economic analyses. Other alternatives can be used alongside to smaller extend and without prioritising any of them. Taxation should also treat different renewable alternatives equally. At the moment, gas and electricity have less stringent taxation than liquid transport fuels.

a) ***Gas-powered vehicles and use of biogas***. Use of gas in transport is restricted by the slow growth of the gas-powered vehicle fleet. It has been estimated that by 2030, we could have some 50,000 gas-powered passenger cars, some 6,000 gas-powered vans and some 1,200 gas-powered heavy duty vehicles, with a total fuel consumption of 50,000 toe/a. Larger fleet is unlikely with current vehicle supply.

   Available raw materials do not restrict biogas production. Household and farm waste could be used in the production of biogas in the area of the existing natural gas network to produce the above-mentioned 50,000 toe/a. After that it is necessary to invest in the production of wood-based SNG (e.g. the plant in Joutseno[10]), which competes with the liquid drop-in products for the raw material. Additional alternatives include fossil CNG and LNG, but the CO_2 reduction achieved is at most 20% if gas replaces gasoline.

   The gas would mainly be used by passenger cars and urban distribution vehicles, not necessarily by long-haul heavy-duty vehicles. If the deployment rate of gas-powered vehicles does not exceed the rate mentioned above by 2030, additional costs would remain relatively low.

   At the moment, gas is distributed by 24 refuelling stations, 18 of which are operated by Gasum. Gasum is also in the process of constructing 35 new stations.[11] Deployment of LNG in ships and the distribution infrastructure directive may improve the availability of gas and thus increase the appeal of gas-powered vehicles in Finland.

---

[10] Gasum, energy company Helsingin Energia and Metsä Fibre are planning to construct a biorefinery adjacent to Metsä Fibre's Joutseno pulp mill. It would produce synthetic biogas from wood materials and the production volume is estimated at some 1.6 TWh/a (137 toe/a).

[11] (http://www.kaasuyhdistys.fi/tiedotteet/kaasuvisio-energia-ja-ilmastotiekarttaan-2050)

b) **Ethanol** is mainly used as a blending component in gasoline in Finland (currently some 170,000 m^3). Most of it is imported. St1 mainly used waste-based ethanol as a blending component in the high-concentration E85 fuel. More than 9 million litres of E85 was sold in 2014[12].

   E10 production will require some 150,000 m^3/a of ethanol in 2030, since new vehicles will consume less fuel than the current fleet. Additional domestic capacity could be both sawdust and straw based and could reach a total volume of 150,000 to 200,000 m^3/a or some 100,000 to 130,000 toe/a. Thus, national production could provide all the ethanol for standard E10 fuel. The DEVELOPMENT scenario assumes the constraint of ethanol use to be as currently, i.e. 10vol-% of the content. However, it is reasonable to assume that gasoline engine technologies will be developed further, and that the fuel standards will be updated in the future to increase the ethanol content to 20% or 25%. However, this will not have a significant impact on the situation in 2030.

c) **Electric vehicles** are still expensive, and will remain to be so in the near future The price excluding taxes is currently more than twice the price of a comparable vehicle with a gasoline engine. Only electric city buses and distribution vehicles that have a high utilisation rate are suitable for cost-effective electrification prior to 2020. After 2020 it is assumed that the cost-effectiveness, supply and performance of (fully electric) passenger cars will reach reasonable levels.

   If the vehicle's cost difference become significantly smaller in the future, the negative GDP impact of electricity-powered car types will also decrease. According to the calculations, wider uptake of electric cars at a later stage, some ten years from now, would result in significantly lower additional costs for the economy than a wide uptake in the near future.

   From the economic point of view, the uptake of electric passenger vehicles should remain very modest at first. It is more cost-efficient to increase their market share only after their prices are significantly lower. This is currently projected to take place after 2025. Thus, a cumulative fleet of rechargeable vehicles could be somewhere between 100,000 and 200,000 vehicles in 2030 in Finland, depending on their share of sales in 2030, and the share of electric vehicles (BEV) versus plug-in hybrid electric vehicles (PHEV). In addition, it is estimated that there will be also about 1,000 electric city buses and a few thousands electric distribution vehicles, as well.

d) **Drop-in fuels** are required to reach the specified emission reduction target of 40%. This is why the use of fully compliant (drop-in) synthetic diesel or gasoline products[13] should grow significantly. Transport would require an additional 600,000 toe/a of domestic biorefinery capacity, depending on their competitiveness and incentives compared to other alternatives and import fuels.

   In the DEVELOPMENT scenario, it is assumed that new Finnish biorefineries will utilise mainly the side-streams of forestry waste and forestry industry as raw materials with gasification or pyrolysis/hydrogenation technologies. They can be either integrated in independent forestry industry or partly adjacent to oil refineries. If the additional biofuel production were to reach a level of 600,000 toe/a, 4 to 7 additional plants would be required, depending on their capacity. This would require of a total of some EUR 1,800 million of investments in the industry.

[12] Gasoline & Biofuels Association Finland (http://www.oil.fi/sites/default/files/3.4_myynti.pdf)

[13] Biocomponents other than bioethanol (currently max. 10% content) can be blended with gasoline according to the drop-in principle. Such components are already produced in the HVO process. It is also possible to use biobased raw material (e.g. tall oil resin) to replace crude oil in the process in the refinery in the production of gasoline components. Neste already does this. It is also possible to manufacture and use biobased ethers, which can bring the share of biobased components up to 20% and over without an excessive oxygen concentration.

The additional demand for wood will be around 2 to 2.5 million m^3 of solid wood per year, depending on the share of black liquor and pine oil fractions in the new biorefinery production. If black liquor, pine oil or pine resin is used as a raw material, the demand for wood will fall. It should also be noted that the development of new technologies and the supporting research and development functions as well as their commercialisation will require significant investments from Finland and the EU. Without them the proposed scenario cannot be implemented by 2030.

Chart 2 depicts the emission reductions achieved by the baseline (CONV) and DEVELOPMENT scenarios.

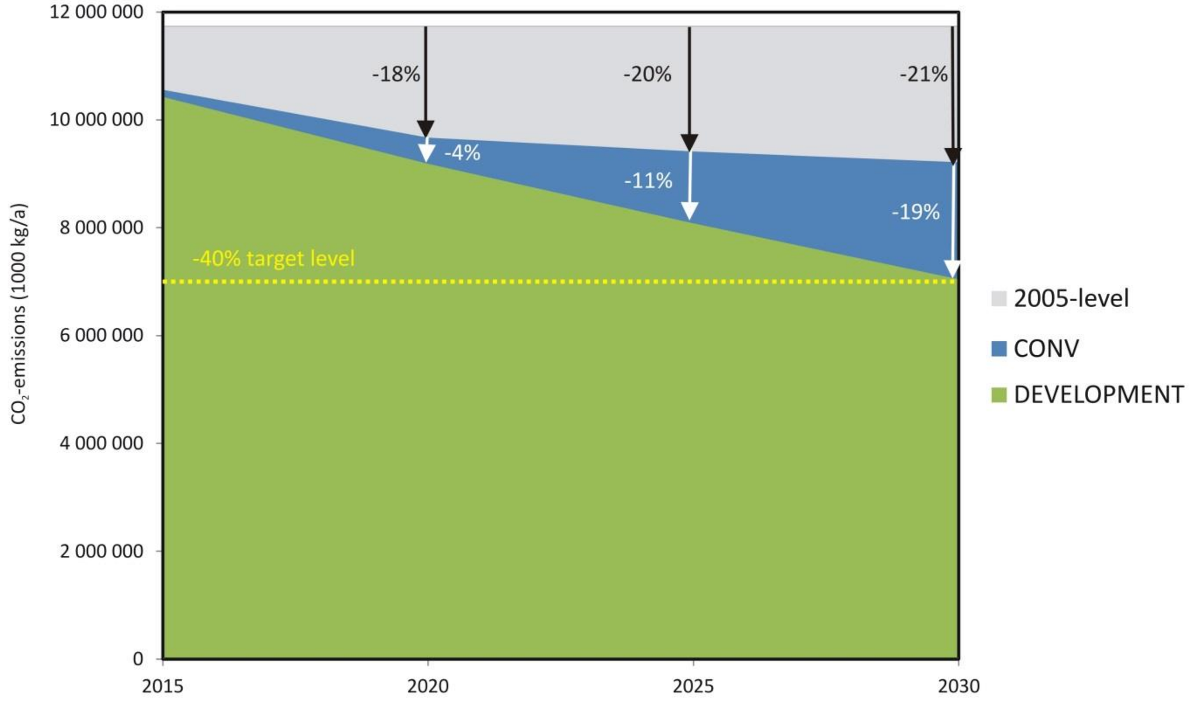

Chart 2: CO_2 emissions of the CONV and DEVELOPMENT scenarios.

Table 4 depicts the emission reductions achieved with the DEVELOPMENT scenario in 2030 and specifies the detailed emission reductions resulting from the use of biogas, electricity and liquid biofuels. The table indicates the extent to which reductions can be achieved with the different technologies. Biogas will contribute an average share of 5%, increased use of electricity some 9% and liquid biofuels the remaining 86% of the total additional reduction requirement (19%). Thus, liquid biofuels are clearly the dominant source in the emission reduction.

Table 4. Emission reductions achieved by the DEVELOPMENT scenario (tonn/a) in 2030 and emissions from the use of biogas, electricity and liquid biofuels.

	Biogas	%	Electricity	%	Liquid bio	%	total	%
Passenger cars	48,241	0.4%	171,090	1.5%	717,033	6.1%	936,364	8.0%
Vans	13,502	0.1%	989	0.0%	221,909	1.9%	236,400	2.0%
Buses	13,205	0.1%	32,869	0.3%	104,530	0.9%	150,604	1.3%
Trucks	33,947	0.3%	-4,464	0.0%	823,413	7.0%	852,897	7.3%
total	**108,895**	**1%**	**200,484**	**2%**	**1,866,885**	**16%**	**2,176,265**	**19%**

5.3 The economic impacts in the DEVELOPMENT scenario

Based on the economic impact analyses, wide-spread use of drop-in fuels would have a minor effect on GDP and on consumer demand in case significant investments are made to domestic biofuel production. However, if all drop-in fuel would be imported, GDP is projected to remain more than 1.5 per cent lower in the long-term than in the baseline scenario. In contrast, large investments in the domestic drop-in fuel production would even increase the GDP minimally compared to the baseline scenario.

Chart 3 depicts the impact of the above-mentioned DEVELOPMENT scenario on the GDP with different assumptions on the future price of electric vehicles.

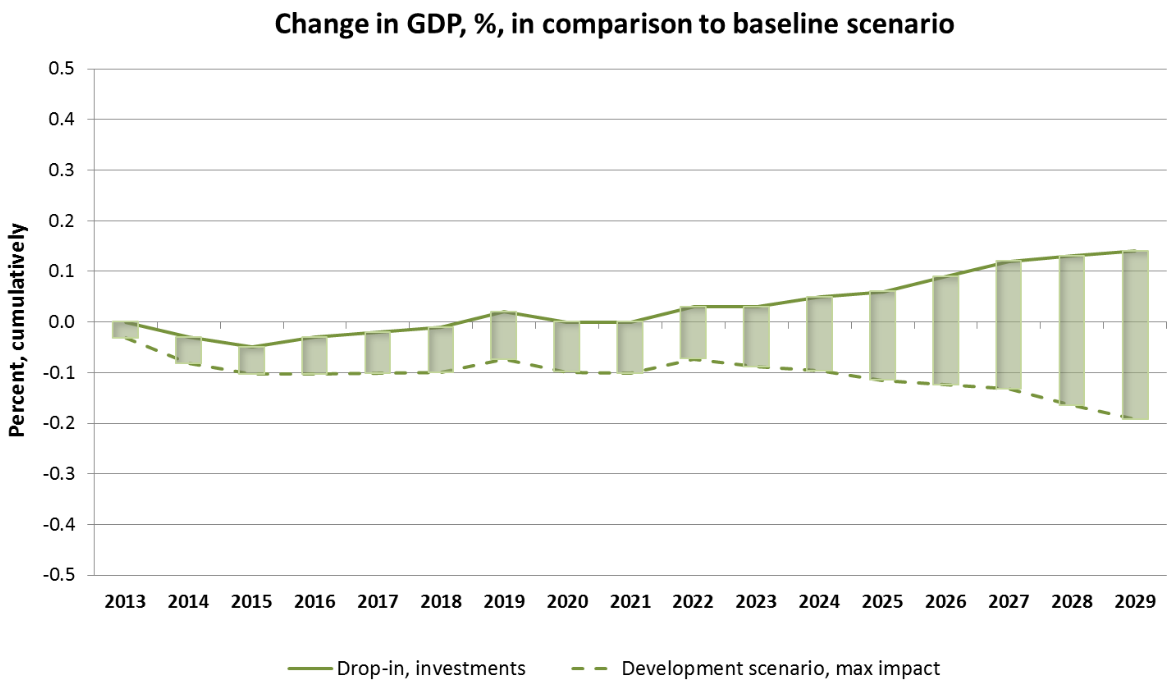

Chart 3: The GDP impact of the DEVELOPMENT scenario (Note the difference in the scale compared to chart 1).

As mentioned, the DEVELOPMENT scenario assumes that uptake of electric vehicles will not take place until about 10 years from now. Most of the emission reductions will results from the use of domestic drop-in fuels. Therefore, there is only a marginal difference in the GDP impacts of the DEVELOPMENT and the Drop-in investment scenarios. However, the final effect of the DEVELOPMENT scenario depends especially on the price developments of electric vehicles. The “Development scenario. max. cost” -line in chart 3 shows the GDP impact if the price of electric vehicles follows the projections presented in section 7. If the price is lower, the GDP impact of the DEVELOPMENT scenario will be somewhere between the two lines in chart 3. Considering that the difference in the long-term cumulative GDP impact between these scenarios is +0.1…-0.2% in comparison to the baseline scenario, it can be concluded that the impact of the DEVELOPMENT scenario is only marginally different from the Drop-in investment scenario. Moreover, change in the value added would remain relatively small in comparison to the GDP impacts of the other technology scenarios depicted in chart 1.

6. Main results and conclusions

The main results and conclusions of the report are the following:

- The baseline option of implementing only current actions will, in 2030, lead to a situation where CO_2 emissions from transport will be already reduced by more than 20% despite the projected growth of fleet mileages. To introduce further emission reductions, it will be necessary to increase the use of low-carbon or carbon-neutral energy in transport. This assessment focuses on propulsion alternatives as such and does not consider any public efforts to influence transport methods or the expected renewal of the vehicle fleet. Based on the economic impact analyses and technology-specific considerations, we were able to identify solutions that can achieve a 30 or even 40% reduction in the transport CO_2 emissions by 2030.
- The most cost-efficient way to reduce emissions is to invest in the production and uptake of domestic, advanced drop-in biofuels. Their use will not require changes on the vehicle fleet or on fuel distribution system.
- Biogas is also a relatively cost-efficient option for reducing transport related CO_2 emissions, but would require a significant increase in the number of gas-fuelled vehicles. However, it is not possible to set obligations for fleet renewal or powertrain choice.
- Major part of the raw material requirements for the new Finnish biofuel factories could be met with the domestic supply of wood and waste materials. With focused public investment support, new technologies can be commercialised so that domestic production is competitive in comparison to imports.
- A sensitivity analysis was conducted to assess the impact of different fossil fuel, biofuels and electric vehicle price assumptions. When the price of biofuels was increased by 30%, and the price of fossil fuels reduced by 30%, the respective order of biofuels and electricity-based options remained unchanged. If the price of electric and combustion engines vehicles would be about the same by 2030, the GDP impact of the electric vehicle scenarios would be significantly closer to the impact in the biofuel scenarios.
- Because of the high price of electric cars, their large-scale uptake will not be cost-effective until technology advancements bring down the costs significantly.
- If the use of gas-fuelled or electric cars would like to be enhanced in the future, it is necessary to identify policies and practices that will work under the Finnish conditions. These could include e.g. the favouring of gas-powered vehicles in public procurement. This would also support the establishment of an effective used-cars-market in the long term. Resale value is a very important factor in consumer purchase decisions of vehicles.

7. Suggested actions

The detailed emission reduction target for Finland might be finalised only around 2016, after the results of the 2015 United Nations Climate Change Conference in Paris become available. Thereafter, decisions on the details of the EU climate and energy package will most likely be made, including the effort sharing decision on binding GHG emission targets for Member States for the transport and other non-ETS sectors.

If the targeted emission reduction for transport sector is around 40%, an additional emission reduction of some 20% is required in the transport sector from the 2005 level in comparison to the baseline scenario (including the 15% of biofuels mandated by the current distribution obligation). This impact analysis focuses on identifying the most cost-effective solutions to reach these additional emission reductions. When selecting suitable propulsion methods, attention must also be paid to the availability of fuels, while creating a favourable environment where all new alternatives could gain ground.

Based on the above, it is possible to suggest the following actions.

- In the selection of steering methods for the transport emissions reductions, it is necessary to consider the maturity of different technologies as well as their economic, social and environmental impacts.
- To promote the market entry of advanced biofuels, the current biofuel distribution obligation should remain also after 2020 and the target for 2030 should be brought to an appropriate higher level. The current trend is focusing on components that replace diesel fuels. A separate solution is required for securing sufficient volumes of biofuels in the market for gasoline-fuelled vehicles. The ethanol content in gasoline blends may well rise from the current 10% content to between 20 and 25%. It is also possible to blend other biobased components with gasoline according to the drop-in principle, which is already done commercially.
- Domestic production must be competitive to avoid a situation where an increase in the use of biofuels leads only to an increased use of imported fuels. The EU and Finland can support new and innovative production facilities and thus reduce the risk to investors. New investments are required in the production of advanced biofuels in Finland (up to EUR 1,800 million), as well as R&D. If the additional biofuel capacity requirement is around 600,000 toe/a, the needed domestic and/or EU investment support for innovative facilities could be even EUR 600 million.
- The main factors preventing the uptake of biogas on a wider scale are the small vehicle fleet and the limited fuel distribution network, not the potential of the feedstock or production capacity. If we want to promote the use of biogas, this problem must be addressed while considering that no direct public support on the procurement of imported vehicles would profitable from the economic point of view.
- Increased wide-scale uptake of electric vehicles and the selection of related policy options will not be topical until after 2020. Preparations can, however, be made, e.g. example by updating the codes and regulations related to buildings to take into account EV recharging possibilities.
- One and the same domestic raw material can be used in the production of liquid fuel, gas and electricity. Thus, taxation should be coherent for all options.
- So-called well-to-wheel analysis should be used in the assessment of GHG emissions of different fuels. It should be made sure at European-wide level that emission reductions achieved with biofuels should have the same ranking as those achieved with renewable electricity. Electric vehicles are currently of more interest to vehicle manufacturers, because electricity is always considered zero-emission fuel, while a vehicle running on biofuel is valued the same way as a vehicle running on fossil fuel.
- To enable smart, low-carbon transport, some EUR 50 million is required by 2020 to support the development of new, sustainable propulsion alternatives, production of advanced biofuels, domestic electric vehicles and their recharging infrastructure, improved energy efficiency as well as the development and wide-scale demonstrations of new service concepts made possible by smart transport. In addition, private companies' demonstration facilities will also require public risk funding.