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Roadmap to renewable methane economy

Extended summary


Finnish Biogas Association and

North Karelian Traffic Biogas Network Development Programme

Publications of North Karelian Traffic Biogas Network Development Programme 2/2012

EUROPEAN REGIONAL DEVELOPMENT FUND
Leverage from the EU 2007–2013
puhas OY
REGIONAL COUNCIL OF North Karelia
Suomen Biokaasuyhdistys
Finnish Biogas Association

Photos: Ari Lampinen (except the historical photo below)

Cover photos: Biogas can be used to power all transport applications:

1. Norwegian LNG fuel cell ship *Viking Lady* in Copenhagen during the United Nations Climate Conference in 2009.

2. CBG train *Amanda* at Linköping station in Sweden in 2009.

3. LBG/LNG dualfuel diesel truck Volvo FM MethaneDiesel at LBG+LCBG station in Gothenburg, Sweden, in 2011.

4. CBG van MB Sprinter 316 NGT and converted CBG car Opel Astra at the 1st Finnish Traffic Biogas Conference and Exhibition in Joensuu in 2010.

Photo below: A snapshot of historical roadmap of renewable methane in transport use:

Ford truck refilling biogas at Rajasaari sewage treatment plant in 1943 (© Photo archive of Helsinki city museum). Finland was one of the pioneer countries, with Sweden and Germany, in taking biogas into transport use. Two biogas refilling stations opened in Helsinki in 1941 and 1943, selling biogas (CBG at 150 and 200 bars) produced at biogas reactors of two sewage treatment plants. They served 92 vehicles, mostly belonging to the municipal fleet of City of Helsinki and its companies. (Lampinen 2011b, 2012)

Finnish Biogas Association (Suomen Biokaasuyhdistys, www.biokaasuyhdistys.net) is a national non-governmental organization of companies, individuals and associations with interest in the biogas field. Finnish Biogas Association promotes the use of biogas technology for production of fertilizers and renewable energy for transport, work engine, power and heat. The primary source material of interest is biowaste (liquid and solid) making the association also a waste management organization in addition to a renewable energy organization. Anaerobic digestion is the core technology, but technologies for production of synthetic biogas (such as thermal gasification of waste wood) and other renewable methane technologies are also included in the field of activities. Use of biogas in transport and mobile machines, such as agricultural tractors, is an active area of interest within the Finnish Biogas Association and many of its 130 members. Finnish Biogas Association is an independent expert organization giving statements and participating working groups and projects for development of legislation and technology. The association gives expert testimonies for Parliamentary and other decision makers, gives presentations for different interest groups, media and the general public, organizes seminars, participates events organized by other organizations and interacts with mass media. The association publishes Biogas magazine (Biokaasu) and other publications, including a series of four municipal decision makers guides for taking municipal biowaste into transport use. These guides are available in Finnish, Swedish and Estonian. Finnish Biogas Association initiated collection of production data from biogas plants in 1994 and publication of the data in Biogas Plant Registries. Biogas magazine, Biogas Plant Registries, municipal decision makers' guides and other publications are available at www.biokaasuyhdistys.net. Finnish Biogas Association is a member of European Biogas Association (EBA) and European natural and biogas vehicle association (NGVA Europe).

North Karelian Traffic Biogas Network Development Programme is an EU ERDF co-funded project (2010-2012) with a purpose to enable establishment of traffic biogas production and refueling network in the province of North Karelia in Eastern Finland. The project is also funded by the Regional Council of North Karelia, several municipalities and companies. The project is administered by regional waste management company Puhas Ltd. owned by municipalities of Joensuu, Kontiolahti, Liperi, Polvijärvi and Ilomantsi. The programme has an important national role, in addition to a provincial role. It created a national traffic biogas information dissemination server at www.liikennebiokaasu.fi ("liikennebiokaasu" means traffic biogas). It also initiated and has organized annual national traffic biogas conference and exhibition since 2010: the latest in the series took place in Joensuu in May 2012. The programme was chosen by the Nordic associations of local authorities and the Nordic Council of Ministers as one of the best examples for climate change work in municipalities of Nordic countries (Nordic authorities 2011).

Preface

This publication is an extended summary of a 133 page publication written in Finnish for Finnish Ministry of Transport and Communications. It is part of work of a task force “Future motive powers in transport” appointed by minister of transport Merja Kyllönen in January 2012. The task force consists of 26 members from ministries, companies and associations related to energy use in transport. By the end of 2012 the task force is to work out targets and plan paths for achieving them for different motive powers in transport in 2020 and 2050. The final report of the task force is to be published in 2013. It will be a national contribution to the work required by the EU white paper on transport. It will also be a contribution to the ongoing work at Ministry of Employment and the Economy for updating national climate and energy strategy and planning an oil independence strategy.

This publication is an extended summary of a sectoral report for renewable methane (RE-methane) and also one of the paths to 2050, called sustainable development path, to be designed during the work of the task force. This publication includes some material that was not included in the original publication, with a purpose of better addressing international audience. Large part of the original publication was devoted to the various environmental, technological, resource efficiency, energy efficiency, economic, health, safety, resource and sociological reasons for making RE-methane a significant part of transport energy consumption already in the short term. This is skipped from the extended summary as is most of the introductory material. The main content – the roadmaps and the toolbox – are covered here, but significantly shortened.

Although the targets for year 2020 are strongly dependent on current national conditions, the targets for 2050 are applicable to all EU countries. Therefore, the sustainable development path could form a model for a corresponding sustainable EU roadmap.

This publication, as well as the original, substantially broader publication written in Finnish and released on 7 June, are available at the WWW server of Finnish Biogas Association (www.biokaasuyhdistys.net) and at the WWW server of North Karelian Traffic Biogas Network Development Programme (www.liikennebiokaasu.fi), which acts as a national traffic biogas server.

Joensuu 1 August 2012 Ari Lampinen

Chairman, Finnish Biogas Association
Project manager, North Karelian Traffic Biogas Development Programme

Contents

Definitions and abbreviations

MF = Methane fuel = Fuel, which energy content comes completely or mostly from methane (CH_4)

RE = Renewable energy

RE-methane = Methane produced by/from renewable energy forms, includes biomethane, wind methane and solar methane, etc.

BM = Biomethane = Methane produced from biomass, includes biogas (BG) and synthetic biogas (SBG)

WM = Wind methane = Methane produced from wind hydrogen and carbon dioxide (from atmosphere or exhaust gases)

FM = Fossil methane = Methane from fossil energy sources (natural gas, shale gas, methane chlatrates etc.) and methane produced thermochemically from coal and other fossil energy sources (SNG)

BG = Biogas = Gas produced microbiologically by anaerobic digestion from biomass, includes reactor biogas and landfill gas; BG can mean raw biogas, purified biogas or upgraded biogas

SBG = Synthetic biogas = methane fuel produced thermochemically from wood or other biomass; SBG can mean raw, purified or upgraded synthetic biogas

NG = Natural gas (one type of fossil methane fuel); NG can mean raw, purified or upgraded natural biogas

SNG = Synthetic natural gas = fossil methane fuel produced thermochemically from coal, peat, crude oil or other fossil energy source

CBG = Compressed biogas, e.g. CBG100 = 100 % biogas, CBG20 = 20 % biogas and 80 % natural gas

CNG = Compressed natural gas

CBM = Compressed biomethane

CFM = Compressed fossil methane

CMG = Compressed methane gas

LBG = Liquefied biogas

LNG = Liquefied natural gas

LBM = Liquefied biomethane

LFM = Liquefied fossil methane

LMG = Liquefied methane gas

ABG = Absorbed/adsorbed biogas)

ANG = Absorbed/adsorbed natural gas

ABM = Absorbed/adsorbed biomethane

AFM = Absorbed/adsorbed fossil methane

AMG = Absorbed/adsorbed methane gas

LCBG station = CBG refueling station, where storage is as LBG

LCNG station = CNG refueling station, where storage is as LNG

Raw gas = Gas obtained from its source (biogas reactor, landfill, natural gas well etc.) without treatment

Purified gas = Gas treated for power and/or heat production (usually onsite)

Upgraded gas = Gas treated for pressurization, liquefaction or injection into gas network (gas in the natural gas networks is upgraded at natural gas production sites)

Traffic biogas = Biogas used in traffic and mobile machines: it is usually upgraded gas, but in some cases only purified gas

Hythane = Mixture of methane and hydrogen for traffic use in methane vehicles

GHG = Greenhouse gas/gases

Notes:

1. Wood gas/producer gas produced by gasification from wood etc. is not a methane fuel, since its main components are carbon monoxide and hydrogen (it also contains methane, but as a minor component)
2. LPG (liquefied petroleum gas) is not a methane fuel, since its main components are propane and butane (it does not contain methane): methane can not be used in LPG vehicles.

1. Introduction

The use of renewable energy sources in transport raises a lot of interest nowadays due to climate change and other environmental issues, and on the other hand due to the proximity of the global peak of crude oil production. Transport is especially vulnerable to crude oil production peak, since crude oil based fuels accounted for over 96 % of global transport energy consumption in 2010 (WEC 2011). Achieving a peak in global crude oil production may have widespread consequences for societies and relations between societies, including armed conflicts.

The scientific foundation for this incoming societal change was laid by geoscientist M. King Hubbert, who in 1956 correctly predicted that the peak in the United States crude oil production would occur in the early 1970's. In 1970's Hubbert utilized similar methodology and predicted global crude oil production to peak in early 21st century. This is often called the Hubbert's peak of which one form is presented in Figure 1.1.

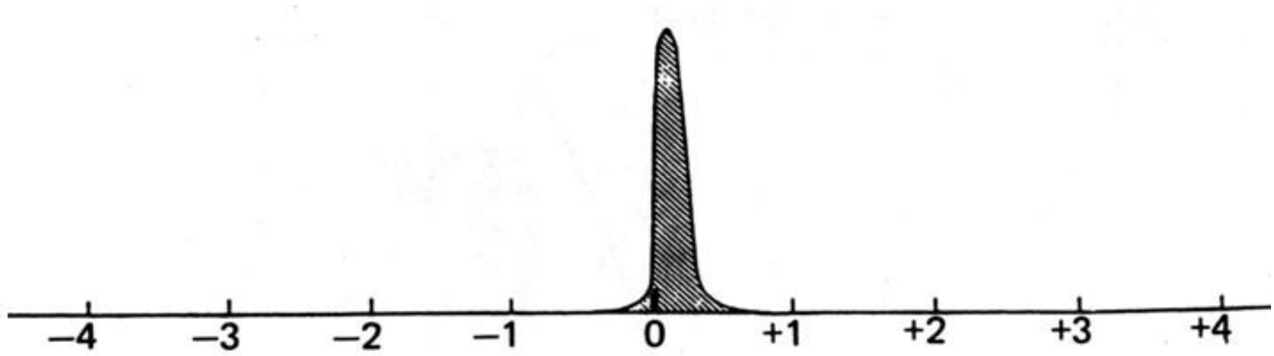

Figure 1.1. The era of crude oil and other non-renewable energy sources is a very short period in the lifecycle of mankind, plotted here in millennia before and after present time. Adapted from Hubbert (1976).

Figure 1.1 illustrates that mankind has survived almost all of its history without using crude oil, other fossil fuels and other non-renewable energy sources. And in rather near future mankind will cease to use crude oil and other non-renewable energy sources continuing its development based again on utilization of renewable energy sources only. The crucial question is how to come down from the peak. Both knowledge-based controlled descent and a chaotic route full of military and other societal crises are possible. History teaches that the latter is unfortunately the more probable way. The purpose of this publication is to try to guide efforts towards the former option. All hard facts would favor the renewable roadmap to the future, if only the sociological development would enable it.

Transformation into renewable energy use after the crude oil era can be considerably delayed by choosing other fossil fuels. Resources of other fossil fuels are adequate for powering global transport for hundreds of years (UN 2000). Negative environmental impacts of this choice would be devastating.

Transport sector increases its greenhouse gas emissions more than any other sector. In the European Union, transport has for a long time been the only sector that still increases carbon dioxide emissions, as shown in Figure 1.2.

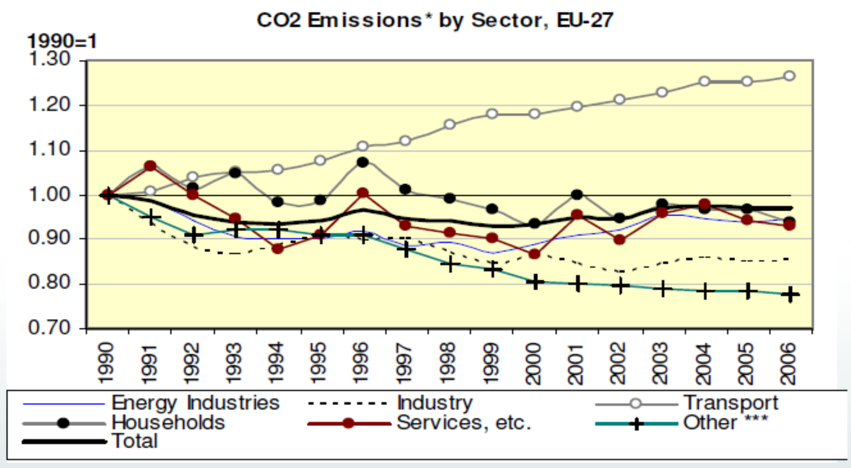

Figure 1.2. Development of carbon dioxide emissions in the EU according to the Eurostat statistics. Transport sector is the only sector, which has increased its emissions since 1990.

Transport is subsidized in the European Union annually by 270-290 billion €, of which road transport receives 125 billion € (EEA 2007). This level of public funding would be adequate for transformation into renewable transport energy system, if the funding were correspondingly addressed. Many steps to this direction have already been taken in the EU level and by member states, and many more will follow. Recent examples of EU level actions are:

- **Renewable Energy Directive** (2009/28/EC) requires minimum of 10 % share of sustainable renewable energy in traffic energy consumption in every EU Member State by 2020.
- **Fuel Quality Directive** (2009/30/EC) sets a 6 % reduction requirement (by 2020 from 2010 level) of greenhouse gas emissions in traffic via the use of alternative fuels.
- **Clean Vehicle Promotion Directive** (2009/33/EC) requires taking environmental impacts into account in public sector purchase decisions of vehicles and transport services.
- **Regulations on pollutant emissions** Euro 6 (715/2007) for cars and vans and Euro VI (595/2009) for heavy trucks and buses improve competitive status of methane especially compared to diesel oil from September 2014 (Euro 6) and from January 2013 (Euro VI).
- **Regulation on CO_2 emissions** (443/2009) for cars (average fleet emissions of manufacturers 130 g/km by 2015 and 95 g/km by 2020) and for vans (175 g/km by 2017). Regulation for heavy trucks and buses is under discussion,
- **The White Paper on Transport** (COM(2011)144) requires breaking crude oil dependence in transport, ending the use of gasoline and diesel oil in city traffic and reducing greenhouse gas emissions from transport by at least 60 % by 2050.
- **The Expert Group on Future Transport Fuels in their first report "Alternative Fuel Strategy"** (FTF 2011a) identifies methane as one of the options for substituting crude oil as an energy source for propulsion in transport. The report includes biogas resource study showing that EU resources of biogas and synthetic biogas are larger than transport energy consumption in the EU.
- **The Expert Group on Future Transport Fuels in their second report "Infrastructure for Alternative Fuels"** (FTF 2011b) identifies methane as the most mature technology to replace crude oil. The report recommends building refueling infrastructure for methane, hydrogen and electricity in every Member State, using directive level requirements if necessary.
- **The Joint Expert Group on Transport & Environment** acknowledged that the main alternative fuels, including biomethane, should be available EU wide (JEG 2011).
- **The Cars 21 High Level Group on the Competitiveness and Sustainable Growth of the Automotive Industry in the EU** in its final report (EC 2012a) identifies biomethane (CBG and LBG), hydrogen, liquid biofuels and electricity as the main options for substituting crude oil. Fossil methane is identified as a complementary fuel and LPG as a possible supplement. Methane represents a mature technology available for all types of vehicles and has a high potential already in medium term. Internal combustion engine will dominate in 2020 in all automotive traffic and in heavy traffic also in the long term. Biomethane and liquid biofuels will be the main fuels used in internal combustion engines. In light traffic also electricity and fuel cells are utilized. A concrete possibility for further decarbonisation is provided by the injection of sustainably produced methane (from biomass or low-carbon electricity, i.e. wind and solar methane etc.), which does not necessitate a change in infrastructure but possibly an expansion of pipelines, depots and distribution facilities. A legislative approach aiming at providing common requirements as to the characteristics of the filling pumps/charging stations is justified and minimum coverage requirements could also be considered to prevent internal market fragmentation and enable free movement of alternatively-fuelled vehicles across Europe. Methane pumps are already well established in some Member States and they have benefited from public support already for the past years. The density of the infrastructure is, however, not yet adequate and public support should continue.

Currently the EU Commission is preparing a "**Clean Power for Transport Package**", which is an EU alternative transport fuels strategy, accompanied by a legislative proposal on infrastructure development for selected fuels, including methane. It will be published in autumn 2012.

Examples of past EU funding decisions are:

- Over 8 billion € has been allocated to clean transport projects from structural and cohesion funds (North Karelian Traffic Biogas Network Development Programme is one example).
- In the EU 7th Research Framework Programme 4.16 billion € has been committed to transport research.
- Green Cars Initiative of the European Economic Recovery Plan has a budget of 5 billion €.
- CIVITAS Initiative has been allocated 180 million €.

New large EU funding sources are e.g.

- TEN-T Connecting Europe Facility (31.7 billion € for transport infrastructure) and
- Horizon 2020 research programme (80 billion €), where "Smart, green and integrated transport" will be one of the key areas, with 6.8 billion €

On the other hand, the EU Commission also has produced negative actions, e.g.

- In the Clean Vehicle Promotion Directive (2009/33/EC) the Commission created a calculation model for lifetime costs in such a way that lifecycle fuel consumption dominates the result instead of emissions. This is directly contrary to the purpose of the directive. This model favours strongly diesel vehicles with large emissions, especially fossil diesel buses, against otto vehicles with low emissions, especially biogas buses. Although it is not compulsory to use this calculation model, it gives a very bad example, which many procurement officials are likely to follow. Several ways to address this problem have been presented by the North Karelian Traffic Biogas Development Programme (Lampinen 2011a).
- In COM(2011)169 the Commission proposed a revision to the Energy Taxation Directive (2003/96/EC) in such a way that environmental impacts have very low weight compared to energy content, and that all fuels, including the most environmentally benign (like biowaste based biogas and wind hydrogen), must have a fuel tax in 2023. Finnish Biogas Association published a position paper, including proposed tax tables to overcome this problem (see Annex). It is generally accepted that all fuels could eventually be taxed (as a control to consumption), but taxing the most environmentally benign fuels should begin only after they have achieved large market share, i.e. displaced most of fossil fuel use.[1] It is clear that environmental impacts should have much larger role than energy content. This is the purpose of revision of the directive, but the proposal of the Commission failed to deliver it. The revision process of the Energy Taxation Directive is still ongoing, i.e. the outcome is not yet known.

The generally correct direction of EU policy development will supposedly eventually end negative incentives like the two examples mentioned above.

The present task force "Future motive powers in transport" of Finnish Ministry of Transport and Communication is one result of the positive EU level actions.

[1] This principle is included in Energy Taxation Directive (2003/96/EC) Article 15(1(g) to enable lowering NG taxes or exempting NG from taxes, if natural gas consumption is less than 15 % of primary energy consumption of a Member State. Several Member States have utilized this option (EC 2012b). Similar principle should be applied to renewable methane in transport use.

2. Key concepts

2.1. Renewable methane (RE-methane)

Figure 2.1 illustrates types of renewable methane. Biomethane is a motor fuel consisting mostly of methane. It is made by upgrading microbiologically produced raw biogas (BG) from biogas reactors or landfills or thermochemically produced raw synthetic biogas (SBG). Upgrading means removing carbon dioxide, and in the case of landfill gas and synthetic biogas also nitrogen, for increasing energy density of the fuel.

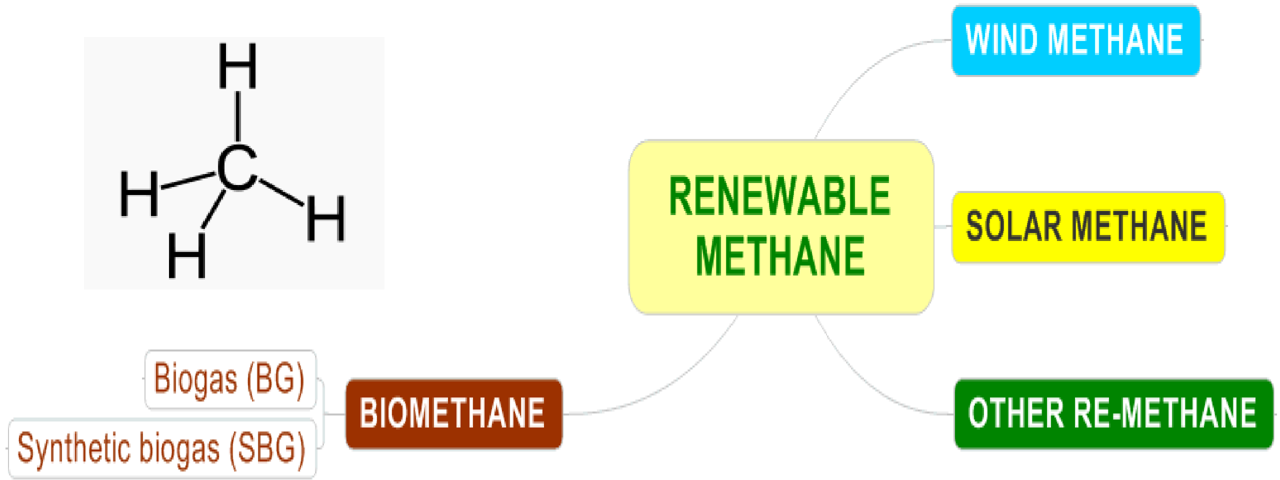

Figure 2.1. Types of renewable methane.

Figure 2.2 shows farm scale biogas reactor, upgrading system and filling station opened in 2002 at Kalmari farm in Finland (Lampinen 2004). It was the first biogas upgrading system and filling station taken into use in Finland after the 1940's (Lampinen 2011b).[2]

Figure 2.2. CBG filling unit, water scrubber based upgrading unit and high pressure gas storage (a) and biogas reactor (b) at Kalmari farm in Laukaa, Finland.

Transport use of synthetic biogas began first in the world in Güssing, Austria in 2009. Figure 2.3 shows 8 MW_{th} steam gasification plant, 1 MW_{th} SBG synthesis plant (including SBG upgrading unit based on amine scrubbing) and SBG filling station.

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[2] During 1940's biogas from two sewage treatment plants was used in 92 vehicles in Helsinki, utilizing two filling stations (Lampinen 2012).

Figure 2.3. Synthetic biogas production plant and SBG refilling unit in Güssing, Austria.

Wind methane is produced by Sabatier reaction from wind hydrogen and carbon dioxide (Fig. 2.4). Wind hydrogen means hydrogen produced by electrolysis from water using wind power as the energy source. Carbon dioxide originates from atmosphere or smoke stacks. Commercial production of wind methane is scheduled by Audi to begin in 2013 in Germany using CO_2 from a biogas power plant in Werlte. First demonstration plant of SolarFuel company has operated in Stuttgart since 2009. In addition, there are currently also four other ongoing power-to-gas plant projects in Germany.

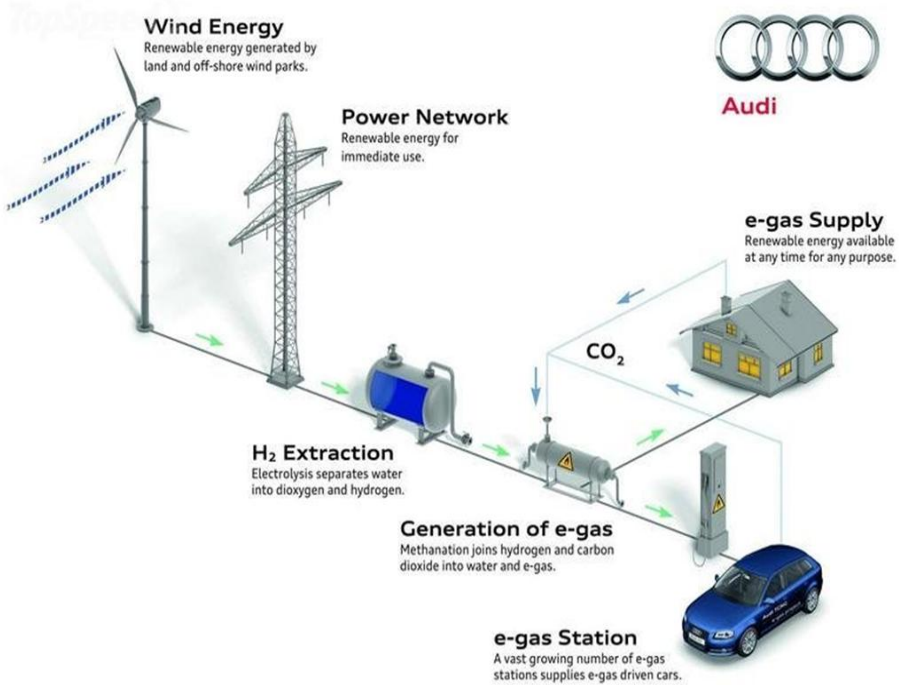


Figure 2.4. Production and use of wind methane (Audi 2011).

Wind methane is transported in the gas grid just like biomethane. Therefore, the gas grid also acts as storage for wind power.[3] In the German gas grid storage capacity is 217 TWh, but it is only 0.04 TWh in the German electric grid. This power-to-gas technology solves the storage problem of intermittent renewable energy generation, especially wind, solar and wave power.

[3] Sometimes gas produced by electricity is called e-gas.

2.2. Fossil methane

Figure 2.5 illustrates types of fossil methane. Fossil methane is produced by upgrading raw natural gas (NG) and other methane containing primary fossil energy sources (like shale gas and methane chlatrates) and synthetic natural gas (SNG) manufactured thermochemically or by other means from coal or other primary fossil energy sources. Coal based compressed SNG was the first methane fuel taken into transport use in the world. This took place in Germany in the 1920's (Lampinen 2012).

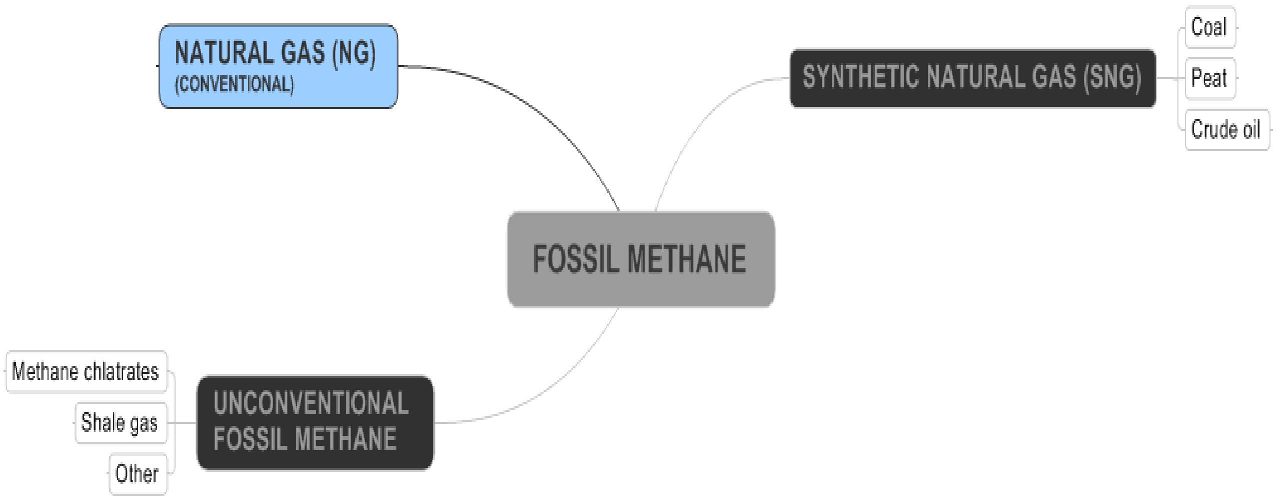


Figure 2.5. Types of fossil methane.

Natural gas and other fossil methane fuels are not suitable for traffic engine use without upgrading. Therefore, upgrading is used in fossil methane production just like it is used in renewable methane production.[4]

Natural gas decreases lifecycle greenhouse gas emissions compared to gasoline and diesel oil. But other types of fossil methane may increase greenhouse gas emissions substantially, even 3-fold, compared to gasoline and diesel oil (EC 2011).

2.3. Compressed (CBG), liquefied (LBG) and absorbed/adsorbed (ABG) biogas

Biogas (and other types of methane fuels) are currently used commercially in vehicles as compressed (CBG, see examples in cover photos 2 and 4) or liquefied (LBG, see examples in cover photos 1 and 3) form. CBG is usually the fuel of choice for cars, vans and light transport, but also for urban buses, boats, locomotives and mobile machines. LBG is used in heavy transport like trucks, intercity buses, ships and locomotives, since it has three times higher energy density than CBG. ABG is in demonstration phase: it may come into commercial market as a solid storage option.

2.4. Renewable methane economy

There is no need to wait for a possible hydrogen economy. Methane already has large share of global energy consumption and its infrastructure is widespread. Methane can be used as an energy carrier (secondary energy source) for all primary renewable energy sources just like hydrogen (Fig. 2.1), but it is easier and safer to use, store and transport than hydrogen.

[4] It is a very common misconception that biogas needs upgrading, but natural gas does not need it. Both need upgrading for transport use and for injecting into gas grids.

Sustainable renewable methane can be used in all forms of transport and all traffic engine types. And it can be used in power and heat production, too. Therefore, energy systems could be based on renewable methane as the main carrier. This is called a renewable methane economy.

Renewable methane economy and renewable hydrogen economy fit together. Both gases can be transported in the same local, national and international gas grids. Intelligent gas grids will have crucially important role as a storage media for intermittent renewable energy sources, such as solar, wind and wave energy. Since storing methane is easier, methane will be more important than hydrogen. In addition to intelligent gas grids, renewable methane economy also includes the use of intelligent electromagnetic power grids. They, however, have poor energy storage potential (Chapter 2.1) and, therefore, require the use of renewable methane grids to be able to achieve large share of intermittent renewable power and large fluctuations of power demand. On the other hand, requirement for reserve power plants will be less than in the current energy system.

Renewable methane economy offers large opportunity for the use of renewable hydrogen in transport as hythane, i.e. mixture of methane and hydrogen (Fig. 2.6). Ordinary methane vehicles can, without changes, use hythane with hydrogen content of up to 5-20 % depending on the vehicle. It means that a large existing vehicle fleet of some 16 million is already now available for the use of hydrogen, whereas vehicles for pure hydrogen are very rare and expensive.

Figure 2.6. Filling units of methane, hydrogen and hythane at campus of University of California, Davis.

There are also hythane vehicles, which have been made for higher than 20 % hydrogen content (Fig. 2.7). And there are vehicles that can use pure methane, pure hydrogen and any mixture of them (Fig. 2.13).

Figure 2.7. Fiat Panda Aria can use 30 % hydrogen.

Another benefit of hythane use is essentially lower purity requirements of hydrogen than those needed for use of pure hydrogen (at least 99.99 %) in fuel cell vehicles. It enables the use of simpler and cheaper hydrogen production methods.

2.4.1. Transport fuel suitability

Expert group of future transport fuels appointed by the EU Commission gave in their report published in January 2011 (FTF 2011a) an estimate of suitability of alternative transport fuels in various transfer modes (Fig. 2.8).

		Road/passengers			Road/freight			Rail	Water			Air
		short	med	long	short	med	long		inland	short-sea shipping	maritime	
Electric	BEV	■			■			■				
	HFC	■	■		■			■	■			
	Grid	■			■			■				
Biofuels (liquid)		■	■	■	■	■	■	■	■	■	■	■
Synthetic fuels		■	■	■	■	■	■	■	■	■	■	■
Methane	CNG	■	■	■	■	■						
	CBG	■	■	■	■	■						
	LNG	■	■	■	■	■	■	■	■	■	■	
LPG		■	■	■	■	■	■		■	■		

Figure 2.8. Suitability of alternative fuels in transfer modes (FTF 2011a, 44).

This assessment ignores LBG (cover photo 3), other RE-methane types except biomethane (e.g. wind and solar methane, Fig. 2.1) and suitability of methane in several modes of transport: CBG is already used in rail (cover photo 2) and water transport (Fig. 2.9) and LBG is possible in air transport[5].

Figure 2.9. CNG water taxi and filling station for CNG boats in Amsterdam.

Table 2.1 is an updated suitability diagram. In addition to CBG and LBG, in the future ABG (absorbed/adsorbed biogas) may become commercially available, but it is not shown in the table.

Table 2.1. Suitability of methane in transfer modes.

		Road/passengers			Road/freight			Rail	Water			Air
		short	med	long	short	med	long		inland	short-sea shipping	maritime	
Methane	Pressurized	■	■	■	■	■		■	■	■		
	Liquefied	■	■	■	■	■	■	■	■	■	■	■

[5] LNG was proven in Tupolev-155 in 1980's. Currently Airbus and Boeing are developing LNG airplanes.

Methane is the only fuel, which is used in all heat engine types applied in motorized transport, i.e. otto (cover photos 2 and 4), 2-stroke, diesel (cover photo 3), wankel, stirling, steam, jet and rocket engines as well as steam and gas turbines. It is also used in fuel cells, especially direct methane fuel cells (cover photo 1). And it is utilized in hybrid power trains combining heat engines and electric motors (Fig. 2.10). It could also be utilized in hybrid systems with compressed air motors.

Figure 2.10. Biogas (CBG) hybrid bus in Uppsala, Sweden, using biogas produced at sewage treatment plant. City buses are the most important short term applications of traffic biogas.

North Karelian Traffic Biogas Network Development Program has created a database showing over 900 different types of available methane vehicles, including light and heavy road vehicles, mobile machines (Fig. 2.11) and rail, water, air and space vehicles.[6]

Figure 2.11. Valtra dualfuel-diesel biogas (CBG) agricultural tractor at 3rd Finnish Traffic Biogas Conference and Exhibition in Joensuu, 28 May 2012. It can also use biodiesel (B100).

[6] The biogas vehicle database is available at http://www.liikennebiokaasu.fi/Biokaasuajoneuvotietokanta.pdf.

2.5. Fuel flexibility and fuel diversity

While **monofuel** vehicles (cover photo 2 and Fig. 2.10) can utilize only one fuel type, fuel flexibility means a capability of a vehicle to use more than one fuel type, either factory made or after retrofitting. Methane monofuel vehicles, and all other types of methane vehicles, can always use biogas, natural gas and other types of methane fuels, both renewable and fossil.

Bifuel methane cars (cover photo 4), which are the most common types of methane cars, are able to use gasoline. Also many other types of bifuel methane vehicles exist, e.g. methane/HFO in steam turbine LNG tankers.[7]

Dualfuel methane vehicles can utilize methane together with diesel fuel, and also 100 % diesel fuel (cover photo 3 and Fig. 2.11).

Multifuel methane cars can utilize at least three different fuels, e.g. ethanol (E100 or E85) in addition to methane and gasoline (Fig. 2.12).

Figure 2.12 Methane/ethanol/gasoline multifuel cars: a) Fiat Siena Tetrafuel (E100) in Manaus, Brazil. b) Saab Trifuel (E85) in Gothenburg, Sweden.

There are also other types of multifuel methane vehicles. Valtra Tractor in Figure 2.11 is not only a dualfuel vehicle able to use methane and diesel oil, but it is also a multifuel vehicle, since it runs on biodiesel (B100), too.

Retrofitting offers even larger fuel flexibility that is available in factory made vehicles. Figure 2.13 shows a retrofitted SUV, which is able to use 100 % methane, 100 % hydrogen or any blend of them (including standard hythane), as well as 100 % methanol (M100), 100 % ethanol (E100), 100 % gasoline and any blend of them (including E10 and E85). It was retrofitted by a Californian company Intergalactic Hydrogen.

Plug-in hybrid technology can be utilized in any of the above mentioned methane vehicle types adding the possibility to use grid electricity.[8]

Figure 2.13. Retrofitted methane/hydrogen/ethanol/methanol/gasoline multifuel Toyota SUV at a renewable energy fair in California in 2004.

[7] There are over 300 such ships transporting LNG globally.

[8] Note: most current hybrid vehicles, such as the bus in Fig. 2.10, are monofuel vehicles, i.e. not able to utilize grid electricity.

Fuel flexibility is an inevitable automotive trend, because gasoline and diesel oil will be replaced by large amount of different fuels, i.e. **fuel diversity** will substantially increase. In some places, like Stockholm (Fig. 2.14) this has been reality for a long time already, although in most places of the world such is still considered science fiction, at most.

Figure 2.14. Biowaste based biogas, ethanol and RE-electricity (fast charging) are sold at a service station in Stockholm in 2001, the year of Arthur C. Clarke.

Therefore, intelligence of vehicles to utilize multiple fuels is of paramount importance.

2.6. Decarbonization

Global energy use has followed a decarbonization trend since the 19th century (Fig. 2.15). It means that in chemical fuel use the share of energy coming from oxidizing carbon atoms is decreasing and the share of energy coming from oxidizing hydrogen atoms is increasing. Development has gone from solid fuels, with the largest carbon content, to gaseous fuels, with the lowest carbon content. Methane has the lowest carbon content of any hydrocarbon fuel. Hydrogen is the ultimate solution, since it is carbon free. Of course, the whole lifecycle of the fuels must be considered. Gaseous fuels have inherently better mixing with oxygen in the combustion process than liquid and solid fuels and, therefore, result in lower pollutant emissions. Since gaseous fuels consist of light molecules, combustion process does not result in heavy molecules, which include the most dangerous pollutants from health perspective.

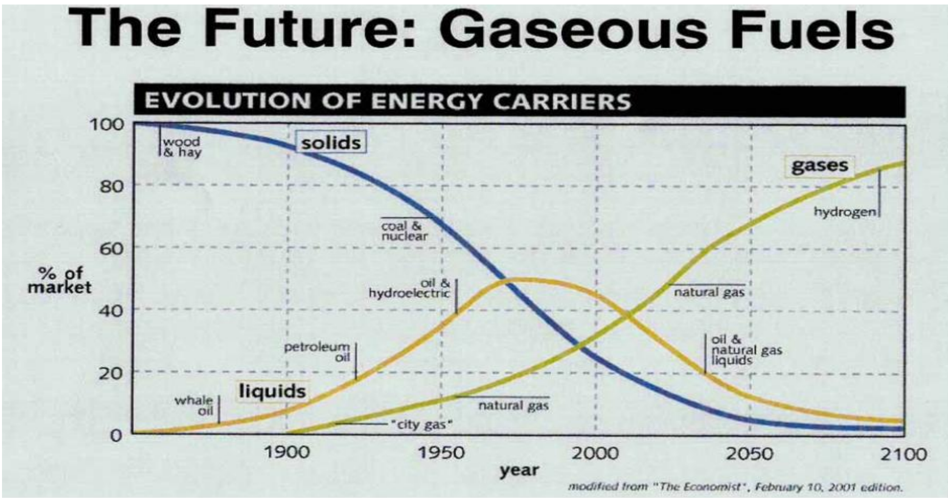


Figure 2.15. Global decarbonisation trend of energy sources. Modified from The Economist, 10 February 2001.

3. Methane utilization targets for year 2020

3.1. Consumption targets

Targets for methane vehicles and their consumption in Finland in 2020 are presented in Table 3.1.

Table 3.1. Methane vehicle status in 2011 and targets for 2020 in Finland.

Vehicle class	Amount 2011	Notes	Amount 2020	Consumption 2020 [GWh]	Notes
HDWs	136		1500	660	buses and heavy trucks
LDWs	77		10.000	600	vans and pick-up trucks
Cars	621		48.500	730	
Mobile machines	22	2 agricultural tractors and 20 forklifts	200	1	
Light vehicles	1	snowmobile	100	< 0.1	
Rail vehicles	0		20	28	locomotives and trams
Water vehicles	0	first in 2013: *Viking Grace* (250 GWh/a) and UVL 10	20	500	ships, boats and ferries
Air vehicles	0		0		
Space vehicles	0		0		
TOTAL	857		60340	2500	

For road transport the target is based on the model of historical development in Sweden and development targets in Germany. In Germany target is to achieve for methane vehicles 4 % share of registered road vehicles by 2020 (DENA 2011). It means a growth from 90.000 vehicles in 2011 to 1.4 million vehicles in 2020.

For Finland a lower target of 2 % share is set resulting in a development shown in Figure 3.1. To achieve it 4.6 % of vehicles registered between 2012 and 2020 should be able to use methane.

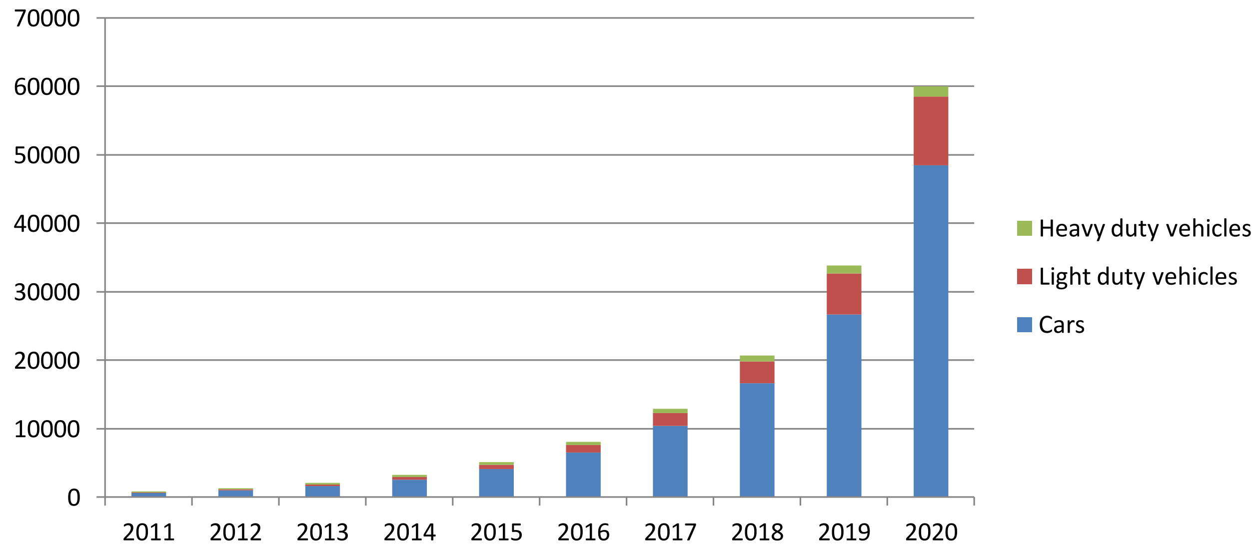


Figure 3.1. Targets for road methane vehicle development in Finland until 2020.

For rail transport the target is 20 units, which can be trains, like in Sweden (cover photo 2), and/or trams, like planned in Bristol (Sustraco Bristol Tram Consortium 2010).

Development is fastest in water transport. In 2013 two first LNG ships will come into service. They are large passenger ship *Viking Grace* for service between Turku and Stockholm and border patrol ship *Ulkovartiolaiva 10*. Their combined methane consumption is 300 GWh/a. Target for 2020 is 20 ships, ferries and boats.

Some mobile machine and light transport is expected to utilize methane, but not yet air transport by 2020.

Of the 2.5 TWh target in 2020, 40 % (1 TWh) would be biomethane (almost all biogas based, but also some synthetic biogas) and 60 % fossil methane (all natural gas based). To reach the BG objectives raw biogas production, which was 0.7 TWh in 2011[9], would need to double. The NG target is easy, since it represents less than 4 % of current natural gas consumption in Finland.

3.2. Production and distribution targets

Targets for biomethane production until 2020 are given in Table 3.2. Wind methane and other RE-methane types are not assumed to be produced yet in 2020.

In July 2012 there are three upgrading plants operating in Finland. One is feeding via natural gas grid to 14 CBG filling stations operated by Gasum Ltd. (Fig. 5.2) and two are producing for local CBG filling stations operated by Metener Ltd. (Fig. 2.2) and MetaEnergia Ltd. Total annual biomethane production capacity of these plants is 8 GWh.

By the end of 2012 three other upgrading plants with production capacity of 20 GWh/a are planned to be taken into use. In addition, there are plans for 17 other upgrading plants to be constructed be the end of 2017, including one SBG plant with capacity of 1600 GWh/a. Of these 23 upgrading plants 8 would be feeding into natural gas grid and 15 directly into CBG filling stations. Target for 2020 is 28 biogas based biomethane plants producing 1 TWh mostly for transport use and 2 synthetic biogas based biomethane plants producing 3 TWh mostly for CHP use.

Table 3.2. Biomethane production and distribution: current situation and development targets until 2020. (BG=biogas, SBG=synthetic biogas)

Year	Upgrading plants	Production [GWh]	Notes	Biomethane filling stations
2010	1	0.7	Kalmari farm in Laukaa since 2002 (BG)	1
2011	2	2	New: Kouvola municipal plant (BG)	15
2012	6	10	4 new (BG)	20
2013	9	40	3 new (BG)	30
2014	12	140	3 new (BG)	40
2015	15	240	3 new (BG)	50
2016	18	1000	3 new (2 BG and 1 SBG)	60
2017	21	2000	3 new (BG)	70
2018	24	2200	3 new (BG)	80
2019	27	3000	3 new (2 BG and 1 SBG)	90
2020	30	4000	3 new (BG)	100

[9] Finnish biogas production statistics has been collected into Biogas Plant Registries since 1994. They are available at the www server of Finnish Biogas Association: http://www.biokaasuyhdistys.net/.

4. Sustainable development path for transport to 2050

Sustainable development path is one of the paths created during the work of the task force “Future motive powers in transport” of Ministry of Transport and Communications. The main basis for the path is Government Foresight Report on Long-term Climate and Energy Policy: Towards a Low-carbon Finland, which gives the national target of reducing greenhouse gas emissions by 80-95 % from 1990 levels by 2050 in all sectors, including transport (Finnish Government 2009). It overrides the less ambitious transport sector EU target of 60 % reduction – and also substantiates the need of scaling up the EU target.

> The average lifetime of automobiles is about 10 years, whereas heating plants last over 20 years and power plants over 30 years. Therefore, dissemination of new technology can be faster in transport sector than other energy sectors. By 2050 power plants can be renewed only once and heating plants twice, but vehicle fleets three times.

Another important domestic background is the vision of distributed bio-based economy in 2050, published by the Finnish Innovation Fund (Luoma et al. 2011). It shows how the whole energy system in Finland could become 100 % renewable, mostly using distributed energy technologies.

The European Commission’s White Paper on Transport (COM(2011)144) and two reports (FTF 2011a-b) of the European Expert Group of Future Transport Fuels appointed by the European Commission give background data and recommendations that are used in the sustainable path.

The Swedish oil independence strategy (Sveriges Regeringskansliet 2006), the Swedish vision for a sustainable transport system (Hunhammar 2001), the Danish renewable energy strategy (Danish Government 2011) and the German biomethane development goals (DENA 2011) are the main foreign examples used as a model in designing the sustainable development path.

The path follows the general global trend of decarbonisation shown in Fig. 2.15 and described by the United Nations Intergovernmental Panel on Climate Change (IPCC 2000, 207).

4.1. Goals

Eight main goals are set as a result of the following policy drivers:

1. Greenhouse gas emissions from transport decrease by at least 95 % from 1990 level. Driver: climate policy, especially Government Foresight Report on Long-term Climate and Energy Policy (Finnish Government 2009).
2. Use of gasoline, diesel oil and other crude oil based transport will end, first in cities, then elsewhere. Use of diesel engines in city transport is the most urgent. Driver: air quality policy, especially the White Paper on Transport: COM(2011)144.
3. Use of monofuel cars able to use only gasoline or diesel oil will end by 2030. Driver: peak oil, especially the Swedish oil independence strategy (Sveriges Regeringskansliet 2006).
4. Solar and wind energy are the most important primary energy sources and other sustainable emission-free renewable energy forms are also used, as well as waste and by-product based bioenergy with fertilizer recycling, but not non-renewable energy sources. Energy is transported and stored in intelligent gas and electricity grids. Driver: energy security, especially the vision of distributed bio-based economy in 2050, published by the Finnish Innovation Fund (Luoma et al. 2011).
5. Use of liquid biofuels will end in road transport. Driver: decarbonisation (Fig. 2.15) and air quality policy (health concerns).
6. Energy consumption in transport will decrease by 2/3. Driver: energy efficiency, especially Finnish Government (2009).
7. Use of field energy crop based biofuels will end by 2030. Driver: ecological sustainability, especially the sustainability requirements of biofuels in the Renewable Energy Directive (2009/28/EC).
8. Natural gas will initially be used more than RE-methane and will continue supporting RE-methane use in decreasing role until its use ends by 2050. Driver: environmental and energy security policy.

Table 4.1 shows transport energy sources in the sustainable development path in 2050 in Finland, with a Swedish comparison.

Table 4.1. Transport sector sustainable development goals in Finland and in Sweden. Source of the Swedish case is Hunhammar (2001).

Goal	Sweden 2040	Finland 2050
Primary energy	100 % sustainable renewable energy	100 % sustainable renewable energy
Main sources		solar energy, wind energy
Complementary sources		bioenergy, hydropower
Supplementary sources		geothermal power, wave power
Speculative sources		tidal power, ocean current power
Secondary energy	100 % renewable energy	100 % renewable energy
Main sources	electricity, hydrogen, methanol*	methane, hydrogen, electricity
Complementary sources		dimethyl ether (DME)
Supplementary sources		compressed air, maglev, wood gas, bio-LPG
Speculative sources		other indirect RE-power technologies, other RE gases, other emission free technologies
Use of gasoline, diesel oil and other fossil fuels	not used	not used
Use of liquid RE-fuels	methanol*	not used
Final energy consumption of motorized transport	35 TWh/a (2/3 decrease)	20 TWh/a (2/3 decrease)
GHG emission decrease from 1990	100 % CO_2 neutral	at least -95 %

*In Sweden methanol development goals have been replaced by biomethane goals after publication of the scenario in 2001.

4.2. Roadmaps

Roadmaps are given below for light and heavy road transport, rail, water and air transport. Colour codes in the bar diagrams are:

- Shades of red: liquid fossil fuels (gasoline, diesel oil, light fuel oil, heavy fuel oil, kerosene)
- Yellow: liquid biofuels
- Orange: natural gas
- Shades of green: renewable gases (methane, hydrogen, DME)
- Blue: renewable electricity directly and indirectly (compressed air, MAGLEV etc.)
- Purple: other electricity
- Brown: other (bio-LPG, wood gas and other RE-gases, other emission free RE-technologies)

In each bar liquid fuels are found in the left, gaseous fuels in the right and electricity and other motive powers in the middle.

Replacing crude oil based fuels takes place in two or three phases. In the first phase diverse liquid biofuels have the main role. In the second phase gaseous renewable fuels are the most important. In the third phase, in light road transport, renewable electricity will have a large role.

Roadmap of light road transport is shown in Fig. 4.1. Liquid fossil fuels dominate still in 2020, but the share of biofuels will grow to 20 % due to transport fuel sales quota obligation (Act 446/2007). Most of the biofuels are expected to be used as low-blend liquid biocomponents with gasoline and diesel oil. Target for biomethane is 10 % of the biofuel quota, which means 2 % of all fuels.

By 2030 the share of liquid fossil fuels has decreased substantially, but they still cover more than half of consumption. Many liquid biofuels are in use and they are still the most important renewable fuels. Also RE-methane and RE-electricity (incl. RE-compressed air) have large presence in the market.

In 2040 renewable energy sources have become dominant, especially RE-electricity and RE-methane, but also RE-hydrogen. The share of liquid biofuels is decreasing.

In 2050 fossil energy is no more used. RE-electricity directly and indirectly, RE-methane and RE-hydrogen are the main energy sources.

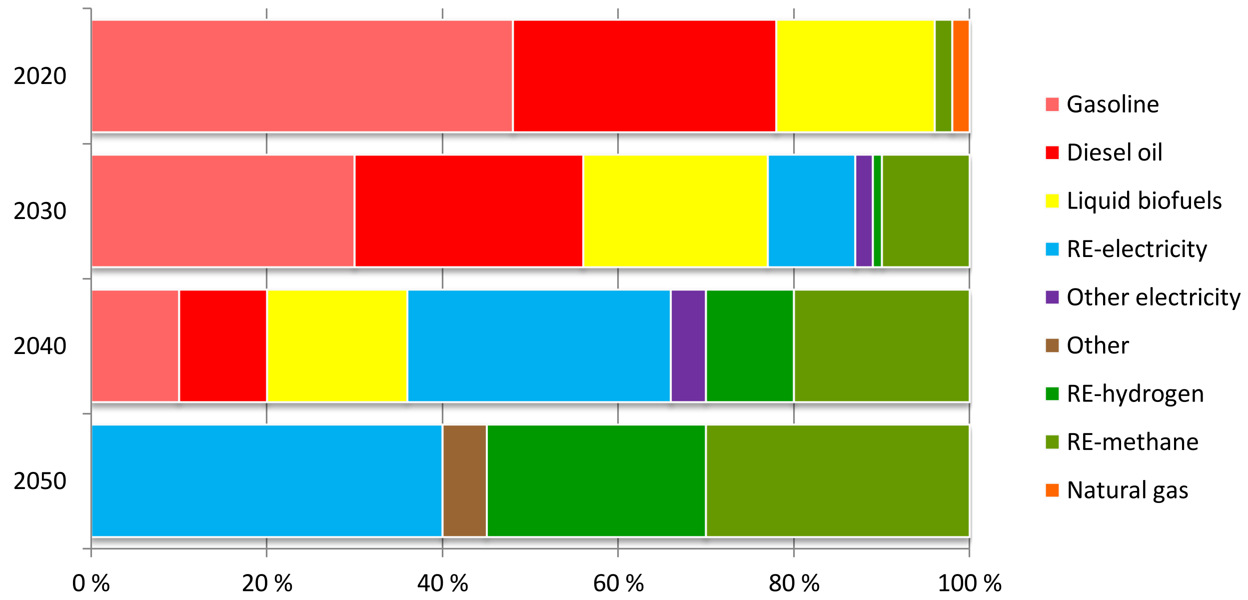


Figure 4.1. Roadmap of light road transport 2020-2050.

Roadmap of heavy road transport is shown in Fig. 4.2. Transport fuel sales quota obligation will bring biofuels into significant role in 2020, like in light road transport. At first, liquid biofuels will be the main choices in replacement of fossil diesel oil. After 2030 RE-methane will take the main role, followed by bio-DME and RE-hydrogen. Electricity will have a minor role.

Mobile machines will follow development of both heavy and light road transport, because same engines are used.

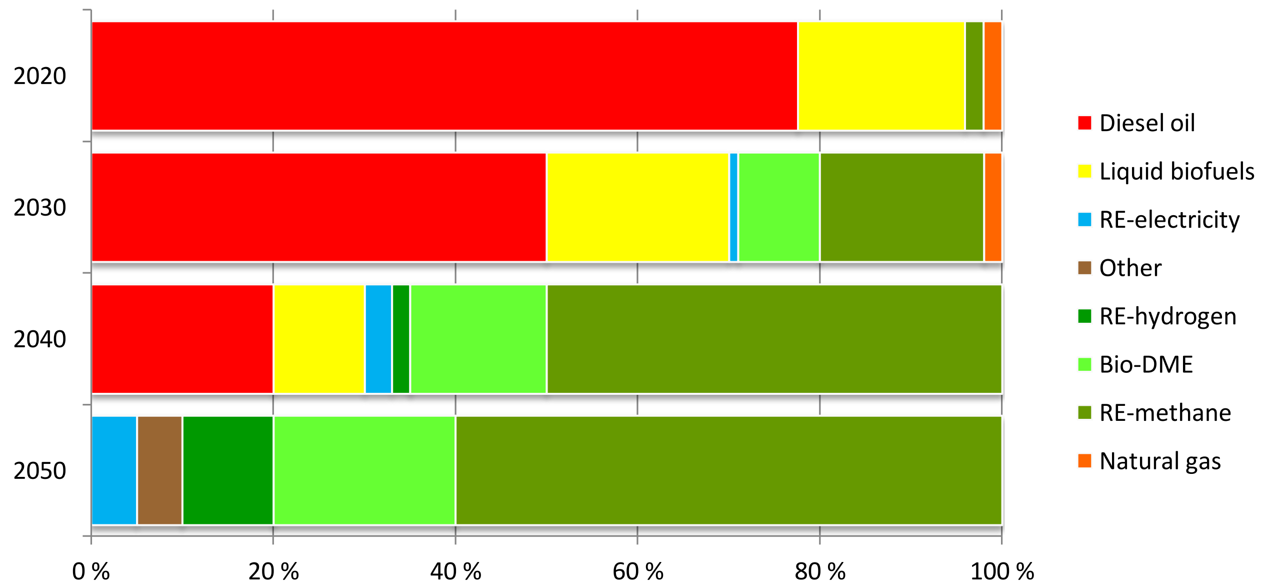


Figure 4.2. Roadmap of heavy road transport 2020-2050.

Roadmap of rail transport is shown in Fig. 4.3. Rail transport vehicles and infrastructure is owned by State (railway) and municipal (trams and metros) companies making it easy to decide on motive power choices by means of ownership policy, without the need of regulatory actions. Use of non-renewable electricity will end by 2020 and fossil diesel oil by 2030. Although RE-electricity (including indirect technologies like MAGLEV) will dominate, not all rail transport will be electrified. In the non-electric rail transport diesel oil is replaced by liquid biofuels, bio-DME, RE-methane and RE-hydrogen.

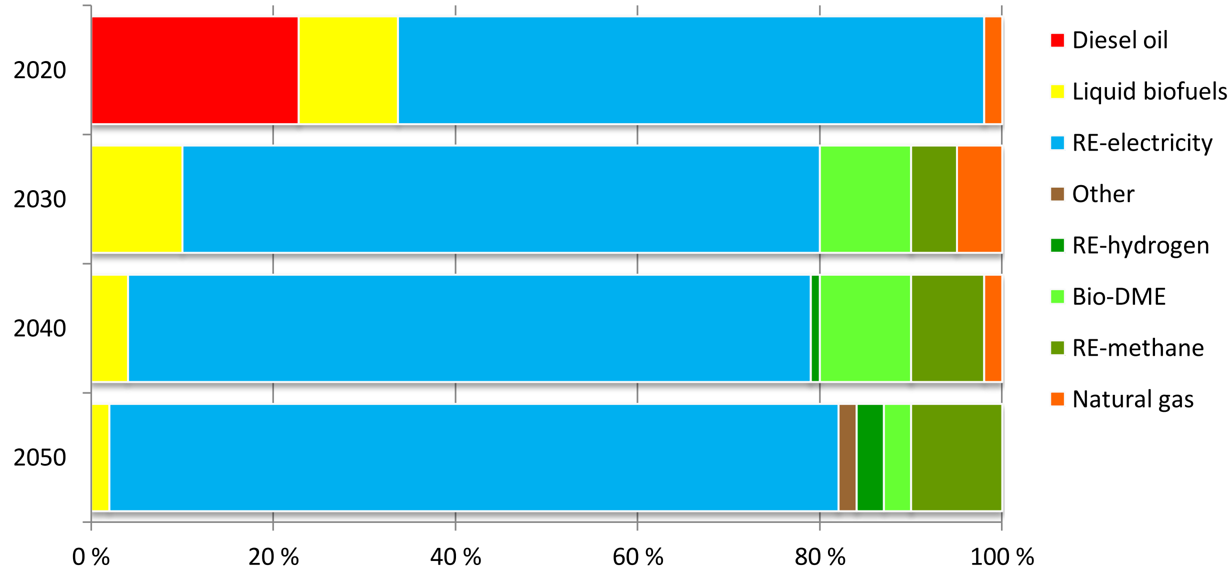


Figure 4.3. Roadmap of rail transport 2020-2050.

Roadmap of water transport is shown in Fig. 4.4. In water transport UN/IMO emission treaties have the largest impact in the near term. Use of heavy fuel oil will end, tax relief of light fuel oil will end and diesel oil use will be reduced. Fossil fuels are displaced first by natural gas (mostly LNG) and liquid biofuels. Later RE-methane (mostly LBG) and RE-hydrogen (mostly LH2) will become the main fuels. Also bio-DME and electricity (including indirectly by MHD technology) will have a role as well as many other emission free technologies, like mechanical wind and wave power.

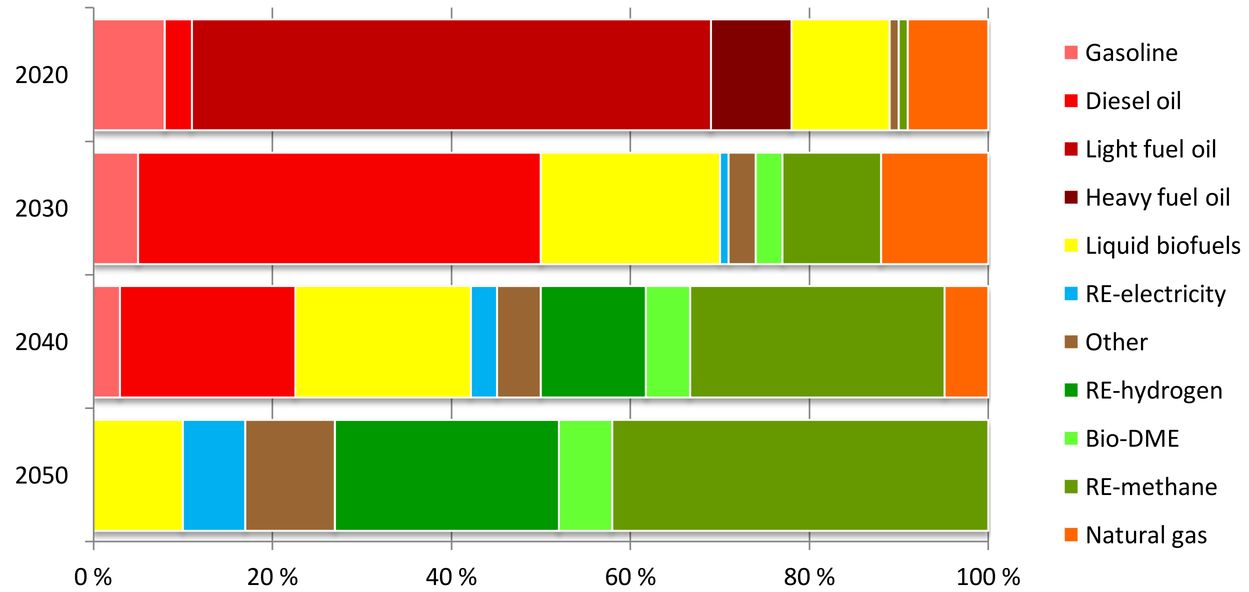


Figure 4.4. Roadmap of water transport 2020-2050.

Roadmap of air transport is shown in Fig. 4.5. Kerosene will be dominant fuel still in 2030, but liquid biofuels will increase their share. In 2040 also RE-methane, RE-hydrogen, bio-DME and RE-electricity (especially in air ships) will have visible roles, as well as natural gas. Almost all gaseous fuel use will be in the form of liquefied gas, but possible adsorbed/absorbed gas as well. Use of compressed gases is marginal.

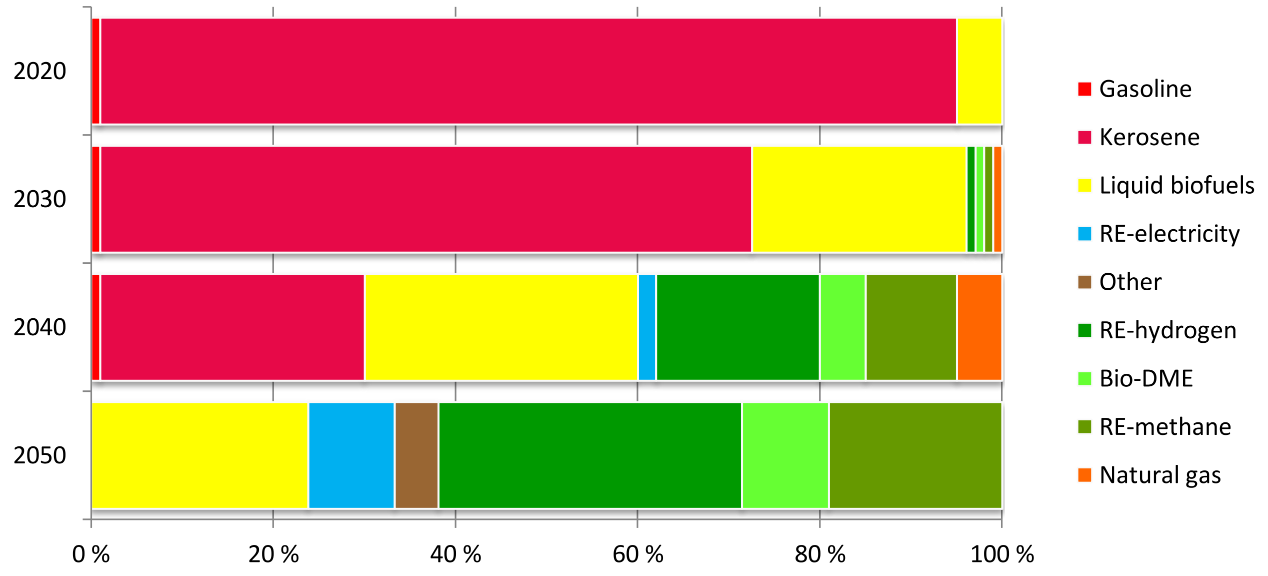


Figure 4.5. Roadmap of air transport 2020-2050.

It is assumed that by 2050 also space transport business will exist in Finland. For that application there are many RE technologies available, of which RE-hydrogen and RE-methane are two examples.

4.2.1. Role of RE-methane

Share of methane is shown in Fig. 4.6 for five forms of transport. In the 2020 target natural gas has 60 % share of methane use. By 2030 RE-methane will pass natural gas based fossil methane and in 2050 all methane is sustainable RE-methane. In 2050 the target for RE-methane is 8 TWh and 40 % of transport energy consumption. This is easy to achieve resource wise, since biowaste based biomethane (BG) could be produced 10 TWh annually (Lampinen et al. 2004) and wood waste based biomethane (SBG), wind methane and solar methane resources are much larger.

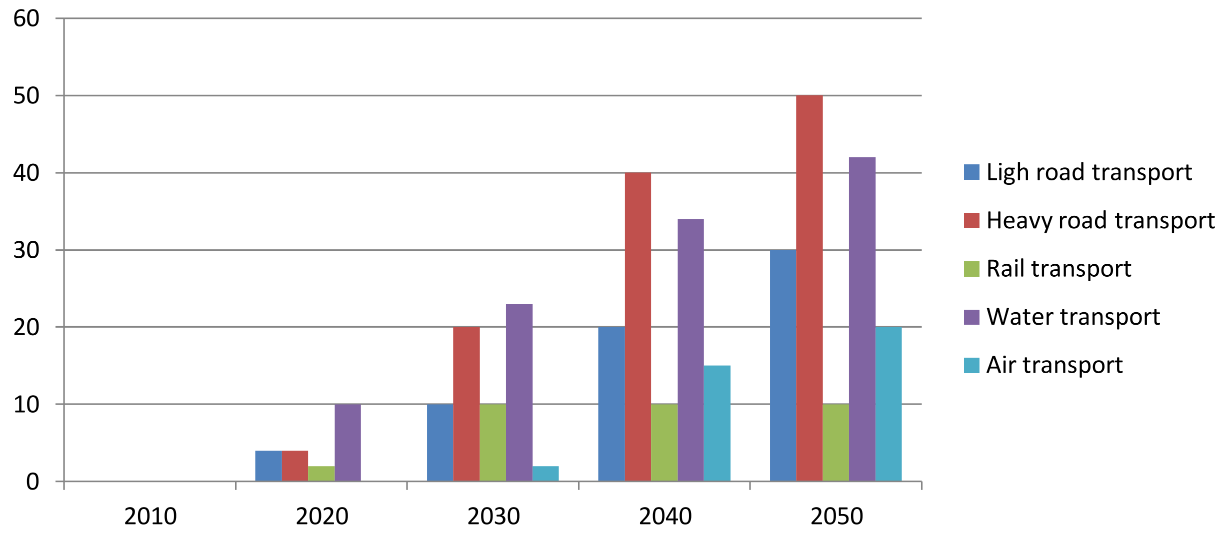


Figure 4.6. Goals in the share of methane (%) in five forms of transport 2020-2050.

5. Action plan for renewable methane

5.1. Starting point

Starting point in Finland is not good, as shown in Fig. 5.1. The main reason for extremely low penetration of biofuels in transport energy market in Finland is historical and political: very strong tax subsidies were given for gasoline and diesel oil use against all renewable energy technologies in transport use since 1965. In 2003 about 10.000 € of annual motor vehicle tax was applied to owners of cars able to use renewable energy sources like biogas, whether renewable energy was actually used or not. And this was also applied to alternative fossil fuels, such as natural gas and LPG. In addition, fuel levy of 330 € had to be paid daily for actual use of gaseous fuels (except wood gas and peat gas), i.e. biogas, hydrogen, natural gas and LPG. Strongest subsidies were removed in 2004, but some subsidies are still in effect, as well as the administrative mindset, which favoured – with success – imported crude oil over domestic renewable energy sources since 1965, despite domestic pressure e.g. from large amount of Parliament Members representing all political parties. State ownership policy has been the main driver in tax policies favouring gasoline and diesel oil. (Lampinen 2008)

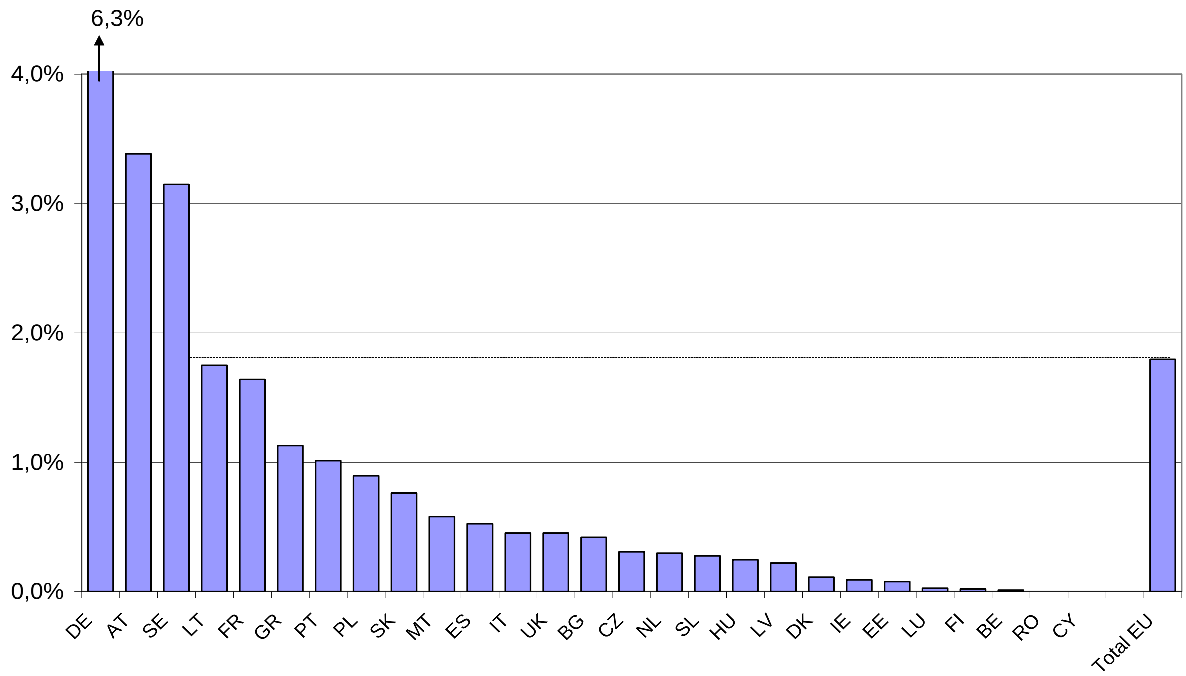


Figure 5.1. Share of biofuels in transport energy consumption in EU27 countries in 2006 according to Member State progress reports to the EU Commission based on Directive 2003/30/EC. Finland is 24th. (Lampinen 2008)

Removal of the annual motor vehicle tax from methane vehicles in 2004 made CBG and CNG use possible. The Kalmari farm filling station (Fig. 2.2) had opened already in 2002 as a demonstration with a special exemption. In 2005 the first public CNG filling station was opened by Gasum. Since October 2011 all 14 Gasum filling stations have sold both CNG and CBG (Fig. 5.2).

Figure 5.2. Gasum CBG/CNG filling station in Kouvola.

After initially resisting implementation of the EU Renewable fuels Directive (2003/30/EC) altogether, it was finally mostly implemented in Finland by Sales Quota Act (446/2007), although only a 4 %

requirement was set instead of the 5.75 % requirement for 2010. The use of renewable gaseous fuels was not accepted in fulfillment of the obligation. In 2010 the Act was amended to implement the RES Directive (2009/28/EC), but with twice higher obligation, i.e. 20 % in 2020. In this amendment, the use of renewable gases was made possible, although open to administrative interpretation.

As a result of historical domestic policy strongly favouring gasoline and diesel oil, and monofuel vehicles capable of using only those fuels, other vehicle types are rare[10] and there are still tax incentives in place against them. Monofuel diesel cars and vans are supported by a reduced car sales tax and monofuel gasoline cars and vans are supported by exemption of annual motive power tax.

> The annual motive power tax for cars and vans is structured the following way. There is no tax for gasoline vehicles, but only if they are unable to use renewable fuels or renewable electricity. If the ability of using biogas is added to the vehicle (at the climate and air protection investment cost of 2000-6000 €) tax will be collected. The same applies to all other technologies for utilizing renewable energies. The annual tax is set based on the weight of the vehicle. E.g. in the case of a car weighting 1800 kg, the annual tax is 33 € for plug-in gasoline hybrids, 99 € for electric cars, 204 € for biogas and natural gas cars and 361 € for all other cars built for using renewable energies, e.g. hydrogen, compressed air, FAME-biodiesels and pure plant oils.

5.2. Toolbox

Toolbox of recommended actions has been provided for development of vehicle fleet, refueling infrastructure, production infrastructure and vertical support for the whole business chain. Most of these are State level actions. Municipalities could also play a vital role, because they are in charge of biowaste generated by communities in their area (i.e. the local biogas resource) as well as a lot of transport: vehicles owned by municipalities and municipal companies as well as transportation services. Therefore, municipalities could initiate traffic biogas production and consumption independently of State and private actors.[11]

Toolbox Compartment 1: Development of vehicle fleet

- Sales quota obligation for vehicles (other than monofuel gasoline and monofuel diesel, especially methane)
- Public procurement policy, guidance and regulations
- Ownership policy of state and municipal companies
- Motive power tax exemption (like is in effect for gasoline monofuel cars)
- Gas system deduction in car sales tax (like catalytic converter deduction in the 1980’s)
- Annual vehicle tax exemption (like is in effect for wood and peat gas cars)
- Type approval of RE vehicles, e.g. dualfuel diesel vehicles and mobile machines
- Removing requirement for professional driver’s license in certain vans (e.g. ambulances), which have their weight increased over the 3.5 ton limit due to the weight of the gas storage system. This is already in place in some EU Member States[12]

[10] In 2011 there were 5437: 857 methane vehicles (Table 3.1), 1175 ethanol vehicles (1172 E85 cars, 3 ED95 trucks), 1106 electric vehicles (131 cars, 975 light vehicles), 1933 motor kerosene vehicles (1881 tractors, 52 cars), 328 LPG vehicles (318 mobile machines, 10 trucks) and 38 wood or peat gas vehicles (29 cars and trucks, 9 mobile machines).

[11] The opportunities of municipalities are not covered in this publication, since Finnish Biogas Association already has published a series of four guides in three languages (Finnish, Swedish and Estonian) for municipal decision makers. They are available at http://www.biokaasuyhdistys.net. A guide for municipalities and other public sector organizations for purchasing biogas vehicles and biogas driven transport services was published by North Karelian Traffic Biogas Network Development Programme (Lampinen 2011a).

[12] There is a similar case with upper weight limit of heavy road vehicles. Recently in British Columbia, Canada, LNG trucks and buses were approved an additional 1500 kg weight tolerance to compensate for the heavier fuel tanks. This is good practice to follow in the EU.

- Market demonstrations
- Correct carbon dioxide emission information in vehicle registry (currently inconsistent and does not allow taking RE-methane use into account)
- Scrap Bond system for scrapping gasoline and diesel monofuel vehicles (a certificate for purchasing other vehicle types)
- Road tolls and congestion charges for monofuel gasoline and diesel vehicles
- Benefits in income taxation and mileage allowances
- Technical education
- Supervision and guidance of public authorities

Toolbox Compartment 2: Development of refueling infrastructure

- Obligation to provide renewable fuels (like in use in Sweden since 2006: largest gasoline/diesel oil filling stations must sell at least one pure or almost pure renewable fuel, i.e. low-blend biocomponents can not fulfill the obligation)
- Sales quota obligation for renewable fuels (such is currently in effect for biofuels, but status of gaseous fuels, pure RE-fuels and high-blend RE-fuels should be improved)[13]
- Ownership policy of state and municipal companies
- Market demonstrations

Toolbox Compartment 3: Development of production infrastructure

- Fuel tax exemption for gaseous renewable fuels (such is in effect and should be kept that way)
- Removal of fossil fuel subsidies (over 30 subsidy and other support mechanisms are currently in effect)
- Development of biowaste management: priority for biogas technology over composting, priority for utilizing landfill gas over microbiological destruction of its energy content
- Production subsidy (such is in effect, but strongly restricted)
- Feed-in tariff (such was in effect for supporting peat power)
- Public service obligation (like in use in Denmark for supporting renewable gas feeding into gas grid)
- Purchase obligation
- Green gas certificate system (it is currently under preparation)
- Regulations for connection into natural gas grid
- Standardization
- Market demonstrations

Toolbox Compartment 4: Vertical support for the whole business chain

- Strategy and action plans (like the Ministry of Transport and Communications roadmap work for which this publication is a part of)
- National renewable energy action plan (an update is currently under preparation)
- Oil independence action plan (it is currently under preparation)
- Supervising group (for suggesting enhanced actions if targets are not being met)
- New business creation plan and support
- Research and demonstration support
- Investment support
- Value added tax benefits
- State funding for municipal environmental project
- Environmental labelling

[13] It is currently implemented in a way that gives no incentives for pure or high-blend RE-fuels, i.e. the obligation can be met with low-blend biocomponents for monofuel gasoline and diesel vehicles. Consequently, no stimulus for development of vehicle fleet for crude oil independency is included.

6. Summary

This publication is an extended summary of a 133-page report written in Finnish for Finnish Ministry of Transport and Communication as a part of a work of a task force “Future motive powers in transport”. It contains sustainable development path to 100 % renewable transport energy system in 2050 as one of the alternative paths developed by the task force. In addition to the roadmap work of Ministry of Transport and Communications, this publication is a contribution to ongoing work at Ministry of Employment and the Economy of updating Finnish climate and energy strategy and creating an oil independence programme.

The main basis of the sustainable development path is the Government Foresight Report on Long-term Climate and Energy Policy setting national goal of 80-95 % decrease of greenhouse gas emissions in the transport sector. The sustainable development path is designed to reach eight goals related to climate, air pollution and other environmental policy as well as energy security policy. The path consists of roadmaps for light and heavy road transport, rail, water and air transport. Mobile machines are assumed to follow the development of road transport, since the engine technologies are the same. In each form of transport crude oil use is decreased in two or three phases and its use ends by 2050. In the first phase liquid biofuels and in the second phase sustainable gaseous renewable fuels are the most important. In light road transport third phase is expected, where direct and indirect sustainable renewable electricity will become the most important. This is already now the case in rail transport.

Most significant, but not the only future motive power is sustainable renewable methane, for which most of this publication is dedicated. Sustainable renewable methane means sustainable biomethane as well as wind methane, solar methane and other forms of RE-methane. Biomethane is both biogas (BG) and synthetic biogas (SBG). Methane can be energy carrier of all primary renewable energy sources making a renewable methane economy possible. However, there is no goal set for a pure RE-methane economy, since also hydrogen and electricity are useful secondary energy sources capable in carrying all primary renewable energy sources. RE-methane and RE-hydrogen form an intelligent gas infrastructure, which can also act as storage for intermittent renewable energy sources, such as solar, wind and wave power.

Solar and wind energy have the largest resources of any primary energy form and they also offer the best environmental quality. Therefore, they form the core of a sustainable energy system. Due to their intermittent nature storage technology is required, if they are to form a large share of energy consumption. Methane offers the largest potential storage capacity, making renewable methane an essential part of sustainable energy system both in transport sector and in power sector.

Of the most environmentally benign transport energy sources, which will be part of the solution also in the long run, in the latter half of this century and beyond, RE-electrified rail transport and RE-methane in almost all transport forms and modes[14] are the only ones that are already technologically mature and used commercially in large scale in many countries. RE-methane offers an ecologically sustainable solution in almost all types of transport in economically competitive and socially acceptable way now, and will always be produced any way, since biowaste is inherent by-product of all societies. Its use is possible to expand very rapidly if political will can be generated. Political will in state and municipal level is needed for creating a satisfactory infrastructure.

This publication gives targets for necessary production, distribution and usage infrastructure and a toolbox of instruments to fulfil the targets. The overall target for sustainable RE-methane in 2050 is 40 % share of transport energy consumption. It means 8 TWh of annual production, which is easy to achieve resource wise. To be able to get RE-methane use into a strong growth trend and visible already in 2020, a target of 2.5 TWh methane consumption in transport is set. This would be met by 40 % (1 TWh) biomethane (BG and SBG) and 60 % (1.5 TWh) fossil methane (NG). Target for road vehicles is 2 % share, which is met if 4.4 % of new road vehicle registrations in time period 2012-2020 are able to use methane.

[14] Methane is used commercially in light and heavy road transport, mobile machines, rail and water transport. In air and space transport it is experimental and expected to become commercial.

Annex: Position paper on revision of the Energy Taxation Directive

Finnish Biogas Association, 5 October 2011

Finnish Biogas Association welcomes the intent of the Commission to increase emphasis on emissions in the Energy Taxation Directive (2003/96/EC), with a purpose of replacing fossil fuels by renewable energy sources. However, the proposal COM(2011)169 not only falls short of necessary actions but contains elements that actually decrease incentive for emission reduction.

The Commission proposal introduces separate carbon dioxide tax and energy content tax, which form the total energy tax. For fuels used in heating, the weight of the CO_2 tax is about 90 % and the share of energy content tax is about 10 %. This is the correct way of balancing the two. However, the weights are reversed in the case of traffic fuels.

The following table shows the current minimum tax levels of traffic fuels in the Energy Taxation Directive. Although environmental objectives are not formally part in defining the taxes, the current levels reflect well not only CO_2 emissions but other emissions, too.

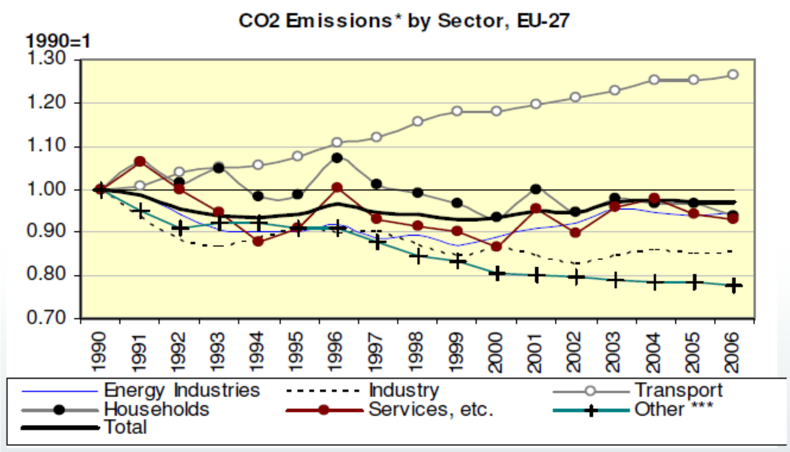
Current	2003/96/EC	Energy unit based
Gasoline	359 €/1000 l	11.2 €/GJ
Diesel	330 €/1000 l	9.2 €/GJ
Kerosene	330 €/1000 l	9.5 €/GJ
LPG	125 €/1000 kg	2.7 €/GJ
Natural gas	2.6 €/GJ	2.6 €/GJ

In the proposed Directive, the weight of emissions is greatly reduced, as seen in the table below.

Proposed	CO_2 tax	Energy content tax	Total	Change	Share of CO_2 tax
Gasoline	1.552 €/GJ	9.6 €/GJ	11.2 €/GJ	0	13.9 %
Diesel	1.486 €/GJ	9.6 €/GJ	11.1 €/GJ	+ 20 %	13.4 %
Kerosene	1.436 €/GJ	9.6 €/GJ	11.0 €/GJ	+ 16 %	13.0 %
LPG	1.136 €/GJ	9.6 €/GJ	10.7 €/GJ	+ 298 %	10.6 %
Natural gas	1.100 €/GJ	9.6 €/GJ	10.7 €/GJ	+ 312 %	10.3 %

Almost 90 % of the taxes are based on energy content meaning that essentially a flat rate for all fuels is created. This removes incentives for using low emission fuels (natural gas and LPG) as their tax level is increased by 4-fold. This is a disaster for biogas sector in those EU countries, where biogas is taxed at the level of or in proportion to the tax of natural gas. And because crude oil based liquid fossil fuels are promoted by this revision, also energy security concerns are increased in the peak oil world.

In the proposed Directive the Commission substantiates this change by arguing that for the sake of competitiveness the CO_2 tax per ton should be 20 Euros for all fuel use and approximately the same as the cost of emission permissions in the EU emission trading system. This is a faulty argument, since different sectors do not compete with each other. Because all sectors need to reduce their CO_2 emissions, the rate should be set according to the features of each sector individually. As seen in the figure (based on statistics from Eurostat), the CO_2 emissions of the EU have been dominated by traffic. Between 1990-2006 traffic sector increased its emissions by 35 %, whereas power production and heat production sectors decreased their emissions, as well as all the other sectors. Total emission in the EU in 2006 were only a little below 1990 levels, because traffic sector alone had neutralized all progress in emission reduction in all other sectors.



Therefore, it is clear that traffic is the main problem in CO_2 emission mitigation. Climate change policies and legislature, including the energy tax Directive, should reflect that. However, the weight of emissions is much less, instead of more than in other sectors.

To correct for this, below is a table where the weight of CO_2 tax is set the same as fuels for heating, i.e. about 90 %. This was calculated assuming that the gasoline tax rate remains the same. It results in a CO_2 emission tax equivalent of 229.9 Euros/ton.

	CO_2 tax	Energy content tax	Total	Change	Share of CO_2 tax
Gasoline	10.08 €/GJ	1.12 €/GJ	11.2 €/GJ	0	90 %
Diesel	9.65 €/GJ	1.12 €/GJ	10.8 €/GJ	+ 17 %	89 %
Kerosene	9.33 €/GJ	1.12 €/GJ	10.4 €/GJ	+ 9 %	90 %
LPG	8.55 €/GJ	1.12 €/GJ	9.7 €/GJ	+ 259 %	88 %
Natural gas	7.14 €/GJ	1.12 €/GJ	8.3 €/GJ	+ 219 %	86 %

Other emissions have not yet been taken into account, as they essentially have been in the energy tax Directive in force today. Finnish Biogas Association does not at this point suggest taking into account pollutant emissions of diesel fuel, although according to the European air quality studies of the European Environmental Agency, diesel exhaust components are the common denominator for pollutants that are not decreasing in the European air. This exerts pressure into raising tax levels of diesel, e.g. at the first revision of the Directive in 2015. The same applies to kerosene: its emissions are mostly taking place in the upper troposphere, and therefore all pollutants have much longer lifetime compared to ground level emissions.

However, the especially low pollutant levels of natural gas and LPG should be taken into account immediately. Compared to gasoline, natural gas reduces NOx emissions by about 50 %, NMHC emissions by 78 %, ozone precursors by 94 % and aromatic compounds as well as fine particles by 99.9 %. A new tax table has been calculated, where CO_2 tax has evolved into emission tax. Basis for tax level of natural gas is the current tax level in Finland, Sweden and Germany. This leads to defining emission tax for natural gas as CO_2 tax with 63 % reduction. For LPG the reduction is 50 %. **Finnish Biogas Association proposes that this tax table replaces the table A in Annex 1 of the revised tax Directive.**

	Emission tax	Energy content tax	Total	Change	Share of emission tax
Gasoline	10.08 €/GJ	1.12 €/GJ	11.2 €/GJ	0	90 %
Diesel	9.65 €/GJ	1.12 €/GJ	10.8 €/GJ	+ 17 %	89 %
Kerosene	9.33 €/GJ	1.12 €/GJ	10.4 €/GJ	+ 9 %	90 %
LPG	4.28 €/GJ	1.12 €/GJ	5.4 €/GJ	+ 100 %	79 %
Natural gas	2.64 €/GJ	1.12 €/GJ	3.8 €/GJ	+ 46 %	69 %

Finnish Biogas Association has also calculated the tax table for working machines and proposes that the following table replaces the table B in Annex 1 of the revised tax Directive. Here the CO_2 tax level of 20 Euros/ton has been retained.

	Emission tax	Energy content tax	Total	Change	Share of emission tax
Diesel	1.486 €/GJ	0.15 €/GJ	1.64 €/GJ	+ 183 %	91 %
Kerosene	1.436 €/GJ	0.15 €/GJ	1.59 €/GJ	+ 165 %	90 %
LPG	0.504 €/GJ	0.15 €/GJ	0.65 €/GJ	- 26 %	78 %
Natural gas	0.300 €/GJ	0.15 €/GJ	0.45 €/GJ	+ 50 %	67 %

Finnish Biogas Association also has the following suggestions for improving the Directive:

- **Excise tax exemption should be guaranteed for biogas** for states wishing to do so (under fiscal control, like the Directive in force permits), without artificial deadline (1 January 2023).
- **Revision of tax rates should be based on environmental and energy policy reasons, not Eurostat consumer price index.** Tax rates should be increased if at any given sector the CO_2 emissions are not decreasing or the share of renewable energy is not increasing.
- **Division of biofuels into two groups is not sufficient: the group for waste and residue based biofuels should be added.** The RES Directive (2009/28/EC) divides biofuels into three groups of which the environmentally most benign group has been omitted in the revision of the Energy Taxation Directive resulting in e.g. that toilet waste based biogas is treated the same way as energy crop based ethanol causing ecological and other environmental damage.

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