Future Mobility in Europe

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Abstract:

Mobility in Europe is facing big challenges, which require solutions to be brought on the way in the next years. The integration of the different transport modes into a coherent European transport system and improvement of the infrastructure should enhance energy efficiency and ensure global competitiveness of Europe. Intelligent transport management should increase overall transport efficiency. The White Paper on a European Transport policy of March 2011 presents a perspective towards 2050 and a comprehensive list of concrete measures. A transition in energy supply to transport towards clean and renewable sources should provide sustainable long term supply and reduce the impact on environment from the emissions of pollutants and greenhouse gases. A European strategy on alternative fuels should be developed to secure energy supply with sustainable use of resources in Europe and globally.

1. INTRODUCTION

Mobility of people and goods is fundamental for the development of society. Connectivity through the availability of transport means is particularly important for the coherence of the European Union, which has only recently integrated most of Europe into a single economic and political space. Transport provides a basis for deepening the political integration of Europe and developing cohesion across the different regions of large economic and cultural diversity. An efficient transport system is essential for economic growth and for the competitiveness of Europe in a globalised world.

The "Europe 2020" strategy[1] underlines the importance of a modernised transport system for the future development of the EU and puts it in the core of the "Resource efficient Europe" flagship initiative. European transport policy should develop the necessary actions and measures to ensure mobility in the larger common space and provide the full integration of Europe into a global network.

2. CHALLENGES TO MOBILITY IN EUROPE

The present transport system in Europe is facing big challenges to the functioning of transport itself, and to its impact on health and environment.

Congestion often is characterising transport more than mobility. Better traffic management and upgrading of transport infrastructures are required to improve fluidity of transport.

[1] COM (2010) 2020, "EUROPE 2020 - A strategy for smart, sustainable and inclusive growth"

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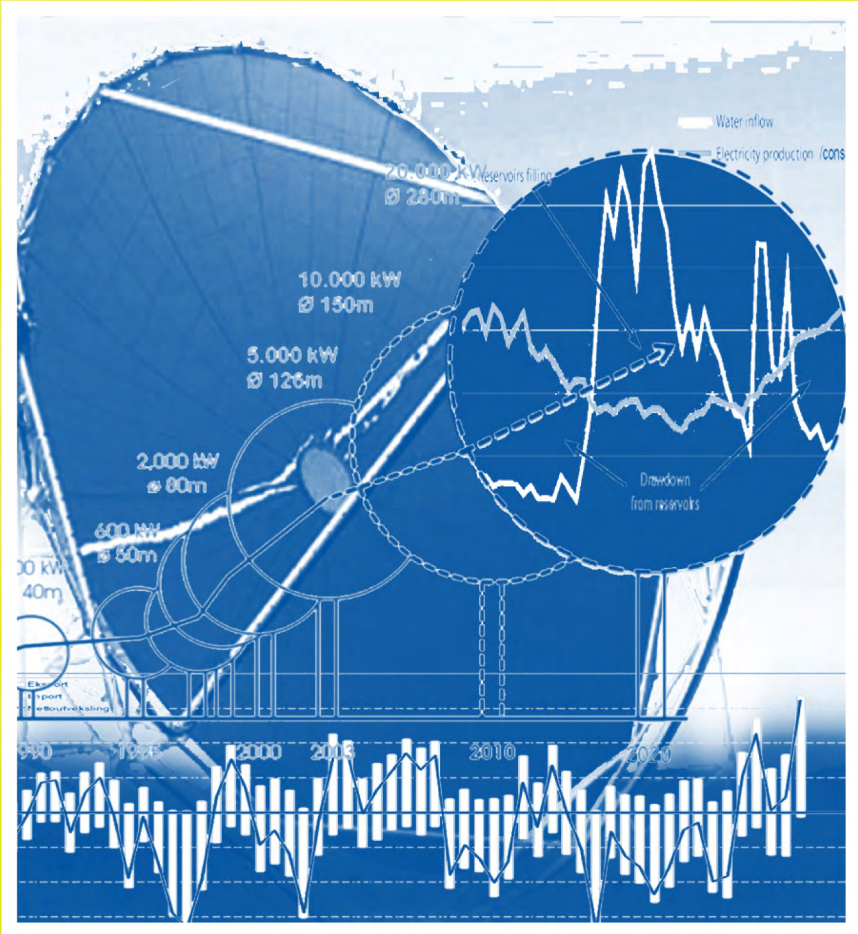

Energiewende

Aspekte, Optionen, Herausforderungen

Vorträge auf der DPG-Frühjahrstagung in Berlin 2012

Herausgegeben von Hardo Bruhns

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The evolution of the transport system in Europe has been strongly influenced by the political East-West divide over half a century. Infrastructures have developed to cope with traffic flows mostly in North-South direction, contrary to the situation a century ago when the ratio of East-West to North-South traffic was about four. It is expected that, after the reunification of Europe completed, the picture will revert close to the historical situation. Infrastructures therefore will need to be substantially enhanced and altered.

Mobility requires, as a pre-condition, sufficient energy supply to the different modes of transport. Transport fuel consumption today is dominated by oil. This gives rise to major societal, economic and environmental concerns. Ever more difficult access to oil resources is putting security of supply at risk, particularly for transport. The growing volatility of the oil price has led to detrimental impacts on the economy in general.

The combustion of growing volumes of oil in transport contributes to air pollution, which damages health. It also has constantly increased the emissions of CO_2 from transport, standing out of all other sectors of economy, which have succeeded to constrain or even decrease their greenhouse gas emissions. CO_2 emissions from the transport sector, including from international aviation and maritime transport, account for approximately 29 % of total CO_2 emissions in the European Union. These emissions have increased by 34 % since 1990. A continuation along the lines of the past two decades would endanger meeting the climate protection goals of the EU.

3. EUROPEAN TRANSPORT POLICY

The European Commission has presented a framework and proposals for concrete actions on European transport policy, with a time horizon 2050, in the 2011 Transport White Paper[2].

Reducing CO_2 emissions from transport by 60% by 2050, with respect to 1990, has been set as the headline target for the whole transport sector in Europe. Ten goals set ambitious milestones for developing new fuels and propulsion systems, optimizing the performance of multimodal logistic chains, and improving transport efficiency with information systems. Three out of the ten headline goals identify fields of priority action with regard to decarbonisation of transport and the introduction of alternative fuels substituting oil:

- CO_2-free city logistics in major urban centres by 2030
- Halving of conventionally fuelled cars in urban areas by 2030, phasing them out by 2050
- 40% of low-carbon sustainable fuels in aviation and 40% (if feasible 50%) less CO_2 emissions in maritime transport by 2050.

Forty initiatives outline a large number of concrete actions in the four areas of

1. Internal Market
2. Innovation and technology
3. Infrastructure
4. International links.

[2] COM(2011) 144 "Roadmap to a Single European Transport Area – Towards a Competitive and Resource Efficient Transport System"

The contributions from transport are vital, together with efforts from the other sectors, to achieve the overall goal of reducing greenhouse gas emissions in the EU by 80-95 % by 2050[3]. The results of model calculations for the main policy scenario adopted by the European Commission for transport, energy, and environment policies, are shown in Fig.1. Their implementation should help to limit global temperature increase to 2°.

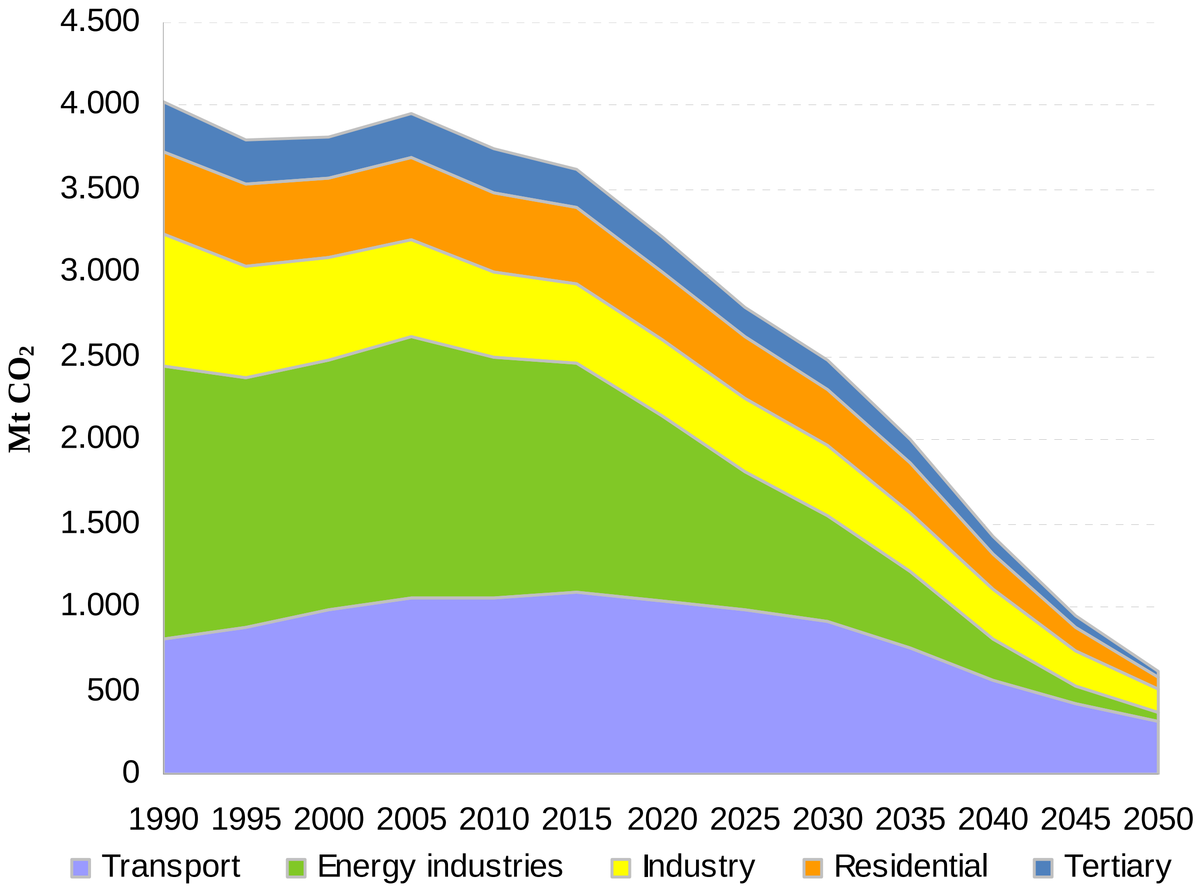

Figure 1: Projected development of EU greenhouse gas emissions from the different sectors of economy, resulting from the proposed European transport, energy, and environment policies

A Single European Transport Area should improve connectivity in Europe, enhance transport efficiency, reduce cost, and contribute to economic growth in Europe. Areas where the internal market needs to be further consolidated are rail services, achieving a "Single European Railway Area"; aviation, by implementing the "Single European Sky"; maritime transport, with a "Blue Belt" facilitating ships travelling in the seas around Europe.

Technological innovation should focus on the three areas of cleaner and more efficient propulsion systems, alternative fuels, and more efficient and safer use of the transport networks through information and communication systems. Early deployment of clean vehicles is pivotal and helps reducing the dependence on oil.

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[3] COM(2011)112 "A Roadmap for moving to a competitive low carbon economy in 2050"

An efficient European transport network is essential to remove bottlenecks in transport infrastructure, reduce costs for transport operators and vehicle users, and minimise impact on environment and health. The focus should be on missing links and multi-modal connections.

Continuity of the transport network should be ensured by extending infrastructure to the neighbouring countries around the EU, and to the main partners in the global markets.

Urban mobility will be a new invigorated field of European transport policy. A broad debate on the scope of possible European action in this area had been organised in the frame of the Green Paper on Urban Mobility[4]. The Action Plan on Urban Mobility[5] of 2009 provided a coherent framework for 20 concrete EU-level actions, which have been carried out until 2012. The 2011 White Paper on Transport has then fully integrated urban mobility into EU transport policy.

Following up, the Commission plans to present a package of proposals for European actions on urban mobility, by mid-2013. The focus should be on sustainable urban mobility plans, which could become a key policy instrument for an integrated urban mobility policy. Implementation should allow full flexibility for local authorities to adapt to their specific needs. A common framework for European cities should help to meet the particular challenges to mobility in urban areas, alleviating the issues of congestion, pollution, CO_2 emissions, and excessive energy consumption, to render urban mobility more sustainable.

Urban mobility measures will play an important role to meet the CO_2 emissions reduction target for transport, as about one quarter of all transport emissions comes from urban areas as depicted in Fig. 2.

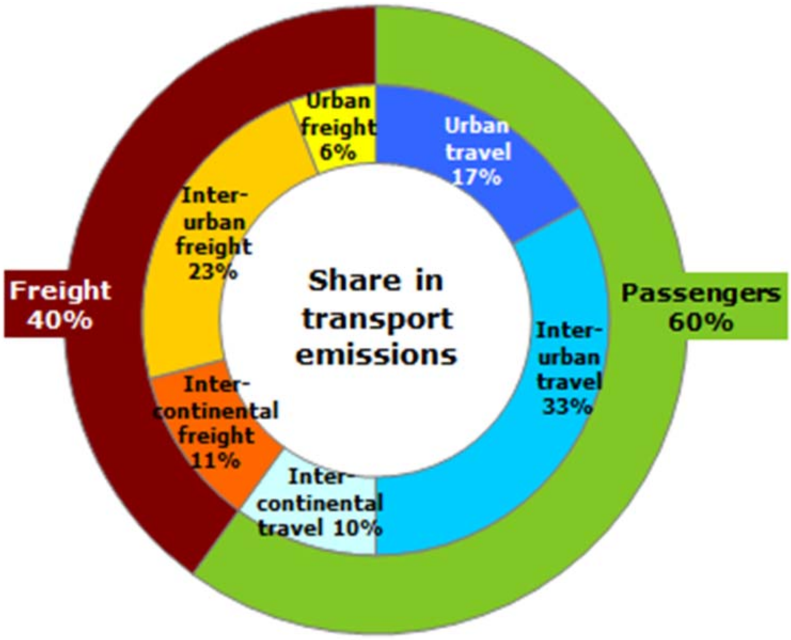

Figure 2: Contributions of the different transport segments to transport CO2 emissions

4 COM(2007) 551 "Towards a new culture for urban mobility", http://eur-lex.europa.eu/LexUriServ/site/en/com/2007/com2007_0551en01.pdf

5 COM(2009) 490 "Action Plan on Urban Mobility", http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:52009DC0490:EN:NOT

4. EU ACTIONS IN SUPPORT OF CLEAN VEHICLES

EU policy actions have already considerably improved the environmental performance of vehicles.

- Pollutant emissions from vehicles have been gradually reduced by EU Regulations setting emission limits with the Euro standards. These standards have been regularly tightened since their introduction in 1992, reducing NOx emission levels again with Euro 6 in 2014/15.
- CO_2 emissions of road transport vehicles have been confined only recently through fleet averaged emission limits, with Regulation (EC) No 443/2009 setting a limit of 130 gCO_2/km for the annual average of new registrations of passenger cars from 2015, and 95 gCO_2/km from 2020, and Regulation (EU) No 510/2011 setting 175 gCO_2/km similarly for light commercial vehicles from 2017, and 147 gCO_2/km from 2020.
- The market penetration of clean vehicles is supported by Directive 2099/33/EC on the Promotion of Clean and Energy Efficient Road Transport Vehicles. This Directive requires public authorities and transport operators working under public services obligations to take into account fuel consumption, CO_2 emissions and main pollutant emissions over the entire lifetime of vehicles for their purchases decisions. A website portal (http://www.cleanvehicle.eu/) has been developed to support public and private purchases of clean and energy-efficient vehicles.

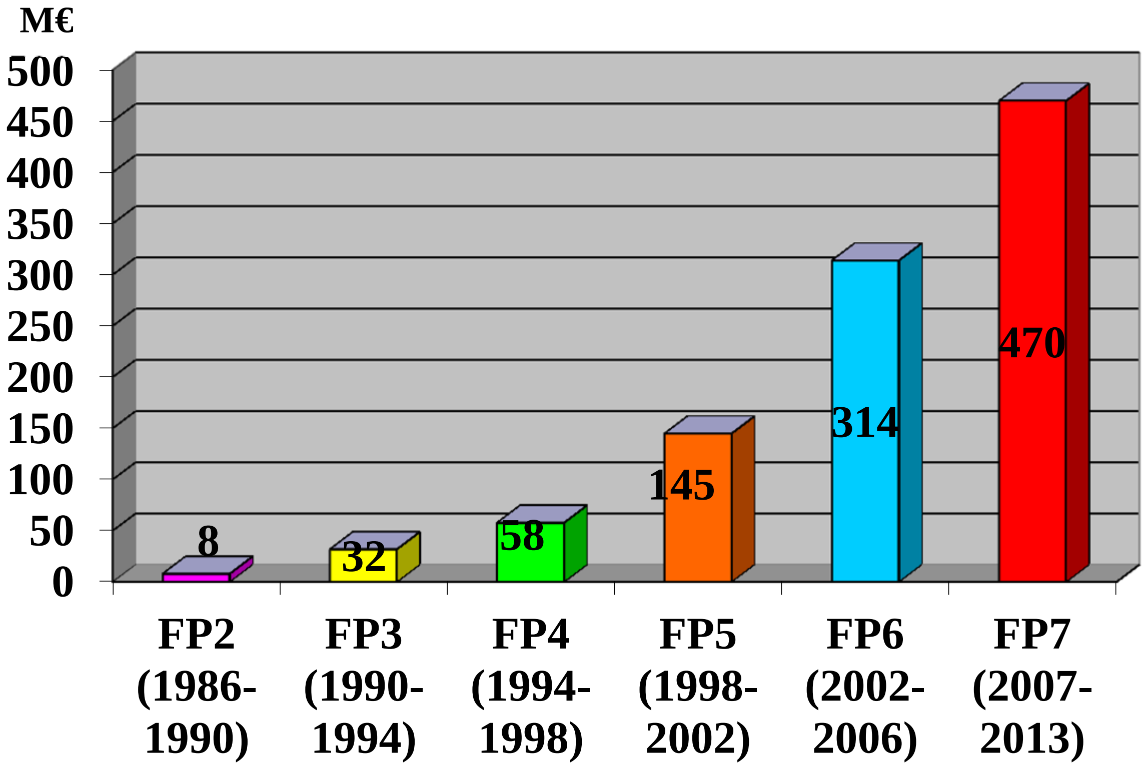

Figure 3: EU funding for hydrogen and fuel cell technologies from the R&D Framework Programme (FP)

The approach of the Clean Vehicle Directive corresponds to an internalisation of external costs (costs due to pollutant and greenhouse gas emissions of vehicles). A methodology for the monetisation of these costs on a lifetime basis is defined in the Directive. The external costs can arise to an important part of total cost, and even exceed the vehicle purchase cost. This gives an economic value to the reduction of these costs by using clean and energy efficient vehicle and fuel technologies minimising them. In consequence, market uptake of these innovative technologies is considerably strengthened in a cost-efficient way. As a result, initially higher cost of higher performance technology can be brought down through economies of scale.

- The European strategy on clean and energy efficient vehicles (COM (2010) 186) has set out a strategy for encouraging the development and uptake of clean and energy efficient vehicles by industry and their market uptake by consumers. It contains an Action Plan with over 40 concrete measures to be implemented by the Commission.
- The Commission has supported major research and demonstration projects on alternative fuels and energy carriers, such as hydrogen and fuel cells, biofuels, methane (natural gas and biogas), including the fuel chain and the vehicles. Community funding through the Framework Programme for Research & Development has been continuously increased. The development for hydrogen and fuel cells over the last 25 years is shown in Fig. 3.

5. TRANSPORT ENERGY SUPPLY

Oil dominates the energy supply to transport, with a share of 94% at present. Transport also is the largest oil consumer of all sectors in economy, with an increasing share, presently at 55% in the EU. All other sectors have diversified their energy supply options; electricity production e.g. has dropped its share from oil to 3% after the oil price shocks of the 1970s. Issues in oil supply are therefore mostly a problem for transport. Railways are the only transport mode less dependent on oil, with 60% supplied by electricity. Road transport has a 6% share provided by alternative fuels, such as biofuels, natural gas and LPG. Inland and maritime navigation use alternative fuels only to a small extent (e.g. nuclear); aviation depends entirely on petroleum based jet fuel (Table 1).

Fuel consumption (Mtoe)	**Road**	**Rail**	**Domestic Navigation**	**Domestic Aviation**	**International Aviation**	**TOTAL**
Oil Products	**287**	**3**	**6**	**8**	**43**	**347**
Electricity		**4**				**4**
Biofuels	**13**					**13**
Natural Gas	**1**					**1**
LPG	**5**					**5**
Total Fuels	**306**	**7**	**6**	**8**	**43**	**370**

Table 1: Fuel consumption (in Mtoe) by the different transport modes (Source: EUROSTAT)

Oil is the energy resource with the shortest range (ratio of known reserves to annual production rate), estimated currently at 40+ years[6]. Oil production has exceeded new discoveries over the last 30 years and has peaked in 2005[7]. Unconventional oil stocks could stretch the availability of oil, but cost, technical risks and environmental impact are becoming increasingly high. The high dependence of our transport system on limited oil resources could compromise the mobility of future generations.

Oil consumed in the EU is mostly imported, presently at a rate of 84 %. This makes transport, and hence the wider economy of Europe, very reliant on the availability of oil products on world markets. Oil supply comes increasingly from politically and environmentally sensitive areas. This has led to geopolitical tensions and environmental desasters.

The high oil import bill, of around € 210 billion in 2010, climbing to € 1 billion per day in 2011, causes an important deficit in the balance of trade in primary goods for the EU, of order 2.5 % of the GDP[8].

Substitution of oil as energy source for transport therefore is not a task to be considered for the far future when oil sources might approach depletion, but a necessity for action now. Alternative fuel options will need to be ramped up in coordinated action in Europe, and globally.

6. ALTERNATIVE FUEL OPTIONS

A single-fuel solution covering all transport modes would technically be possible with synthetic fuels. These fuels are drop-in fuels with the same characteristics as conventional crude oil based fuels. All existing fuel infrastructure, and all vehicles, vessels, trains, and planes with internal combustion engines could be used without modifications. But feedstock availability and sustainability considerations constrain the supply potential. The expected future energy demand in transport therefore can most likely not be met by one single fuel.

A fuel mix solution with several main alternative fuels therefore is the only realistic option[9]. The main alternative fuel options should therefore be developed in parallel, with adjustments to the different technological, economic, and environmental issues of the different fuels.

A comprehensive long-term oriented multi-fuel strategy can give a stable framework for research and market development of fuels and transport and energy applications. Steady development with a time horizon of several decades is essential.

The main alternative fuel options considered for substituting oil in transport are:

- Electricity and hydrogen for electromobility (energy carriers for all energy sources)
- Biofuels (liquid)
- Synthetic fuels (from natural gas and biomass)
- Natural gas (gaseous as CNG, and liquefied as LNG) (from fossil and bio-methane)
- Liquefied Petroleum Gas (LPG).

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6 Reserve-to-production rate 46.2 years in the 2010 BP Energy Outlook 2030

7 IEA World Energy Outlook 2010

8 Eurostat statistics 2010

9 Report of the European Expert Group on Future Transport Fuels: "Future Transport Fuels" (http://ec.europa.eu/transport/urban/cts/doc/2011-01-25-future-transport-fuels-report.pdf)

The use of energy carriers can improve security of supply through resource diversification and allows a gradual decarbonisation by progressing from fossil to renewable resources on the input side, whilst maintaining the same fuel characteristics for the final application in a power train. Electricity and hydrogen are universal energy carriers produced from all sources; synthetic fuels and natural gas can act as energy carriers produced from any hydrocarbons.

The different modes and segments of transport require different options of alternative fuels, as shown in Table 2:

- Road transport could be powered by electricity on short distance, hydrogen and methane up to medium distance, and biofuels/synthetic fuels, LNG and LPG up to long distance.
- Railways could be electrified wherever feasible, otherwise use biofuels.
- Waterborne transport could be supplied by biofuels (all vessels), hydrogen (inland waterways and small boats), LPG (short sea shipping), LNG, and nuclear (maritime).
- Aviation could be supplied from biomass derived kerosene.

		Road - passenger			**Road - freight**			**Rail**	**Water**			**Air**
		short	medium	long	short	medium	long		inland	short-sea	mari-time	
Electric	**BEV**	■			■			■				
	HFC	■	■		■			■	■			
	Grid	■			■			■				
Biofuels (liquid)		■	■	■	■	■	■	■	■	■	■	■
Synthetic fuels		■	■	■	■	■	■	■	■	■	■	■
Natural Gas	**CNG**	■	■	■	■	■						
	CBG	■	■	■	■	■						
	LNG	■	■	■	■	■	■	■	■	■	■	
LPG		■	■	■	■	■	■		■	■		

Table 2: Coverage of transport modes and travel range by different alternative fuels.
***BEV**: Battery Electric Vehicle; **HFC**: Hydrogen/Fuel-Cell vehicles; **Grid**: Grid connected electric vehicle (e.g. tram, metro, train, trolley bus); **CNG**: Compressed Natural Gas; **CBG**: Compressed Bio-methane Gas; **LNG**: Liquefied Natural Gas; **LPG**: Liquefied Petroleum Gas*

Modelling of different fuel scenarios was performed with the energy-transport model PRIMES-TREMOVE, combined with the PROMETHEUS world energy model[10]. Oil substitution capacity for transport should be provided, consistent with the 60% greenhouse gas emission reduction target by 2050. In all scenarios substantial energy efficiency improvement of ICEs is obtained. Oil consumption falls to 30% of the present level, by 2050. The main energy supply to transport comes from biomass, grid-supplied electricity and hydrogen, complemented by natural gas.

[10] http://ec.europa.eu/transport/urban/studies/doc/2011-11-clean-transport-systems.pdf

7. STATE AND PERSPECTIVES OF ALTERNATIVE FUEL TECHNOLOGIES

Electricity and hydrogen, as universal energy carriers can be produced from all primary energy sources. The energy can be supplied via three pathways, in all cases powering an electric motor for propulsion ("**electromobility**"):

- *Battery-electric,* with electricity from the grid stored on board vehicles in batteries.
- *Fuel cells powered by hydrogen*, used for on-board electricity production.
- *Overhead Line / Third Rail* connecting to the electric grid.

Hybrid configurations, combining internal combustion engines and electric motors, without external charging possibilities do not contribute to oil substitution, and are not considered under alternative fuel technologies. They can, however, save oil and reduce CO_2 emissions by improving the overall energy efficiency of a vehicle. Only configurations with additional external energy input in form of electricity or hydrogen offer routes to oil substitution.

Battery-electric vehicles are about a factor 3 more energy efficient than vehicles powered by internal combustion engines (ICE). With the low efficiency of the electricity grid (EU average 35% at present), the overall energy consumption well-to-wheels, however, is similar for electric and ICE powered vehicles. The lower CO_2 intensity of electricity (EU average 430 g/kWh at present), on the other hand, allows significant reduction of CO_2 emissions, by 30% when comparing vehicles like to like, at present conditions.

Electric vehicles emit no pollutants and are therefore particularly suited for urban areas, where air quality is still of concern in many regions in Europe. Deployment of electric vehicles for urban freight distribution can also facilitate extended hours delivery with silent low-emission vehicles, thereby improving transport efficiency and reducing congestion.

The main issues of battery-electric vehicles are the low energy density and high weight of batteries, imposing considerable range limitations, and high cost. Batteries take about a factor 50 more volume than a gasoline or diesel tank for the same energy content. The real-world range of present battery electric vehicles is of order 100 km. Battery cost is of order 10-15,000 € for present mid-size cars. Industry studies predict cost coming down to a level competitive with conventionally fuelled ICE vehicles within a decade.

Charging of battery-electric vehicles takes several hours (7-8 hours for a full charge), with low-power (<3.7 kW) technology. Fast charging modes exist, either with high power (about 0.5 hour for a full charge) or battery exchange (about 4 minutes). Durability of the battery and high investment cost presently are obstacles to a wide application of the fast modes. Basic infrastructure exists for home charging from the grid.

Deployment of battery-electric vehicles is in an early stage. Total numbers of vehicles and dedicated charging stations in the EU were of order 6,000, for both, by end of 2011. Expectations on future market penetration of electric vehicles are high, with numbers, however, varying in a wide range, between 1 and 20 million for 2020. The higher numbers generally include plug-in electric vehicles, which are much closer to market viability due to lower cost for the battery, which serves only a short range of a few tens of kilometres in pure electric mode; standard long-distance range is provided in conventional ICE mode.

Public support to technological and market development of electric vehicles has been strongly ramped up in recent years, in many Member States and on EU level. Electric vehicles have received priority funding in the EU R&D Framework Programme 7 (2007-2013) through the Green Cars initiative, with a total envelope of € 5 billion (€ 1 billion project funding and € 4 billion EIB loans). A series of large EU funded demonstration projects of electric cars, vans, and buses, recently started, should provide technology proofing in a wide range of conditions across Europe and co-ordinate data assessment in co-operation with other major projects in the Member States (see e.g. the electromobility demonstration project "Green e-Motion"[11]).

Member States have provided large financial support as well, Germany e.g. € 1.5 billion for R&D, over a period of 4 years in the frame of a National Electromobility Plan. Several Member States provide tax incentives and substantial purchase aid, up to levels of order € 5,000, covering a large part of the presently high cost of the battery.

Hydrogen as a transport fuel is most efficiently used when converted to electricity in a fuel cell – twice as efficient as a combustion engine. Hydrogen fuel cell vehicles share many drivetrain technologies with battery electric vehicles (motors, power electronics, batteries). Hydrogen is stored in vehicles in high pressure tanks.

Hydrogen fuel cell vehicles are technically ready, with satisfactory range and performance. Refuelling times are short and comparable to present gasoline and diesel vehicles.

Hydrogen could enter the broader market in the medium to long term, starting around 2015, and would then require strategic integration of hydrogen production and distribution facilities in current transport infrastructure planning. Hydrogen could also be provided at offshore production facilities to ships as a bunker fuel.

The main issues of hydrogen powered vehicles are high cost, mainly due to expensive fuel cells, and the need to build up re-fuelling infrastructure from scratch. No market therefore exists yet. Industry studies give the perspective of the cost of fuel cells dropping by a factor 10 within five years, and overall cost becoming comparable to battery electric vehicles, and both possibly lower than conventional petrol and diesel vehicles by 2025[12]. But this requires economies of scale through a volume market. A co-ordinated roll-out of infrastructure and vehicles is essential to provide conditions for a competitive market to develop.

Hydrogen and fuel cell technologies have been consistently supported on EU level through the R&D Framework Programmes, ramping up funding continuously, to a total of € 470 million in the present FP-7. Among the landmark projects was the world largest hydrogen bus project CUTE, including also partners from China and USA. Public funding has been provided also in several Member States, in Germany € 700 million for 10 years.

European activities have been co-ordinated in gradually closer co-operation. A European Hydrogen and Fuel Cells Technology Platform, created in 2003, has developed a common research agenda for public and private programmes in Europe. Subsequently, all Community efforts have been bundled in a Joint Technology Initiative, established by Council Regulation in 2008. A Partnership of European Hydrogen Regions was initiated by the European Commission in 2008, and widened to all forms of electromobility in 2010.

First commercial hydrogen fuel cell vehicles are now appearing. Start of a roll-out has been announced by several major car manufacturers for the next years. Public-private initiatives on the build-up of re-fuelling infrastructure have recently started. In Germany, 20 filling stations are planned for 2015, increasing to 50 stations the following years, and ramping up to 1000 stations by 2025. Linking this network to Netherlands, UK, and Scandinavia is envisaged.

[11] http://www.greenemotion-project.eu/

[12] "*A portfolio of power-trains for Europe: a fact-based analysis. The Role of Battery Electric Vehicles, Plug-in Hybrids and Fuel Cell Electric Vehicles*", McKinsey&Company, 2010

Future market development of hydrogen fuel cell technologies will require EU-wide co-ordination, and the implementation of common standards as a pre-condition.

Global standards exist with harmonised requirements for hydrogen purity, fuel connectors, refuelling station safety and layout. They need to be implemented to avoid stranded investments. European vehicle type approval legislation has recently integrated hydrogen.

Biofuels could technically substitute oil in all transport modes, with existing power train technologies and re-fuelling infrastructures[13]. The feedstock of biofuels, however, is limited by the availability of land, and sustainability considerations, in particular for present generation biofuels, such as bioethanol and biodiesel. Optimisation of land use, plant selection, and biomass use could possibly considerably increase the resource potential. Alternative sources of biomass in future could be also algae.

Liquid biofuels can be blended with conventional fuels and are compatible with existing fuel distribution infrastructure and most vehicles up to certain limits in concentration (10% ethanol, and 7% biodiesel). Higher contents may require some vehicle adaptations, but offer also the prospect of higher engine efficiency. Advanced types of biofuels, already in the market and under development, can be blended at any ratio with petrol and diesel fuels, and are fully compatible with existing vehicles and re-fuelling infrastructure. Cost of production and logistics of feedstock supply, however, are still issues for advanced biofuels.

The market share of biofuels is presently 3%, and is expected to rise to about 10%, mostly biodiesel, by 2020, following the renewable energy plans of the Member States. Market development has been supported through low fuel taxes, mandates on market quota, and mandates on re-fuelling stations.

Synthetic fuels can be produced from a wide feedstock range, converting biomass to liquid (BTL), coal to liquid (CTL) or natural gas to liquid (GTL) fuels, or converting plant oils and animal fats to Hydro-treated Vegetable Oil (HVO), or using Di-Methyl-Ether (DME). Current production is 2 Mt/y of HVO, and 8 Mt/y of GTL. Synthetic fuels are fully fungible and can be blended into fossil fuels at any ratio. Therefore, synthetic fuels can be distributed with existing infrastructure, and used in existing internal combustion engines.

Synthetic natural gas derived fuels (GTL) can contribute to the substitution of oil without modifications to the existing vehicle fleet and refuelling infrastructure.

The main issues for synthetic fuels are high cost, and feedstock and process optimisation for biomass based supply chains.

Natural gas has now become the energy resource with the highest potential for future supply, with recent discoveries of shale and tight gas reserves bringing estimates on its range up to 250 or more years[14]. Natural gas is supplied from fossil sources, from biomass and waste as biomethane, and possibly in future also from methanisation of renewable hydrogen. Bio-methane provides the highest energy yield per agricultural area used. It can be fed into the natural gas grid to supply natural gas powered vehicles from a single grid. Natural gas, as fuel can be used in gaseous (**CNG**) or liquefied form (**LNG**).

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[13] EU project REFUEL: http://eaci-projects.eu/iee/page/inc/Popup_PDF.jsp?prid=1693

[14] IEA, World Energy Outlook 2011; natural gas: http://www.iea.org/aboutus/faqs/gas/

Natural gas vehicle and infrastructure development have been supported by Community funds; their market development through Cohesion Funds, state aid, and favourable taxation. A private initiative in Germany has built up some 900 filling stations within 10 years, supporting a rapid growth of the natural gas vehicle fleet from near zero to presently about 90,000. A total of about 1 million natural gas vehicles exist presently in the EU, and some 3000 filling stations.

Natural gas vehicle technology is mature for the broad market, and the existing dense natural gas distribution network in Europe can supply additional re-fuelling stations. Extension of the infrastructure and closing of gaps in Member States with scarce publicly accessible filling stations would still be necessary for EU-wide mobility.

LNG is an attractive fuel option **for ships and boats** to reduce air pollution presently caused by heavy fuel with high sulphur content, allowing meeting the future emission limits in sulphur emission control areas, such as Baltic Sea, North Sea and English Channel. These obligations will be relevant for about half of the 10,000 ships currently sailing in European Short Sea Shipping.

LNG has also a large potential as fuel **for trucks**, due to its high energy density, comparable to diesel. It reduces also air pollution from particulate and nitrous oxide emissions. Technical solutions for trucks exist, and are introduced in small fleets. Broader market uptake is mostly hampered by the lack of re-fuelling infrastructure.

Boosting the market uptake of LNG with growing demand for fuel for ships, boats, and trucks would also support the development of a global natural gas market, with diversified sources and supply routes, and competitive prices. LNG, presently accounting for 10% of total natural gas consumption, provides a leverage to connect so far segmented regions[15] with very different price levels, in Europe presently a factor 5 above US prices, and Far East Asia a factor 2 above Europe. Globalisation of the natural gas market is expected to lead to decreasing prices in Europe, and an increasing decoupling from the oil price.

LPG (Liquefied Petroleum Gas) is a by-product of the hydrocarbon fuel chain, currently resulting from crude oil and natural gas, in future possibly also from biomass. LPG is currently the most widely used alternative fuel in Europe, accounting for 3% of the fuel for cars and powering 5 million cars. LPG infrastructure is well established, with over 27,000 dispensing sites in the EU.

LPG is expected to keep its position as fuel primarily used in passenger cars and vans, with the potential of increasing its market share to around 10% by 2020. In the long-term perspective, bio-LPG could be sourced from bio-refineries.

Multi-fuel solutions comprising the alternative fuel options as described, meet the needs of transport in Europe and worldwide and can provide a gradual substitution of oil in all transport. Co-ordinated action of public and private actors is required to resolve outstanding technological issues, improve economic viability, and build customer acceptance, all indispensable for a broad market uptake of new technologies.

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[15] BP Statistical Review of World Energy, June 2012: http://www.bp.com/sectionbodycopy.do?categoryId=7500&contentId=7068481

8. AN INTEGRATED TRANSPORT-ENERGY SYSTEM BASED ON RENEWABLES

Renewable energy sources are expected to provide the dominant contribution to overall energy supply on the long term. The Renewable Energy Directive[16] requires a share of 20 % by 2020. It also sets a goal post for the route away from oil in transport, requiring a market share of 10 % of motor fuels from renewable sources by 2020. Alternative fuels for transport can play an important role to support the transition to an energy system with dominant supply from renewable sources.

Electricity production, with an increasing share, is coming from variable renewable energy sources, such as wind and solar. European electricity industry is working towards full decarbonisation of electricity production by 2050. This requires a massive build-up of new energy storage on the supply side, and control of power consumption on the demand side, to compensate for a mis-match between random power production and independent consumer demand.

Battery electric vehicles can offer a certain amount of controlled energy consumption, part of it possibly also for feeding back into the grid. The size of available battery storage, however, is small compared to the expected needs. Total power consumption of 5 million electric vehicles, as projected for Europe by 2020, would be of order 0.3% of EU electricity production, whilst 40% of EU power production is expected to come from renewables by that time. Less than 1% of all renewable electricity would then go to electric vehicles. But charging of batteries, aligned with renewable electricity supply and supported by smart metering and a smart grid, could smooth out the load on the grid. Feeding power back from the batteries could assist in grid stabilisation.

Hydrogen is considered a possible option for large-size energy storage, produced through electrolysis from water. Hydrogen could then be used in fuel cells, or fed into the natural gas grid, enriching its energy content. It could also be converted to methane in a reaction with CO_2 ("e-gas": from electricity to gas). Studies show that economic conditions may be achieved despite the low energy efficiency of the hydrogen production process.

Natural gas can be sourced from two renewable pathways:

a) gasification of biomass producing biomethane

b) "methanisation" of hydrogen generated with renewable electricity from water through electrolysis, producing methane as "e-gas". Pilot projects on combined renewable electricity/methane production have started[17].

LPG can be sourced from bio-refineries as a by-product. Integrated bio-refineries can optimise the use of biomass for mobile, stationary, and industrial applications.

Alternative fuels thus are an integral part of a renewables based energy system and facilitate the build-up of it. Electricity and hydrogen for electromobility, and natural gas for vehicles, boats and ships, in their role of energy carriers, can increasingly provide renewable and low-CO_2 energy supply to transport.

[16] Directive 2009/28/EC on the promotion of the use of energy from renewable sources

[17] Vattenfall project in Berlin-Brandenburg

9. CONCLUSIONS

Mobility is a basic need of people and essential condition for the development of societies. The fundamental changes in the political landscape of Europe, with the integration of most of the continent into the European Union, and the rapidly progressing globalisation of economy, require major adaptations and re-orientations of the transport system. Corrections are necessary also to respond to growing environmental challenges.

The 2011 White Paper on a European transport policy has presented a comprehensive programme of actions, based on the vision of sustainable mobility by 2050. The main lines are completing the internal market in Europe, fostering cohesion in Europe through an integrated transport system with efficient links to neighbours and global partners, and improving transport efficiency and environmental performance through technological innovation.

Alternative fuels play an important role, as they should help to solve the major issues of oil dependency and growing greenhouse gas emissions. A comprehensive alternative fuel strategy for Europe should provide the stable long-term policy framework required for research and technological development and the gradual market build-up.

All needs of transport for long-term sustainable energy supply can be met by a fuel mix comprising the main options of electricity, hydrogen, and biofuels, complemented by natural gas, and supplemented by LPG.

Technologically mature solutions exist for all alternative fuels, with different preferences for the different transport modes. Major research and development efforts, however, are still required in most cases to firm them up for a broad market introduction. Decisive will be a well co-ordinated alignment of the ramp-up of the marketing of alternative fuel vehicles and vessels and the build-up of the required fuel infrastructure.

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