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THE CHANGING MARKET FOR ENERGY IN TRANSPORT

IMPACT OF THE COMPETITION FOR LOW CARBON MOBILITY IN EUROPE

BY KOEN GROOT

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KOEN GROOT

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EXECUTIVE SUMMARY

Oil consumption in Europe is broadly regarded to have reached a peak, a message that has been put forth by international organizations of both public and private nature. This is considered to be primarily the result of the economic maturity and the aging population of the EU. Another explanation is that at the sector level, the use of oil products in industrial processes is expected to drop, mostly due to restructuring within the European refining and petrochemicals industry.

Demand reduction in the transport sector has the largest potential influence on future oil demand in Europe. The likeliness of this is increasing, now that European lawmakers are focusing on the introduction of alternative fuels and mandatory improvements in the fuel efficiency of new vehicles, in an effort to combat climate change. In order to grasp the effect of this, one must bear in mind that this change is taking place in a mature market – with high vehicle penetration rates characterising the region's economic maturity – leaving little room for market growth.

The abovementioned causes and the combination thereof are very explicit in Europe, although various aspects are shared also by other OECD states. As a result of the regional specificity, perspectives on the future oil market barely extrapolate the European decline to a global level. This clearly relates to the expected development trajectories of the global economy and population, which are very likely to grow significantly in the decades to come – one needs only to think about South and East Asia. The expected growth trends there and in other regions translate to the high growth expectations for future global demand for oil (and transport fuel), as conveyed in international forecasts.

We are of the conviction, however, that there is more to the changing demand for transport energy in Europe. In response to technological and societal developments, markets for low-carbon mobility are emerging. New products and services are being developed and consumed, increasing the competition for oil in transport. In this paper, we seek to highlight these dynamics, which are taking place in several domains and as such are contributing to the long-term decline in European oil demand:

- Consumer demand is changing, facilitated by innovation in (information) technology and accommodated by the increasingly urban communities people live in. The plateauing of total passenger distances covered in the EU seems to confirm this trend. The development of new IT and mobility services allows a broad range of companies to compete for low-carbon mobility demand, through propositions ranging from virtual mobility to vehicle-sharing schemes.

- In response to the demand for increased fuel efficiency (in the EU, as well as in the other large vehicle markets, such as the US, China and Japan), automobile manufacturers around the world are investing in achieving better fuel efficiency. They are doing so by introducing lighter materials, more IT and hybrid powertrains.
- The competition for low-carbon vehicles has also opened up the competition for alternative powertrains, with companies dedicated to electric mobility entering the domain of incumbent car manufacturers and growing rapidly.
- In the energy sector itself, competition for the transport market is in full swing. Natural gas producers and marketers increasingly look to the transport sector for future demand, utilities are awakening to the opportunities of electric mobility, and companies from the chemical industry are taking on a larger role in developing new generation biofuels.

Changing societal perceptions translate into new policy directions and altered consumer preferences. Markets are opening up for alternative transport arrangements – alternative here meaning other than the traditionally dominant type of privately owned on-road vehicles, which are fuelled by oil products and driven by internal combustion. Companies – global and European, incumbent and entrepreneurial, and from a broad range of economic sectors – are focusing on the development of products and services for these markets. As such, competitive forces will place further pressure on oil product volumes consumed in EU transport.

The economic and demographic factors that play a role in the decline of EU oil consumption are mostly specific to the region and as such difficult to extrapolate. The growing international competition for the European demand for low-carbon mobility, however, may be generalizable to the global transport sector, even if the effect of these new forces might take much longer to materialize in other regions due to differences in development patterns.

1 INTRODUCTION

In recent years, various new policies have been introduced throughout the EU, intended to reduce the carbon footprint of the transport sector and to diversify the energy use in transport. While policy is known to have influenced energy use in transport before, the extent of the effects of these policies will depend on developments in other domains. Without the widespread availability of low-carbon fuels and vehicle technologies, or without adjustments in consumer behaviour, transitioning to a low-carbon transport system will be a slow process.

Globally, energy consumption in the transport sector accounts for approximately 20% of primary energy demand.[1] In the case of the EU, this number is even higher, where transport energy consumption is close to one-third of total primary energy demand[2] (see Figure 1).

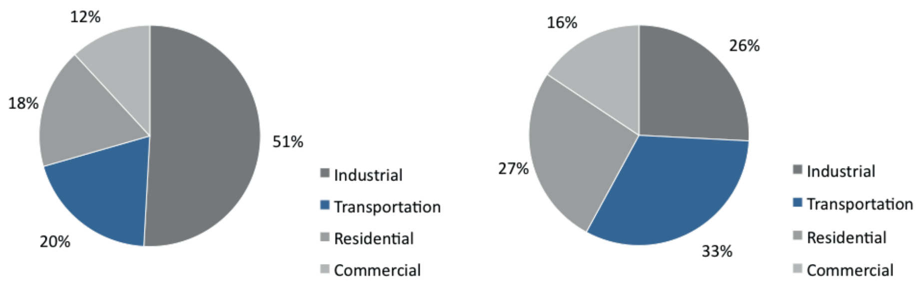

FIGURE 1. PRIMARY ENERGY DEMAND PER SECTOR GLOBAL (LEFT, CA. 255 MBOE/D)[3] AND EU (RIGHT, CA. 34 MBOE/D)[4]

When it comes to oil consumption, the role of transportation is even more pronounced. Globally, 57% of all oil products are consumed in transport. In industrialized countries, such as those of the EU, the transport sector accounts for 75%[5] of total oil consumption; mainly as gasoline and diesel, but also through oil products such as bunker fuel and kerosene.

1 EIA, http://www.eia.gov/tools/faqs/faq.cfm?id=447&t=1, accessed June 2014; BP, 2013, 'Energy Outlook 2030'
2 Eurostat, 2013, 'Consumption of Energy'
3 255 million barrels of oil equivalent, based on 12,730 million tonnes of oil equivalent from BP data (2014, 'Statistical Review of World Energy'); sector consumption share data from EIA (2013, 'International Energy Outlook').
4 34 million barrels of oil equivalent per day, based on 1,676 million tonnes of oil equivalent from BP data (2014, 'Statistical Review of World Energy'); sector consumption share data from Eurostat (2013, 'Consumption of Energy').
5 IEA, 2014, 'World Energy Outlook'; EIA, 2014, 'International Energy Outlook'

In the past hundred years, oil and its derivatives such as gasoline have become virtually synonymous to energy, because of their omnipresence in our daily lives. Automobiles, buses and trucks account for the vast share of (automated) mobility.[6] Globally, oil products are the main source of energy used for transport,[7] and in the European Union, 94% of all energy consumed in the transport energy is oil-based.[8] The place of oil products in the (global) transport fuel mix is rooted in the combination of *available technology and associated supply chains, the focus of policy* and *the preferences of consumers*.

Of all transport modes, most energy is consumed in road-bound transport (73% globally): the cars, trucks and buses that transport goods and passengers. These vehicles are propelled mostly by internal combustion engines (ICE) fuelled by gasoline or diesel (see Figure 2).

The transport fuel mix is not only determined by the availability and affordability of propulsion technologies and corresponding energy carriers – the consumer, producer and government perspectives – but also by macro-economic and social-political considerations. Issues of government income through taxes and levies, the cost of energy imports to the country, economic activity and associated jobs related to automotive and energy value chains, and the impact on the environment come to the fore in policy discussions regarding energy use in transport.

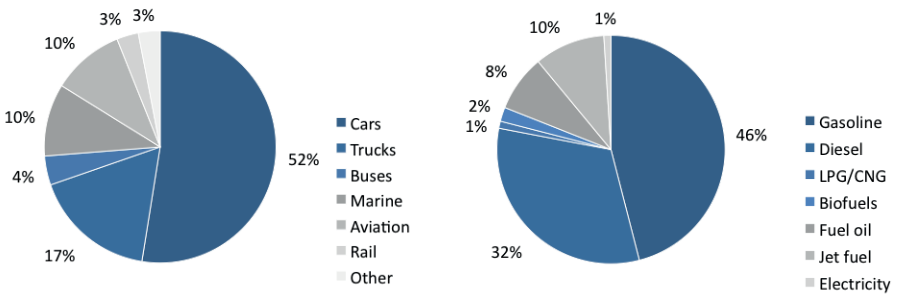

FIGURE 2. SHARE OF TOTAL GLOBAL ENERGY USE BY TRANSPORT MODE AND BY FUEL TYPE (TOTAL CA. 50 MBOE/D)[9]

6 In the EU, distances covered by private cars account for about 90% of passenger kilometres. Combined with the passenger kilometres covered by transport in bus and coach, this increases to an approximate 95% of passenger kilometres travelled. These proportions have been constant since 2005 (CEPS, 2013). In the US, Passenger car journeys account for approximately 72% of all passenger kilometres (New University of Lisbon, 2011, 'Electric Vehicles in the European Union: Conditions for success, impact on the power system and CO2 emissions'). In 2010, 83% of final energy demand in transport came from passenger and freight road transport (EU, 2013, 'Trends to 2050', Figure 25)

7 In 2010, over 96% of transport energy consumed was oil based (World Economic Forum, 2011, 'Repowering Transport')

8 EC, 2013, 'Clean Power for Transport: A European alternative fuels strategy'

9 50 million barrels of oil equivalent per day, based on 20% of 255 Mboe/d or 12,730 Mtoe from BP data (2014, 'Statistical Review of World Energy'), share per transport mode and fuel type data from World Energy Council (2012, 'Global Transport Scenarios 2050').

The past decade has seen climate change and air quality become important drivers for policy in areas such as electricity production, energy consumption and transport. Globally, the transport sector accounts for 20% percent of greenhouse gas emissions;[10] in the EU, this share is even larger, at approximately 30%.[11] In the EU, in concordance with the overall ambition to reduce GHG emissions to be 80-95% below 1990 levels by 2050, transport sector emissions should be 60% below 1990 levels in 2050[12] – which roughly translates to a 70% reduction of current transport sector emissions.[13]

There are various ways to achieve the decarbonization of transport. It can be done by limiting mobility, shifting from individual to public transport, improving efficiency related to infrastructure, improving energy productivity of vehicles and vessels, and/or using alternative – zero- or low-carbon – energy.

So *how* will the competition for this declining carbon space for transport develop in the years to come? Moreover, how will this transpire in the various competitive domains that shape energy use in transport?

The relevance of understanding the development of transport energy demand and the drivers thereof extends beyond the implications for the European market. Thus far, various international organizations share the belief that European demand for oil has peaked (see Figure 3), as it is characterized by economic maturity and an aging population. The expected development of *global* oil demand is in stark contrast to this and relates mostly to growth prospects for the world population and economy.

10 Cornell Energy, http://energy.mae.cornell.edu/mobileplatform.html, accessed June 2014

11 IEA, 2012, 'Technology Road Map Fuel Economy'

12 "At the same time, the EU has called for, and the international community agreed, on the need to drastically reduce world greenhouse gas emissions, with the goal of limiting climate change below 2ºC. Overall, the EU needs to reduce emissions by 80-95% below 1990 levels by 2050, in the context of the necessary reductions of the developed countries as a group, in order to reach this goal. Commission analysis shows that while deeper cuts can be achieved in other sectors of the economy, a reduction of at least 60% of GHGs by 2050 with respect to 1990 is required from the transport sector, which is a significant and still growing source of GHGs. By 2030, the goal for transport will be to reduce GHG emissions to around 20% below their 2008 level. Given the substantial increase in transport emissions over the past two decades, this would still put them 8% above the 1990 level." (EU, 2011, 'White Paper Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system')

13 CEPS, 2013, 'Pathways to low carbon transport in the EU'

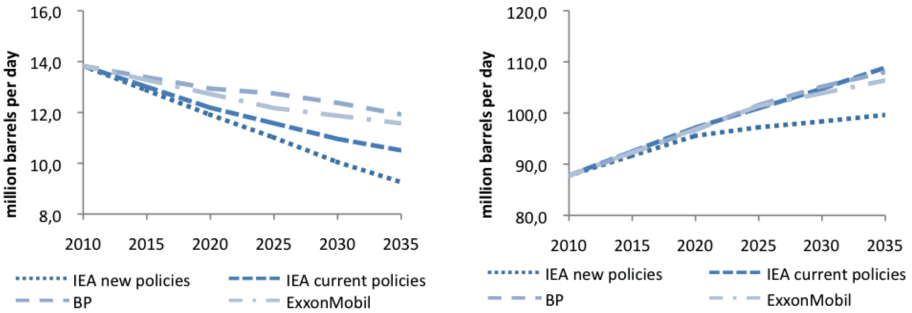

FIGURE 3. DEVELOPMENT OF OIL DEMAND IN EUROPE (LEFT) AND GLOBALLY (RIGHT)[14]

For the first time in a hundred years, the dominant combination of internal combustion and oil products is being challenged.[15] This paper sets out to identify the drivers for change in road transport energy use by analyzing developments in different domains, both from a demand side and a supply side perspective. As such, the paper focuses on how these developments influence the transport energy mix in Europe – or have the potential to do so. Thereby we seek to infer about the direction in which change will develop and what the potential implications of this route might be.

The structure of the paper is as follows. In Chapter 2, the focus is on energy use in transport, on the composition of the fuel mix and on the already observable changes taking place. Chapter 3 provides a description of the demand side of energy in transport; it thereby focuses on (changing) consumer preferences and on the demand management strategies of governments. In Chapter 4, the focus is on the automotive sector and the way technological innovations contribute to changes in energy consumption within the transport sector. Chapter 5 then looks at the developments in the energy sector, focusing on developments in the natural gas, biofuels, electricity and oil industries and on how these influence energy used in transport.

14 The growth trajectories displayed in the graphs are based on the growth trends in oil demand as presented in the annual energy outlooks by BP (2014), IEA (2014), and ExxonMobil (2014). These trends were used to extrapolate the historical oil demand in 2010 (BP, 2014, 'Statistical Review of World Energy').

15 Foreign Policy, 2014, Rose and Tepperman, 'Power to the People: What will fuel the future?'

2 TRANSPORT, FUEL MIX AND TRANSITION

ENERGY USE IN TRANSPORT

Over the past 50 years, world GDP has grown, in nominal terms, from 1.9 trillion US$ in 1965 to 72.7 trillion US$ in 2012.[16] In this same period, world population has more than doubled, from 3.3 billion in 1965 to over 7 billion in 2012.[17] This tremendous jump in population and economic growth has contributed to a continuous increase in demand for mobility, in terms of the movement both of people and of goods. As a result, demand for oil has nearly tripled, from 30.6 million barrels per day in 1965 to 89.9 million barrels per day in 2012.[18]

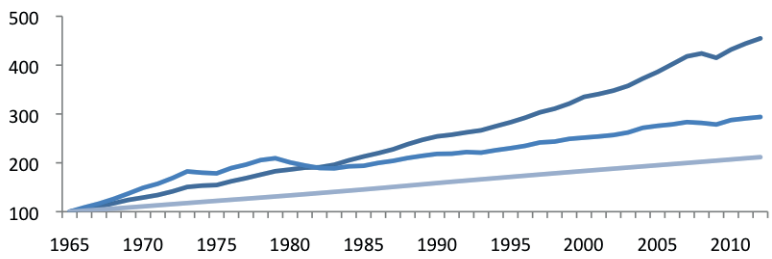

FIGURE 4. DEVELOPMENT OF GLOBAL (ECONOMIC) INDICATORS (INDEXED 1965 = 100)[19]

When looking at the development of these indicators, it seems that from the 1970s onwards, world oil consumption has developed in line with population growth trends while following short-term adjustment trends of global GDP (see Figure 4). In this sense, economic growth has been the enabler for the growing population to make more use of transport services. By taking a closer look at transport energy consumption of the past decades, it becomes clear that growth in road transport has been the main contributor to increases in transport energy use: light-duty vehicles (LDV) and heavy-duty vehicles (HDV); see Figure 5.

16 World Bank, 2014, http://data.worldbank.org/indicator/NY.GDP.MKTP.CD/countries. In real terms – after adjustment for inflation – world GDP increased by an approximate 450% (based on World Bank data (http://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG)

17 World Bank, 2014, http://data.worldbank.org/indicator/SP.POP.TOTL

18 BP, 2014, 'Statistical Review of World Energy'

19 Annual percentage growth rate of GDP at market prices based on constant local currency. Aggregates are based on constant 2005 US dollars, as retrieved from: http://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG; Source: BP (2014); World Bank (2014)

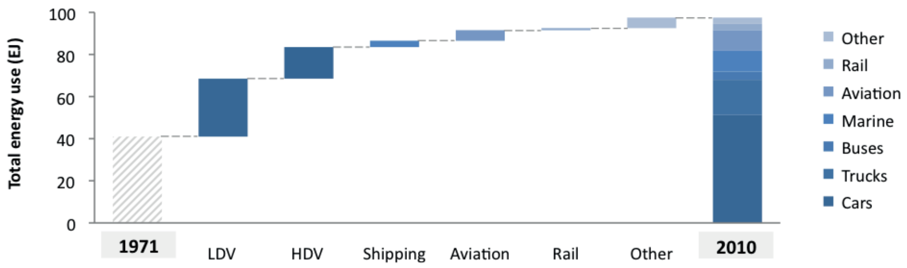

FIGURE 5. CHANGES IN GLOBAL TRANSPORT ENERGY CONSUMPTION PER MODE FROM 1971 (TOTAL 41 EJ) TO 2010 (TOTAL 97 EJ)[20]

Over the past four decades, the transport sector has been characterized by an average energy consumption growth of 2%.[21] Globally, road transport represents the largest share in the transport sector (73%; see Figure 2), as most people and goods are transported by car, bus or truck. These vehicles are virtually all ICE powered, enabling oil products to make up the largest energy source for road transport. Apart from this, oil products dominate maritime transport (bunker fuel), aviation (jet fuel) and rail transport (diesel).[22] Altogether, these oil products (and their variations) satisfy 96% of global transport energy demand.

The EU is no exception to this. Diesel and gasoline dominate the transport fuel mix (see Figure 6). When looking at the development of the European fuel mix over the past decade, it can be observed that gasoline is losing market share to diesel. This substitution is related to diesel-friendly tax regimes in the EU, imposed to increase fuel efficiency – policy that dates back to the 1980s.[23] The share of biofuels has grown, too, in the past decade (to an approximate 4.4% of the total mix),[24] also the result of policy choice. In the case of biofuels, this is related to climate change policy focused on reducing emissions through EU biofuel blending policies.[25] Other fuels have also become more prominent; Liquefied Petroleum Gas (LPG) and Compressed Natural Gas (CNG) in European road transport fulfilled an approximate 3.5% of

20 IEA, 2012, 'Technology Roadmap Fuel Economy'
21 IEA, 2012, 'Technology Roadmap Fuel Economy'
22 Globally, over 60% of rail transport is diesel powered (IEA, 2011, 'Energy Technology Systems Analysis Programme technology brief: Rail Transport')
23 Through favourable taxation regimes for diesel as compared to gasoline (IFRI, 2008, 'Gasoline and Diesel Prices and Taxes in Industrialized Countries')
24 EC, 2013, 'Clean Power for Transport: A European alternative fuels strategy'
25 Enforced by Directive 2003/30/EC on the promotion of the use of biofuels or other renewable fuels for transport, the EU established the goal of reaching a 5.75% share of renewable energy in the transport sector by 2010; and repealed by Directive 2009/28/EC on the promotion of the use of energy from renewable sources, this share rises to a minimum of 10% in every Member State by 2020

demand in 2013[26] as compared to 1.7% in 2005.[27] Even given this growth of natural gas and biofuels, oil products (including LPG) still satisfy 95% of energy demand in European road transport.

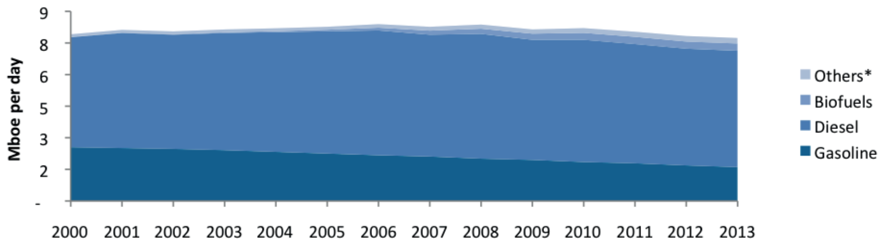

FIGURE 6. THE EUROPEAN FUEL MIX FOR ROAD TRANSPORT28 I*LPG, CNG AND ELECTRICITY[29]

CHANGING PATTERNS IN TRANSPORT ENERGY CONSUMPTION

In general, the transport fuel mix is determined by – in no particular order – the properties of the automobile fleet with regard to the prevalent powertrains[30] in vehicles, the variety and availability of affordable energy for transport (whether fuels or other energy carriers, e.g. batteries or fuel cells), the mobility needs of consumers, and the policy framework. Globally these determinants have thus far favoured oil products. Changes taking place in recent years, however, might influence the total energy volume consumed in road transport and the average volume consumed per person, as well as the volumetric distribution of the energy sources used for vehicle propulsion. The energy use in transport is shaped by technological, societal and political developments and their relations to business activities and consumer preferences (depicted in Figure 7).

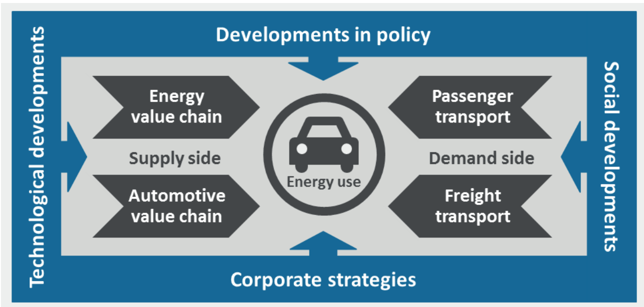

FIGURE 7. FORCES DETERMINING THE USE OF ENERGY IN TRANSPORT

26 AEGPL (2013); Oxford (2014); EC (2007, 2013); Wood Mackenzie (2014)
27 European Commission, 2007, 'European Energy and Transport Trends to 2030'
28 JODI Oil (2014), AEGPL (2014), European Commission (2007,2013), Wood Mackenzie (2014), Oxford (2014)
29 The share of total others is estimated at about 3.5% of total EU transport energy demand in 2013: the share of LPG has grown from approximately 2% in the early 2000s to 3% anno 2013; the share of CNG is approximately 0.5%; the share of electricity is still very small, therefore used in upward rounding
30 The mechanisms that transmit the drive from the engine to the axle

Technological and societal developments have the potential to significantly change demand patterns in mobility around the globe. Advancements in and the precipitation of new information and communication technologies – for example virtual mobility and 3D printing – already have an effect on the physical transportation of people and goods, and this is likely to increase. The declining rate of new driver's license holders in countries like Germany and other EU Member States as well as other OECD countries globally[31] is an example of how mobility demand patterns might be changing. Meanwhile, growing urban populations form a pool of consumers who engage in mobility arrangements like car sharing. These innovations lead to the development of new markets, where companies old and new compete for market share.

Technological and market developments in the energy sector, especially concerning the relative competitiveness of various energy carriers, are another driver of change for energy use in transport. Since the early '00s, several alternative transport fuels have become serious alternatives to oil products. Natural gas is making significant inroads into the transport energy mix by way of CNG,[32] which is mostly used for the propulsion of light-duty vehicles (LDV). Meanwhile, LNG is expected to grow as a transport fuel, especially in maritime vessels and in road-borne heavy-duty transport vehicles (HDV). An already impactful development in transport energy has been the increase in biofuels, which production increased by over 500% from 2002 to 2012,[33] contributing nearly 5 percent of EU transport fuel use in 2013.[34] The momentum for biofuels, however, seems to have turned – at least for the moment – in the EU, as *first* generation biofuels[35] raise concerns regarding sustainability. New generations of biofuels, such as cellulosic ethanol,[36] might offer new growth potential; however, commercial success is still limited. In the European electricity market, the margins of large utilities, the traditional suppliers of electricity, are under pressure.[37] As such, these firms are looking for new markets, and electrification of transport is one way in which some are approaching this. At the same time, oil companies are engaged

31 Frontier Group, 2012, 'Transportation and the New Generation: Why Young People Are Driving Less and What It Means for Transportation Policy'; IHS and Futuribles, 2012, 'Is Car Ownership a Thing of the Past?'

32 There were over 15 million CNG vehicles on roads around the world in 2012, compared to less than 2 million in 2000 (Citi, 2013, 'Global Oil Demand: The end is nigh'). In 2012, demand for natural gas in transport reached 5 billion cubic meters (Wood Mackenzie data in Reuters, 4 February 2014, 'Global Transport Sector Looks to Ride Natural Gas Boom'

33 BP, 2013, 'Statistical Review of World Energy'

34 EC, 2013, 'Clean Power for Transport: A European alternative fuels strategy'

35 First generation biofuels are considered those derived from vegetable oil such as soybean, sunflower, palm and rapeseed; and those derived from starch, such as potatoes, cassava, wheat and corn. (Potters, Van Goethem & Schutte, 2010, 'Promising Biofuel Resources: Lignocellulose and algae', in Nature Education 3(9):14)

36 Biofuel produced from the inedible (parts of) plants (Huber and Dale, 9 April 2009, 'The Fuel of the Future is Grassoline', in Scientific American)

37 Groot, 2013, 'EU Power Utilities Under Pressure', Clingendael Energy

in producing less polluting and/or more efficient oil products such as high-octane gasoline[38] and ultra-low-sulphur fuels.[39]

Technological developments in the automotive value chain also have the potential to alter energy use in transport, through the development of more energy-efficient vehicles and the development of alternative powertrains. The development of new powertrains towards commercialization and mass production are quintessential elements herein. Exemplary for this trend is the increase of hybrid-electric and electric vehicles in the product ranges of automotive original equipment manufacturers (OEM).[40] As a result, both technologies are advancing and new generations of hybrid-electric vehicles and plug-in electric vehicle technologies are being marketed. Pioneered on a large scale by Toyota, hybrid drive technologies have become instrumental in the approaches by OEMs to increase fuel efficiency and decrease emissions. Meanwhile, electric mobility is also developing steadily, moving beyond the early adoption stage. Driven by French (and, outside Europe, Japanese) OEMs and independent entrepreneurial firms, EV is now integral to virtually every automotive OEM's portfolio.[41] By 2020, more than three million plug-in electric vehicles are expected on EU roads.[42] In anticipation of (and in response to) changes in the legislative framework of their markets (e.g. on tailpipe emissions), many OEMs are pushing for more efficient vehicles, whether through downsizing their models, weight reduction, drive-train optimization or hybridization. Manufacturers of trucks are also moving in the direction of powertrain hybridization,[43] and in addition to this, various OEMs are manufacturing trucks with bi-fuel engines capable of running on liquefied natural gas.[44]

FAR-REACHING INFLUENCE OF CLIMATE CHANGE ABATEMENT POLICIES IN EUROPE

Thus far, policy has been instrumental in shaping the EU energy mix of transport (as shown in Figure 6). It determines fiscal conditions, stimulates R&D, finances

38 E.g. by blending GTL distillate

39 Ultra-low sulphur fuels such as ultra-low sulphur diesel (ULSD) and ultra-low sulphur gasoline (ULSG), produced by desulfurization of refinery produced diesel and gasoline as well as the blending with GTL refinery products and potentially biofuels (ICCT, 2011, 'An Introduction to Petroleum Refining and the Production of Ultra-low Sulphur Gasoline and Diesel Fuel')

40 In the automotive industry, the term OEM is applied in reference to car manufacturers.

41 Major global automotive companies like Toyota Motor, Volkswagen Group, General Motors, Ford Motor, BMW Group, Daimler, PSA Citroën, Fiat, Nissan Motor, Honda Motor, Renault and Hyundai Motor, all market electric vehicles

42 Navigant (2013), 'Electric Vehicle Market Forecast'

43 E.g. Volvo FE hybrid engines especially applied in stop-and-go vehicles – auto buses, garbage trucks – where the excess kinetic energy involved with breaking is captured and reused through regenerative breaking technology

44 E.g. Volvo (http://www.volvotrucks.com/trucks/global/en-gb/trucks/new-trucks/Pages/volvo-fm-methanediesel.aspx)

infrastructural development and provides industry support. The direction of policy is primarily determined by a mix of fiscal, trade balance, employment and environmental considerations. The past decade has seen climate change and air quality become important drivers for policy on electricity production, energy efficiency and increasingly also for transport. As mentioned earlier, transport accounts for 20% of greenhouse gas emissions globally, with an even higher share in the EU, at approximately 30%. In response to the climate change abatement challenge,[45] the EU has set out to reduce GHG emissions to be 80-95% below 1990 levels by 2050 (see Figure 8). The implication of this effort for the European transport sector is that emissions should be 60% below 1990 levels in 2050.[46]

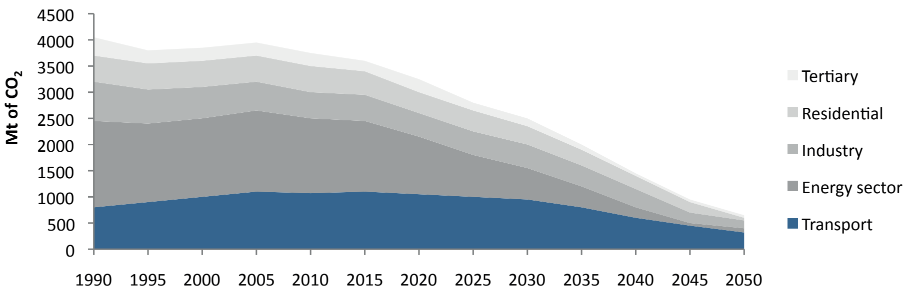

FIGURE 8. EU GHG EMISSION DEVELOPMENT SCENARIO TOWARDS 80-95% REDUCTION[47]

Driven by climate change considerations and associated policy requirements, the 'carbon space'[48] for transport will decrease (see Figure 8). One way of fulfilling these requirements would be by improving the fuel efficiency of vehicles. When it comes to fuel efficiency improvements, it is generally assumed that manufacturers in the automotive industries still have room to improve by 30-50% as compared

45 For more on the issue of the influence of resource consumption on climate change, see reports by the Intergovernmental Panel on Climate Change.

46 "At the same time, the EU has called for, and the international community agreed on the need to drastically reduce world greenhouse gas emissions, with the goal of limiting climate change below 2oC. Overall, the EU needs to reduce emissions by 80-95% below 1990 levels by 2050, in the context of necessary reductions of the developed countries as a group, in order to reach this goal. EU Commission analysis shows that while deeper cuts can be achieved in other sectors of the economy, a reduction of at least 60% of GHGs by 2050 with respect to 1990 is required from the transport sector, which is a significant and still growing source of GHGs. By 2030, the goal for transport will be to reduce GHG emissions to around 20% below their 2008 level. Given the substantial increase in transport emissions over the past two decades, this would still put them 8% above the 1990 level." (EU, 2011, 'White Paper Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system')

47 IEA, 2012, 'Technology Roadmap Fuel Economy'

48 Especially in pursuit of the 450 Scenario (or 2DS), "an energy pathway consistent with the goal of limiting the global increase in temperature to 2°C by limiting concentration of greenhouse gases in the atmosphere to around 450 parts per million of CO2" (IEA, 2014, http://www.iea.org/publications/scenariosandprojections/)

to today's fuel efficiency, by 2030.[49] Another way would be to promote alternative energy carriers in transport that have lower carbon emissions, be it biofuels, electric batteries, fuel cells or natural gas. The past decade has shown that economic growth in emerging economies, rising demand for mobility and high oil prices go hand in hand. In response to this, reducing the exposure to high and potentially volatile oil prices has become a policy priority for many governments,[50] this being reinforced by the projections for future global oil (product) demand.[51] From a policy perspective, increasing efficiency and diversifying the fuel mix has the potential to contribute to several aims at the same time: bringing down GHG emissions, improving trade balances and limiting EU (Member States') exposure to increases and volatility in oil price.

In the EU, a broad range of policies aims to reduce transport GHG emissions. These policies focus on fuel efficiency,[52] the promotion of alternative fuels[53] and the promotion of alternative transport modes.[54] As a result, the transport fuel mix in Europe is likely to undergo significant change. Not only is it likely that other energy sources – alternatives to gasoline and diesel – will increase their share in the mix, but policy efforts are also likely to contribute to a decrease in total transport energy demand in the mature EU market.

The energy efficiency and diversification efforts in the EU are part of a greater international effort, shared by governments and international institutions globally.[55] A similar situation of market maturity is also observable in other OECD countries.[56] In these economies, policy efforts focused on making the transport fuel mix more efficient and diverse will accelerate the maturation of these markets.[57] In the emerging economies, transport energy demand is to grow significantly still, as economic development will lift more people into the middle classes. However, as emerging economies become more urbanized and are facing the consequences of limited air quality control, local air pollution is quickly moving to the top of policy agendas, too.

49 CEPS, 2013, 'Pathways to Low Carbon Transport in the EU – From Possibility to Reality'
50 IEA, 2013, 'Redrawing the Energy-Climate Map'
51 "The era of cheap oil is over." (Birol, 27 May 2010, OECD Annual Energy Forum)
52 The European emission standards (EURO standards), see http://ec.europa.eu/environment/air/transport/road.htm
53 See the proposal EU directive to invest in an alternative transport fuel mix infrastructure (EC, 24 January 2013, 'Proposal for a Directive on the Deployment of Alternative Fuels Infrastructure'; and EC, 2013, 'Clean Power for Transport: A European alternative fuels strategy')
54 E.g. public transport, car sharing/pooling or cycling for passengers and rail and waterway transport for freight transport
55 E.g. the European Union and the International Maritime Organization
56 E.g. in the US and Japan
57 Sulphur emission targets on diesel and gasoline are most stringent in the EU, the US, Japan and South Korea (OPEC, 2014, 'World Oil Outlook', figures 5.14 and 5.15)

The advancements by policymakers worldwide on the issues of energy efficiency and air quality are a potent driver for change in the transport fuel mix, globally as well as in the EU. In combination with the developments in demand for transport energy and developments in the value chains of the automotive and energy industries, the developments in the policy realm are sure to affect the transport energy mix. How far-reaching the consequences and implications of demand side developments will be depends on what transpires in the different domains. Moreover, the consequences and implications of changes in the transport energy mix will depend on the interrelation of development in the various domains. How this will play out and what the implication will be is discussed in the next chapters, respectively discussing demand side, automotive industry and energy industry dynamics.

3 DEMAND SIDE DEVELOPMENTS: CONSUMER BEHAVIOUR AND POLITICS

CHANGING DEMAND FOR MOBILITY AND TRANSPORT

Consumer preferences

Evolving demand patterns have the potential to change the transport fuel mix drastically, in size as well as in composition. Driver's license possession rates under youths throughout the EU (as well as in other OECD countries) are in decline (see Figure 9). At the same time, continued urbanization increases the awareness of pollution and the demand for clean air and noise reduction. Meanwhile, changing communication methods – advancements in information and communication technologies and the widespread ownership of personal computers and smartphones – affect demand for mobility. In response, new mobility concepts are being pioneered by entrepreneurial as well as established firms in the transport sector.

When it comes to motorized mobility, most kilometres are made by passenger cars.[58] The European Union is the second largest market for automobiles, after the US. On an aggregate level, this market is widely regarded to be saturated, especially in the largest (Western) EU economies (see Figure 9). Notwithstanding the accelerated drop in new car registration since 2007, which shows the impact of the economic downturn in the EU, the market for new cars in Europe seems to have reached a plateau. Although growth in vehicle demand is still expected in Eastern European countries, where car ownership per capita is still significantly lower,[59] it seems unlikely that this growth will turn the perspectives for the EU automotive market bullish, given the weight of the mature economies.

58 In 2010, total distance travelled in the EU equalled an approximate 6500 billion passenger kilometres, of which an approximate 4700 billion passenger kilometres were fulfilled by passenger cars (EC, 2012, EU Transport in Figures: Statistical Pocketbook, p.45)

59 This is driven mainly by increases in car-ownership, now at 350 cars per 1000 persons, where NWE sees 500 cars per 1000 persons.

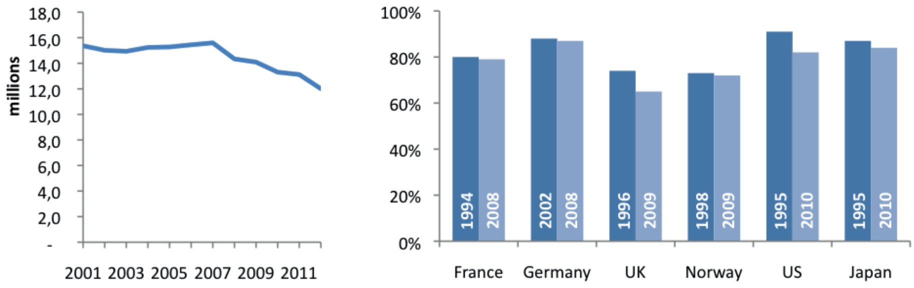

FIGURE 9. ANNUAL PASSENGER CARS SOLD IN THE EU (LEFT[60]) AND SHARE OF LICENSED DRIVERS AMONGST YOUNG ADULTS (RIGHT[61])

On a national level, the stabilization of vehicle demand in itself is not a new phenomenon. In Japan, for example, vehicle sales have been in decline since 1992.[62] The saturation of the EU car market, however, coincides with other trends, which have the potential to alter further demand for mobility in the EU. These developments are likely to not only impact the size of the car market, but the energy consumption in passenger transport. In contrast to the EU, the number of vehicles – cars, trucks and buses – in the world is expected to grow, from 1.025 billion in 2010[63] to 1.7 billion in 2035[64] (also see Figure 9). Practically all of this growth is to take place in non-OECD countries, especially in the growing urbanized areas of China, India, the Middle East and Latin America. Given the general trend toward urbanization, and the congestion and resulting pollution it brings, the market for vehicles with low to no tailpipe emissions will pick up.

At the same time, new forms of mobility are arising: virtual mobility (private and professional) – or, as it is more commonly phrased, the IT revolution – and the use of car sharing services. Consumer preferences with regard to car ownership are changing; this is especially relevant as issues related to energy consumption are gaining more prominence. This surely relates to the price elasticity of transport (energy) use[65] and the recent years of economic moderation in this area. When it comes to consumer preferences regarding new vehicles, the number one priority for consumers over the next five years will be fuel efficiency.[66] Meanwhile, the issue of

60 ICCT, 2013, 'European Vehicle Market Statistics'
61 IFMO, 2013, 'Mobility Y – The emerging travel patterns of generation Y'
62 Wall Street Journal, 2013, 'EU Car Sales Slump'
63 Ward's Auto, 15 August 2011, 'World Vehicle Population Tops 1 Billion Units'
64 IEA, 2012, 'World Energy Outlook'
65 For studies on price elasticity of gasoline consumption see e.g. Hanly et al. (2002, 'Review of Income Elasticities and the Demand for Road Traffic'), or Musso et al. (2013, 'Road Transport Elasticity: How Fuel Price Changes Can Affect Traffic Demand on a Toll Motorway')
66 KPMG, 2013, 'Global Automotive Executive Survey 2013'

environmental impact is growing in importance as a factor of consideration.[67] As a result, demand for vehicles in the EU – and other OECD countries – is shifting towards cars that are more energy efficient.[68]

Some automotive OEMs have started exploring new product markets in anticipation of changes in mobility demand. The investment in mobility planning software[69] and the development of car sharing services[70] by car manufacturers is clearly an example of this. This is especially true in the context of the highly urbanized European continent, where people in densely populated areas perceive limitations to the availability of parking space, which influences their decisions related to vehicles ownership. These (new) mobility arrangements or car use propositions are by no means the prerogative of car manufacturers, or businesses or that matter. Many internet-based car-sharing services have emerged in recent years.[71] These services enable the vast untapped potential of car owners looking to earn on their idle property, through offering their cars for temporary usage, thereby increasing the utility of their vehicles.

Transport companies

The activities and strategies of transport companies, regarding both freight and passenger transport, can be major drivers for change when it comes to alternative energy arrangements. For these companies, the actual cost of mobility is the highest component of their cost structure. Reducing the (operational) costs of transport is therefore regarded as a core task. Increased operational costs associated with higher fuel prices and anticipation of perpetual increases in the future[72] provide an impetus for freight transport companies to make investments in alternative energy for transport. Government support and fiscal policies related to transport fuels – subsidies and especially duties and levies – play crucial roles in the investment strategies of these companies because of the aforementioned impact on the operational cost.[73]

67 KPMG, 2013, 'Global Automotive Executive Survey 2013'

68 GFEI, 2014, 'Fuel Economy: State of the World'

69 E.g. by Daimler https://www.moovel.com/en/US/

70 E.g. by Daimler https://www.car2go.com/en/; Another example is the French Autolib's (https://www.autolib.eu/en/) car sharing service – in the spirit of the renowned Velib bicycle sharing scheme – introduced by French industrial conglomerate Bolloré, which markets its own full electric vehicle developed in cooperation with Italian Pirinfarina, in association with Atos the global IT solutions and services company.

71 Examples include http://www.zipcar.com/ and http://www.lyft.com/. Another example is the taxi service offered via http://www.uber.com enabling non-professional drivers to use their vehicles for taxi services.

72 Global population and global GDP are expected to growth substantially still in the decades to come and thereby have the potential to significantly drive up demand for oil and, as a derivative, global oil prices.

73 When fiscal policies aid in establishing fuel competitiveness for (alternative) fuels, transport companies will be among the first to adopt such fuels.

Public transport companies often facilitate road passenger transport in the EU. The public dimension of such companies (mainly government owned or publicly financed), can be a stimulus for pioneering alternatives. As such, public transport companies can pave the way for larger-scale implementation of alternative transport fuels, propulsion technologies and other initiatives.

Consumer perception is also an important variable for transport companies, both that of individual consumers and, in the case of freight transport companies, that of the companies for which they ship goods. Moreover, corporations have the possibility to steer their employees towards certain alternative mobility uses, potentially providing reductions in corporate expenditures related to transport. Corporate social responsibility and thereby also sustainability, environmental issues and climate change are increasingly relevant aspects of consumer demand. Together with consumer preference changes, the changing rules and regulations on emissions and efficiency are a powerful driver for change in the energy consumption patterns of freight companies.

Driven by various stimuli, transport companies are increasingly investing in fuel efficiency, thereby reducing the energy component of transport costs. Depending on the efficiency options adopted, some companies are introducing alternative energy sources, whether natural gas, biofuels or electricity. Many companies seek to achieve both by introducing hybrid vehicles that use two or more distinct power sources. These hybrids provide fuel-switching (arbitrage), fuel-saving and (local) emission abatement advantages.[74]

74 Plug-in hybrid vehicles have major potential in the medium- and heavy-duty vehicle segment (PWC, 2013, 'State of the Plug-in Electric Vehicle Market'). Fleet managers, much more than passenger vehicle purchasers, take a total cost of ownership approach to vehicle purchase decision making. In the transport sector, CAPEX are are a relatively small component of total costs, as compared to OPEX, therefore vehicle price differences are more likely to be annulled by savings in operation expenses. Not only are operating costs lower for PHEV than for ICE, given the discount with which electricity is sold over diesel, but also the costs for maintenance are significantly lower, varying between 26-42 percent of the costs of maintenance costs of conventional vehicles. As compared to conventional vehicles, the maintenance costs of light-vehicles PEV are 42%. For medium truck applications, this figure is 36%, and for heavy trucks 26% (PWC, 2013, 'State of the Plug-in Electric Vehicle Market'). "Utility, telecommunications, and other service fleets are also developing ancillary applications for PEVs' on-board batteries. This mobile source of power storage has applications for everything from power tools to lift buckets." (PWC, 2013, 'State of the Plug-in Electric Vehicle Market'). Postal, delivery, garbage and municipal public transport companies with fleets that consist largely of stop-and-go vehicles, stand to gain significantly from powertrain electrification. Most firms have already moved from pilot projects in which new powertrain technologies are tested, to deploying trucks partly powered by electric motors on a broader scale (http://www.truckinginfo.com/channel/fleet-management/article/story/2013/11/top-50-green-fleets/page/10.aspx).

The effects of changing demographics

The effects of demographical developments are potentially transformative to energy use in transport. In the coming decades, world population will not only grow in size and wealth (as indicated in Figure 4), but will also be more and more urbanized. The number of people living in urban communities will grow from an approximate 3.5 billion now to potentially 6.4 billion by the year 2050.[75] These urbanized areas shelter the growing middle classes, the prevalent source of new energy demand. Urbanization is set to continue throughout the EU, too, resulting in ever larger and more densely populated urban areas.[76]

At the same time, the use of energy in transport in the OECD countries – typically countries with high shares of urban populations[77] – will continue its downward trend.[78] In addition to aging populations, market maturity and high levels of economic development, the continued urbanization in these countries seems to contribute to this trend. This is due to the conditions in urban areas that affect car ownership and usage, such as shorter distances, spatial limitations (parking issues), more congestion (and resulting emissions), and the availability of public transport and, by extension, of car sharing services.

The aging population in many EU Member States is another demographical development likely to influence the demand for transport fuels in terms of volumes. At the same time, this demographic has the potential to accelerate the demand for autonomous mobility, opening a wide array of opportunities for keeping this group mobile and thereby remaining in need of transport energy.

75 See e.g. World Health Organization (2014, http://www.who.int/gho/urban_health/situation_trends/urban_population_growth_text/en/)

76 http://ec.europa.eu/regional_policy/activity/urban/index_en.cfm

77 Anno 2012, an average of 80% of the total populations of OECD countries were living in urban areas, compared to 50% in East Asia and 31% in South Asia (World Bank, 2014, http://data.worldbank.org/topic/urban-development, accessed on 15 May 2014).

78 "The developed world is using much less oil. Consumption in the OECD is in long-term decline: in 2012, the industrialized countries used the same amount of oil as they did in 1995; today's European Union countries are back at consumption levels last seen in 1967." (BP, 2014, 'Over the Hump for Oil Demand') In addition: "Despite rising consumption in the developing world, the share of oil in the global fuel mix is set to decline, in part due to rising transport fuel efficiency and in part due to the relentless growth in power generation where oil is little-used…" (ibid) – and even less in the future.

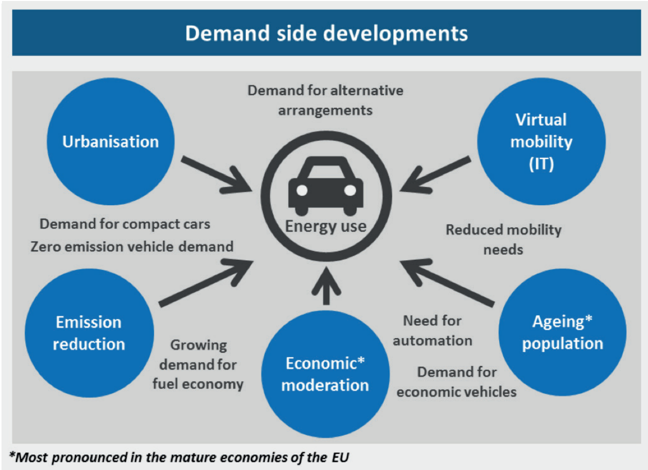

FIGURE 10. DEMAND SIDE DEVELOPMENTS THAT INFLUENCE ENERGY USE IN TRANSPORT

Taken together, these demand side developments exert (or have the potential to exert) significant influence on the transport energy use in terms of total volume and in terms of the shares of various fuels (Figure 10). Changes in living conditions, awareness, demographics and technology use may very well contribute to lower overall demand for energy in European transport.

THE ROLE OF GOVERNMENT IN TRANSPORT (ENERGY) DEMAND

In the EU, there is a longstanding practice of managing the fuel mix of road transport. The growth of diesel at the expense of gasoline (see Figure 6) is a clear example of this. Through the introduction of favourable tax regimes for diesel consumers in the 1990s,[79] larger shares of diesel use in transport were stimulated. This has resulted in the inclination by consumers and producers to choose automobiles with diesel engines. While this significant change has a clear policy component to it, without the then already existing fuel and engine technologies such a change would have been much harder to establish.

Top-down decisions are thus important catalysts for change in the transport fuel mix, as policy contributes to the creation of demand. Markets respond to this, among others through technology and business model development, which leads to policy-induced demand. Apart from the dieselization in Europe, this can be observed in e.g. Brazil in biofuels[80] and the US in fuel efficiency.[81]

79 Europia, 2013, 'Fuelling Europe's Future', http://www.fuellingeuropesfuture.eu/en/refining-in-europe/how-a-rafinery-works/diesel-gasoline-imbalance, accessed on 18 November 2013

80 Approximately a quarter of Brazilian energy demand for road transport is fulfilled through biofuels (http://www.iea.org/topics/biofuels/); of total transport sector energy consumption in Brazil, 15% is from domestically produced biofuels (IEA, 2013, 'World Energy Outlook').

81 Corporate Average Fuel Economy (or CAFE) standards of the US are the countries regulations on fuel efficiency.

Over the past decade in Europe, a new attempt to use policy to steer the transport fuel mix has come about. The blend-in requirements for biofuels are perhaps the most impactful of these attempts thus far, whereas biofuels make up nearly five percent of energy used in EU road transport (as visualized in Figure 6). The future of the transport fuel mix in the context of the climate change abatement effort gained prominence with the European Commission's White Paper on Transport.[82] This work draws from the broader framework set out by the Europe 2020 strategy[83] and by the Roadmap to 2050.[84]

As a result, EU policymaking for the transport sector has focused on the latter aspects of combating air pollution. While air pollution is a longstanding policy priority in the EU, before the emphasis on climate change the focus of transport emission regulation was on tailpipe emissions of pollutants like NOx and particulate matter. This occurred through the European Emission Standards for cars (light-duty vehicles)[85] and for trucks and buses (heavy-duty vehicles).[86] In order to move towards a cleaner transport sector – and fulfil the other requirements mentioned above – EU policy is taking three main directions: (i) increasing efficiency in transport, (ii) diversifying the fuel mix and (iii) increasing support for alternative mobility arrangements.

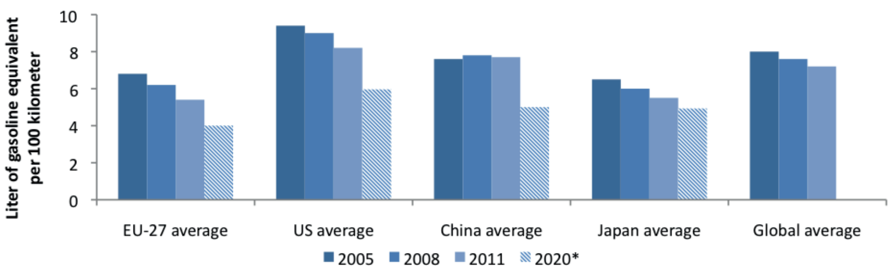

FIGURE 11. IMPROVEMENTS IN AVERAGE FUEL EFFICIENCY OF NEW PASSENGER VEHICLES[87] |*BASED ON POLICY AIMS[88]

82 EU, 2011, 'White Paper Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system'

83 EC, 2010, 'Communication from the Commission – Europe 2020: A Strategy for Smart, Sustainable, and Inclusive Growth'

84 CEPS, 2013, 'Pathways to Low Carbon Transport in the EU – From Possibility to Reality'

85 http://ec.europa.eu/enterprise/sectors/automotive/environment/euro5/index_en.htm

86 http://ec.europa.eu/enterprise/sectors/automotive/environment/eurovi/

87 Source: Global Fuel Economy Initiative, 2014, 'Fuel Economy the State of the World'; GFEI, 2014, 'International Comparison of LDV Fuel Efficiency'

88 For 2021 in case of EU, 2020 in case of Japan and China, 2020 in case of US based on linear development of trend between 2016 aim of 6.9 litre/100 km and 2025 aim of 4.8 litre/100 km

Achieving a reduction in the need for energy through increased efficiency[89] has the potential to not only contribute to reducing greenhouse gases and toxic emissions, but also to decrease the import bill for energy in the EU.[90] The newest set of standards is the EURO 6 norm for light-duty vehicles (LDV), to be implemented in 2015 and the EURO VI norm for heavy-duty vehicles (HDV), for which the implementation date is not yet set. The EURO 6 norm on LDVs demands that the average new vehicle on the market from 2015 onwards emits at most 130 grams of CO_2 per kilometre (g/km), which equates to an energy productivity of five litres of gasoline (equivalent) per 100 kilometres.[91] By 2021, the average new LDV on EU roads has to achieve a maximum of 95 g/km, comparing to an approximately four litres of gasoline (equivalent) per 100 kilometres.[92] This would constitute a reduction of 40% compared to the 2007 fleet average in Europe.[93] In comparison, anno 2011, the average new car in the US needed about eight litres of gasoline (equivalent), while in the same year, the global average was over seven litres per 100 kilometres (see Figure 11).

In addition to the policy focus on energy efficiency improvement in vehicles, EU policy aims to diversify the energy use in transport. Such policy consists of stimulating the introduction of new energy carriers in the transport mix, which has the upside of increasing optionality and diversifying the risks inherent to dependence on one source of energy derived from a limited group of producers. The aforementioned biofuels support is part of this diversification strategy, in that the EU aims to have 10% of transport demand be fulfilled by biofuels in 2020.[94] The recent maximization of the share of first generation biofuels in the mix, at 7%,[95] potentially makes the 10% harder to achieve, as new generation biofuels are less economical and not (yet) available in large quantities. EU and Member State policy support for the use of alternative energy sources in transport is not limited to biofuels. Throughout the EU, policymakers are employing many instruments to achieve change, from directives determining minimum alternative fuel infrastructure requirements to elaborate R&D

89 Of transport, whether in traffic, logistically or technically in vehicle powertrains
90 EU is a net importer of oil and gas, moreover of oil products consumed in transport
91 Transport & Environment, April 2014, 'T&E Bulletin no. 225, 30% Car-CO2 Cut becomes Law after MEPs Vote'
92 Transport & Environment, April 2014, 'T&E Bulletin no. 225, 30% Car-CO2 Cut becomes Law After MEPs Vote'
93 Europe fleet average of 2007 at 158 g/km (Transport & Environment, 2012, 'How Clean are Europe's Cars?')
94 Directive 2009/28/EC on the promotion of the use of energy from renewable sources this share rises to a minimum 10% in every Member State in 2020
95 "After more than a year of talks, the Energy Council says it wants to limit the amount of food-based biofuels to 7% of petrol and diesel sold. Without policy change, around 8.6% would likely come from such biofuels; the Commission proposed a stricter limit of 5%. The deal also further weakens the reporting of biofuels emissions resulting from indirect land-use change" (Transport & Environment, 13 June 2014, 'Ministers seal a modest reform of EU biofuels policy, Energy ministers today finally agreed to change the EU's biofuels policy')

programmes with associated budgets.[96] As such alternatives like electrified mobility, hydrogen and natural gas in transport are promoted – issues to be elaborated upon in the ensuing chapters of this study.

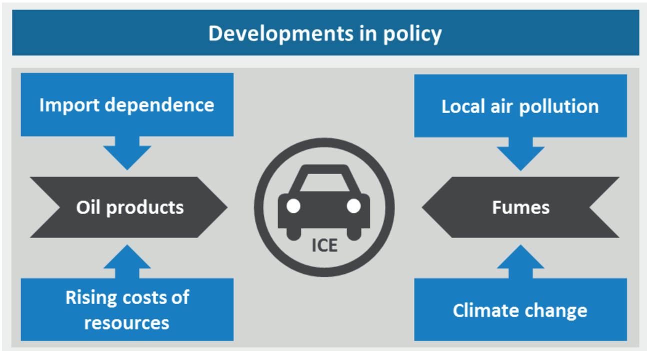

FIGURE 12. DRIVERS OF POLICY THAT INFLUENCE ENERGY USE IN TRANSPORT

Given the extent of contemporary policy aims and measures in the EU, as well as the previous experiences with policy-induced changes in the transport fuel mix, the use of energy for transport in the EU is likely to transform. The (perceived) urgency of the issues for which policymakers and politicians deem these policy responses appropriate contributes to this (see Figure 12). The advancements made in policy on local air quality in Europe and its expected continuation, moreover the precipitation of this trend in emerging economies are another potent driver for change. The apparent trend of strategic political (economic) considerations becoming more prevalent in a world that is seemingly less cooperative also supports this direction. Becoming particularly explicit in the stance towards dependence on non-domestic energy resources in the EU (as well as in other parts of the world); where the reduction in consumption of energy in transport and the creation of domestic resource bases for energy in transport, aid in reducing the dependence on non-domestic energy resources.

These dynamics in the policy realm, only add to the momentum for change in the transport fuel mix, as perceived on the demand side, driven by changing living conditions and the growing availability of alternative communication and transportation services. How far this change will go and how strong the effect will be on demand for energy in transport, moreover demand for oil, will partly depend on the stringency and effectiveness of the policies, as well as on the developments in the other domains, especially with regards to the energy and automotive value chains.

96 "Europe has invested close to €2 billion in various R&D projects ranging from electric vehicle powertrain to grid" (Frost and Sullivan, 2013, 'Competitive Pricing and Introduction of New Models Drives Success of Global Electric Vehicle Market').

4 SUPPLY SIDE DEVELOPMENTS: THE AUTOMOTIVE INDUSTRY

EFFICIENCY IMPROVEMENT: ADVANCED MATERIALS AND COMPUTERIZATION

Fuel efficiency improvement is an increasingly important driver for innovation in the automotive sector (see Figure 11). Automotive firms seek to establish these efficiency gains in different ways, by using new and advanced lightweight materials, as well as by optimizing the drivetrain (e.g. starting and braking). Information and communication technology (ICT) plays a major role in these efforts. Car manufacturers are also experimenting with new propulsion technologies and fuels. Over the past ten years, various technologies have moved beyond the early adaption stage into mass commercialization. Particularly eye-catching is the adoption of electric mobility and hybrid vehicles[97] in the product range of virtually every automotive OEM.

Part of the push towards greater fuel efficiency is taking place through changes in the use of material in vehicles. The average car produced today consists for approximately 70% of steel, and as such the automotive industry accounts for 12% of global steel demand.[98] Automotive OEMs are experimenting widely with alternative materials, to bring down the weight of the vehicles that is determined for a significant part by the materials used in the vehicle components and thus to boost fuel efficiency. While much attention is being paid in this respect to aluminium and composites like carbon-fibre, these materials are relatively costly and as such are not likely to fully replace steel in the years to come. Costs notwithstanding, recent years have seen the share of aluminium and composites in vehicles increase each to approximately 10% of a vehicle's weight.[99] In response to the progression of these materials, steelmakers are focusing on the development of advanced high-strength steels. The properties of this material are such that it offers the possibility to use less steel without affecting function or safety.[100] Similar to competing alternative materials like aluminium and composites, the advanced high-strength steel is also more costly. The drive for greater fuel efficiency of vehicles contributes to the further development and the (accelerated) introduction of advanced materials in vehicles.

97 Hybrid vehicle (vehicles with at least two different energy converters and two different energy storage systems (on vehicle) for the purpose of vehicle propulsion)
98 EY, 2014, 'Global Steel 2014'
99 IHS, September 2013, 'The Heat is on Steel'
100 IHS, September 2013, 'The Heat is on Steel'

In addition to improving fuel efficiency by adjusting passive components of vehicles, active components are under continuous scrutiny for improvement, a development in which electronics play an indisputable role. Electronics have long been part of automobiles, from power steering to cruise control, adaptive breaking to navigation systems. The continuous development in ICT especially contributes to the further integration of electronics in automobiles. Fuel efficiency, safety and infrastructure efficiency may stand to benefit from the further integration of such technologies in the vehicle. One of these directions is through the development and incorporation of new applications like intelligent transport systems (ITS), focused on establishing interaction between vehicles and their environment. Such systems could enable direct rather than mass targeting of vehicles on the road and allow for car-to-car communication, enabling semi-connected driving patterns.[101] The increased connectivity of cars is likely to be an enabler of a next step in the computerization of the automobile, namely the endeavours towards autonomous vehicles.[102] As such, intelligent transport systems are being pursued by many companies throughout the automotive and IT supply chain.

In addition to adding improved efficiency and overall performance to vehicles, other factors also play a role in the advancement of IT in vehicles. The aforementioned apparent slump in demand for cars from younger customers[103] could provide another trigger for car manufacturers to accelerate development trajectories for autonomous vehicles, as this technology has the potential to prolong the active engagement of elder consumers, whereby market share under the ageing 'baby-boom' generation might be kept. The product development of autonomous vehicles from pilot to market option however, is likely to be impaired by the requirements of the transport system as a whole, including insurance, legislation and physical infrastructure, which may very well cause it to take decennia.[104] Nevertheless, various manufacturers are bullish about their ability to produce a self-driving car, some announcing to do so by 2020 already.[105]

The increase of electronics in automobiles may result in greater involvement of IT and electronics companies in the automotive industry. This could contribute to more

101 Platooning is such a pattern, pioneered in the EU Sartre Project (http://www.sartre-project.eu/en/Sidor/default.aspx), focused on the usage of 'road-trains', a string of vehicles travelling at the same speed and in the same direction lead by a platoon-leading vehicle which directs speed and direction.

102 Famously pursued by Google's self-driving car programme, as well as automotive industry participants like tier companies Bosch and Continental and OEMs Daimler and Volkswagen.

103 Bloomberg, 20 October 2013, 'Self-Driving Car Demand Seen Boosted by Japan's Aging Population'

104 It might moreover require a replacement of the car park, in order for the cars to indeed to be susceptible for car-to-car and infrastructure-to-car communication (TNO presentation, 24 September 2013, 'Ontwikkelingen Rond Autonoom Vervoer')

105 Nissan, (http://reports.nissan-global.com/EN/?p=13004)

momentum for the deployment of electric motors in automobiles. Automobiles might increasingly become a service platform, enabling optimized navigation, car sharing and the like. The blurring of industry boundaries also relates to automobile companies offering energy management and mobility planning software for other purposes than usage in vehicles.[106]

ELECTRIFICATION OF POWERTRAIN AND HYBRIDIZATION

In the efficiency effort, or differently phrased, the effort to increase the distance travelled per litre of oil product used, the electric motor is already proving to be a success. The hybridization of powertrains is likely to play a growing role in improving the fuel efficiency of vehicles. Ever since the global introduction of the Toyota Prius in 2000, automotive OEMs have rapidly adapted hybrid electric powertrains in their vehicles.[107] While the first patent for a hybrid engine appeared already in 1905,[108] it took a century before virtually every car manufacturer turned to featuring hybrid electric vehicles in its product portfolio.[109] These hybrid electric technologies are likely to become a standard part of the automobile drivetrain, similar to the way in which catalyst converters were integrated into automobiles in the 1980s and 1990s. This is driven by the ability of electric motors in hybrid cars to facilitate the reduction of greenhouse gas emissions by improving fuel efficiency.[110]

In addition to hybrid electric (HEV) vehicles – where the electric motor is an ancillary system to the internal combustion engine – recent years have seen the rise of plug-in hybrid electric vehicles (PHEV). PHEV combine the features of a HEV with the ability to recharge the battery from an external electric power source. Initially PHEVs were adaptations of HEV,[111] where the electric motor would operate in conjunction with or in addition to the internal combustion engine. As the technology advances and more manufacturers are incorporating hybrid electric vehicles in their product ranges, more customers are finding their way to buying these vehicles.[112] A new generation of hybrid electric vehicles, referred to as 'extended range electric vehicles (EREV)',

106 Ford is looking to expand its on-board energy management platform to manage customers' home energy consumption (Navigant, 2014, Electric Vehicles White Paper), while Daimler offers mobility planning software (https://www.moovel.com/en/US/).

107 A powertrain which combines twin internal combustion and electric engines. Achieving the theoretical fuel efficiency of a hybrid (electric) vehicle is dependent on driving behaviour.

108 Levi, 2013, 'The Power Surge', p. 114

109 As a result of the societal and policy changes discussed in the previous chapters, fuel efficiency and emission abatement have gained prominence and hybridization is part of the automotive sector's response to this.

110 Frost and Sullivan, 23 July 2013, 'Demand for Greater Comfort and Performance in Vehicles Boosts European Automotive Electric Motors Market'

111 E.g. Toyota Prius Plug-In, Volvo V60 Plug-in Hybrid, Ford Fusion Hybrid, etc.

112 In 2012, the Prius was the third most sold vehicle globally (Levi, 2013, 'The Power Surge', p. 116)

are vehicles that feature a full electric powertrain to which an internal combustion engine is the supplement rather than the other way around. This range extending engine is installed to charge the battery – on board – if it runs flat.

In the early nineteen hundreds charging stations for electric vehicles (EVs) were commonplace in New York,[113] where EVs were part of the New York taxi fleet.[114] Now more than a century onwards, EVs have returned to the centre stage. Battery electric vehicles (BEVs) have made inroads in global car parks, even while the global sales numbers do not (yet) parallel those for hybrid electric vehicles. Globally, sales of plug-in PHEVs and BEVs have more than doubled, exceeding 100,000 in 2012[115] and again in 2013 to over 200,000 vehicles globally.[116] In Western Europe, when it comes to the market for plug-in electric vehicles (PEVs; BEVs and PHEVs), the number of vehicles sold in 2013 reached 40,000, up nearly 60% from 2012 sales numbers[117] – out of a total of 12 million light-duty vehicles (LDVs) sold[118] (or 0.33%). Given these numbers, continued acceleration in sales and deployment of PEVs is required for the total number of plug-in electric vehicles to reach 9 million in 2020.[119]

The manufacturers of electric vehicles are focusing their efforts on tackling the inhibitors to the incremental growth of EV sales. The main challenges for EV are considered to be the relative cost of the vehicle, the energy content of batteries and associated range anxiety, battery degradation and the inferior charging technology.[120] These challenges are witnessed in the consumer perception of electrified vehicles, whereas consumers *in casu* EV are most concerned about the cost of fuel (i.e. battery), ease of recharging, driving distance, vehicle lifespan (i.e. battery life cycle) and

113 'Batteries of the Future', 9 February 2013, Michigan University, video by Don Siegel, Assistant Professor of Mechanical Engineering, College of Engineering

114 IEA, 2013, 'Global EV Outlook'

115 IEA, 2013, 'Redrawing the Energy Climate Map', p. 25

116 http://evobsession.com/world-electrified-vehicle-sales-2013/; Over 50% of these vehicles were BEVs (110,000 plus); out of 68 million passenger cars sold globally in the same year (or 0.29% of total) (http://www.statista.com/statistics/200002/international-car-sales-since-1990/)

117 AID data in Forbes (6 February 2014, 'Electric Car Sales in Western Europe Spurt, but from Miniscule Base')

118 ICCT, 2013, 'European Vehicle Market Statistics'. Anno 2012, an approximate 290 million passenger vehicles (OICA, 2012)

119 This number as previously described is envisioned in policy (EC, 2013, Clean Power for Transport: A European alternative fuels strategy). The significant increase of (P)EVs in Europe is not only anticipated (or aimed for) by European and national policymakers; also consultancies (e.g. Navigant predicts annual electrified vehicle sales in Europe to be nearly 900,000 by 2020: Navigant, 2013, 'Electric Vehicle Market Forecasts'), and automotive companies anticipate considerable shares of electrified vehicles in the EU fleet (BMW for one is adamant to attain a share in the growing market for cars with electro-mobility (including PHEV), which it estimates will "make up 5 to 10 percent of the [German] market by 2020, from well under 1 percent now" (Bloomberg, 23 October 2013, 'VW Calls Germany's 1 Million Electric-Car Goal Achievable'); in line with the German ambition of 1 million electric vehicles on the road by 2020 (Fraunhofer, 2013).

120 'Batteries of the Future', 9 February 2013, Michigan University, video by Don Siegel, Assistant Professor of Mechanical Engineering, College of Engineering

battery management.[121] Improvements in batteries are notoriously difficult, especially advancements in power density of batteries are difficult to attain.[122] Nevertheless, in the five years leading up to 2013, battery costs went down by 20 to 40 percent.[123] Cost reduction are expected to continue (see Figure 13).[124] Enabled by production growth, associated economies of scale and learning could contribute to reduction rates of 7.5-10% annually.[125] By means of comparison, in the period from 1997 to 2012, laptop battery cost reductions developed at a rate of 15% annually.[126] If the general trend develops as expected, by 2025, the total cost of ownership of electric vehicles may very well be comparable to that of vehicles with ICEs.[127]

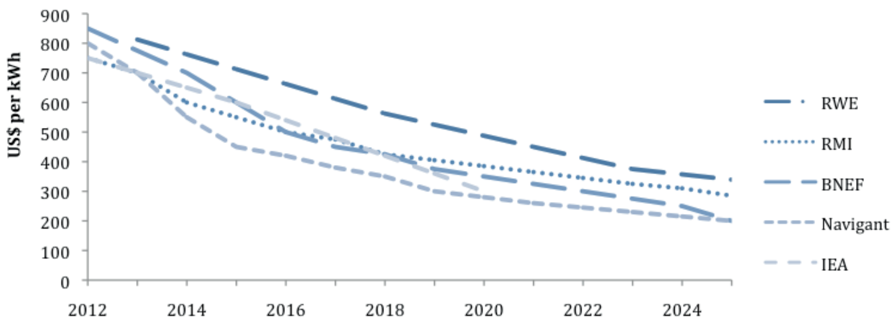

FIGURE 13. EV BATTERY COST DEVELOPMENT SCENARIOS[128]

Apart from advancements in existing battery technologies, other technologies are being pursued. One highly anticipated technology is the lithium-air battery.[129] Much research and development effort is being focused on these lithium-air batteries;[130]

121 KPMG, 2013, 'Global Automotive Executive Survey'

122 'Batteries of the Future', 9 February 2013, Michigan University, video by Don Siegel, Assistant Professor of Mechanical Engineering, College of Engineering

123 Frost and Sullivan, 2013, 'Competitive Pricing and the Introduction of New Models Drives Success of Global Electric Vehicle Market'

124 IEA, 2013, 'Global EV Outlook', Figure 16

125 "Battery packs, which can account for as much as half of PEV costs, are expected to decrease during the forecast period. HEVs and PHEVs are anticipated to see a 10% and 26% decline in pack costs by 2020, respectively, while BEVs will likely remain flat, but see improvements in vehicle range and performance during that period." (Navigant, 2013, 'Electric Vehicle Market Forecast')

126 IEA, 2013, 'Global EV Outlook'

127 McKinsey, 2010, 'A Portfolio of Power-trains for Europe: A fact-based analysis'

128 Based on data by Rocky Mountain Institute (2014,'The Economics of Grid Defection', Figure 11 and 19); RWE (28 September 2014, presentation 'The Future Role of Natural Gas in Europe - and the World', slide 5, battery pack trend; converted from €/kWh to $/kWh based on average September2014 €/$ exchange rate of 1.25); and IEA (2013, 'Global EV Outlook', Figure 16).

129 While not commercially viable yet, the lithium-air battery technology, when fully developed, is likely to reveal a storage capacity of five to ten times greater than traditional lithium-ion batteries, thereby coming nearer to the energy density of a gas tank (IEEE, 14 May 2013, 'A Nanoscale Peek at Lithium-air Batteries Promises Better Electric Vehicles').

130 E.g. by IBM, MIT, etc.

commercialization, however, is only expected to take place between five and ten years from now. Super- or ultra-capacitors[131] may be another solution to the power storage and energy density problem of the current generation electric vehicle batteries. Yet other battery technologies are being developed, in the attempt by firms to establish the new standard in electricity storage. Two such technologies are the aluminium-air, which in testing has achieved a 1600 kilometre range,[132] and the dual carbon battery, which provides higher charging capacity and limited thermal impact of charging, allowing for usage that is more intensive.[133] Investments in R&D for battery technologies are thus taking place on a vast scale and are initiated by various actors, ranging from governments to research institutes and companies from different industries.[134] As these battery technologies advance, it is likely that OEMs will start to play a smaller role in the actual development of battery technologies. The activities are then likely to shift towards alliances of battery producers and tier-1 suppliers.[135]

In the meantime, carmakers and tier suppliers are seeking other ways to deal with the deficiencies of today's batteries. Various automotive OEMs have introduced battery-leasing programmes. These programmes contribute to overcoming the investment hurdle, while at the same time dealing with the limited lifetime of batteries. As in various leasing programmes,[136] battery packs can be exchanged to the latest technological standard. This also increases the accessibility of improved battery technologies, thereby limiting the lock-in of old technologies. Just as the ownership of the actual batteries might be changing, so is the charging of vehicles undergoing change, likely to large-scale adoption in the short run. Several OEMs have

131 "Super-capacitors from Maxwell Technologies are currently being used in Chinese hybrid buses. The super-capacitors are charged when the bus breaks and then discharged to help the bus accelerate. Yet, the super-capacitors alone cannot sustain the energy needs of the bus." (Berkeley Energy & Resources Collaborative, http://berc.berkeley.edu/storage-wars-batteries-vs-supercapacitors/)

132 A battery pioneered by Alcoa and Phinergy (Alcoa, June 2014, 'Alcoa and Phinergy Debut Electric Car with Aluminium-Air Battery')

133 A battery pioneered by Power Japan Plus and Taisan (Yahoo Finance, June 2014, 'Team TAISAN and Power Japan Plus Form Partnership to Develop World's First Electric Vehicle Powered by the Ryden Dual Carbon Battery')

134 E.g. the US government, recent ARPA-E project: http://www.arpa-e.energy.gov/sites/default/files/documents/files/RANGE_ProjectDescriptions_082013.pdf; recent investment by Ford in cooperation with the University of Michigan (http://www.autoguide.com/auto-news/2013/10/new-ford-battery-lab-to-speed-ev-development.html); the EU funded research in which, among others, Volvo is engaged https://www.media.volvocars.com/uk/en-gb/media/pressreleases/134483/volvo-car-group-makes-conventional-batteries-a-thing-of-the-past. Also Tesla's announcement to build a five billion dollar battery production facility in the US, which when materialized, would double the global production capacity of automotive lithium-ion batteries, from less than 500,000 lithium-ion packs in 2014 (The Economist, 3 March 2014, Driving Ahead)

135 E.g. Robert Bosch and GE (PWC, 2010, 'Batteries for Electric Cars')

136 E.g. by Nissan: http://nissannews.com/en-US/nissan/usa/releases/nissan-announces-battery-replacement-program-for-leaf

already announced that they will introduce alternative charging services. Whereas some pair their electric vehicles with wireless charging stations,[137] others focus on battery swapping services.[138] The momentum for this change in charging technology is picking up as automotive equipment suppliers have also introduced aftermarket equipment compatible with existing cars.[139] Battery swapping, on the other hand, is not a new development entirely.[140] The novelty in battery swapping technology lies in automotive OEMs that now offer battery swapping facilities,[141] rather than a third party, thereby enabling consumers to overcome the hurdles of (relatively) long battery charging times and limited range.

Overcoming range problems of EVs can go beyond developing more powerful batteries, more intricate charging infrastructure and fossil-fuelled range extenders. An alternative route to range extension of an EV is to add a fuel cell[142] to the vehicle. On a small scale such fuel cell electric vehicles (FCEV) are being pioneered.[143] In the EU, Denmark is the first country to start a pilot project for the introduction of this vehicle, providing attractive fiscal terms to owners of hydrogen-fuelled cars, driving down the total cost of ownership to that of an ICE powered car.[144] At the same time, investments in H_2-compatible drivetrain and fuel-cycle technologies are proliferating widely, with many companies, including OEMs, dedicating significant budget to R&D of fuel cell technology in their vehicles.[145] However, the uptake of hydrogen as a major transport fuel requires significant investments in vehicle and drivetrain technology, as well as in infrastructure.[146]

137 Nissan is expected to be the first automotive OEM to roll out inductive charging (Herald Sun, 01 December 2011, Nissan Leaf Goes Wireless – Charged by Electromagnetic Induction from Floor Pad). Volvo is engaged in a project focused on bringing inductive battery charging technologies to market (Volvo, 24 November 2013, http://www.volvocars.com/nl/top/about/news-events/Pages/default.aspx?itemid=184).

138 Tesla: http://www.teslamotors.com/batteryswap

139 E.g. Evatran: http://www.pluglesspower.com/ and Qualcomm: http://www.qualcommhalo.com/

140 The company Better Place has marketed battery swapping technology and facilities from 2008 to 2013 (http://www.betterplace.com/the-company/press-room).

141 Tesla offers these services in the US (http://www.teslamotors.com/batteryswap)

142 A fuel cell is a device that through a chemical reaction converts fuels into electricity. Various fuels can be used as input for a fuel cell, however, in the effort to reduce carbon emissions of transport, the focus is on the combination of hydrogen and fuel cells.

143 Hyundai for one started with the production and marketing of its IX350FCEV; Toyota has pioneered the technology commercially, with its first fuel cell hybrid vehicle (FCHV) already marketed in 2005 (Toyota, http://www.toyota.nl/innovation/design/concept_cars/fchv/index.tmex).

144 H2Logic, 2012, 'The Cost of Establishing a Hydrogen Infrastructure for Transport: A case study covering Denmark'

145 Virtually all OEMs are engaged, or have been engaged at some point in time in developing FCEVs. In addition to Hyundai, Toyota is also to feature an FCEV in its product portfolio, starting in 2015 (http://www.toyota-global.com/innovation/environmental_technology/fuelcell_vehicle/).

146 McKinsey, 2010, 'A Portfolio of Power-trains for Europe: A fact-based analysis'

When it comes to the introduction of electrified vehicles, be it hybrids, battery electric or fuel-cell electric vehicles, the cost competitiveness of these technologies is the main challenge. However, as these technologies are increasingly adopted in mass-produced vehicles, advancements will be made in performance and cost efficiency; all the while significant R&D efforts continue to be made by leading automotive OEMs in these technologies.[147] Finally, costs do not have to be an inhibitor of vehicles to be sold on a large scale, as long as the right market is targeted.[148]

LESS NEED, MORE OPTIONS

Beyond the push for increased energy efficiency, the developments along the automotive supply chains also seem to be contributing to a broader range of options as to how to power a car. The increase in energy options is not only the case between vehicle types, but the developments that are ongoing also suggest an increased presence of various energy and propulsion technologies within the automobile. Plug-in hybrid EVs, range-extended EVs and fuel-cell EVs are examples of this trend in which electric motors are combined with either a fuel cell or an internal combustion engine.

The trend of technologies enabling the use of different energy sources for the propulsion of the same vehicles goes beyond the combination of different engines in one vehicle. Bi-fuel vehicles have become commonplace in many countries where natural gas takes up a substantial part of the transport fuel mix, in order to overcome infrastructural impediments in case of not fully developed natural gas refuelling infrastructure, while also providing the opportunity to play arbitrage between fuel prices.[149]

147 "The Volkswagen Group invests over seven billion euros in research and development each year. A significant share is spent on developing technologies and components for electric mobility – more than in any other field. The key to rolling out electric mobility swiftly and efficiently across all brands and vehicle classes is the modular toolkit systems, which from the start have been designed for assembling electric drives. Production in Bratislava, Puebla, Wolfsburg, Leipzig or Ingolstadt can now respond flexibly, at low risk to demand as it arises, and can reduce both weight and costs using proven components. According to Winterkorn, anyone who genuinely takes ecological responsibility seriously goes one step further: 'We must have a holistic mind-set and a comprehensive approach to mobility – from generating energy through development, production, retail and vehicle operation right down to recycling. Our clear goal, therefore, is to lead with holistic, modern mobility concepts.'" (Volkswagen, 9 September 2013, 'Volkswagen Launches Bold Offensive for Age of Electric Mobility')

148 Tesla has announced in a letter to shareholders that it will sell more than 100,000 per year by 2015 (Business Week, 31 July 2014, 'Elon Musks Tesla game plane make 100,000 cars next year').

149 In the US, bi-fuel vehicles are marketed by GM, Ford and Chrysler, offering consumers the option to use either gasoline or CNG – albeit in different tanks (Citi, 2013, 'Global Oil Demand Growth: The end is nigh').

Driven by the government push for ethanol in the transport fuel mix of Brazil, the country's domestic automotive industry has developed flex-fuel vehicles that can process any blend of gasoline and bio-ethanol.[150]

In addition to the powertrain technologies that are already making inroads in the portfolios of automotive OEMs, there is a new set of flexible fuel technologies still under development. One such technology is the DLR free piston linear generator,[151] which would allow for the combustion of oil product, biofuel, natural gas or hydrogen. The advent of a propulsion technology that does not differentiate between fuels has the potential to facilitate the deployment of many alternative fuels, as infrastructure and range become less of the issue.

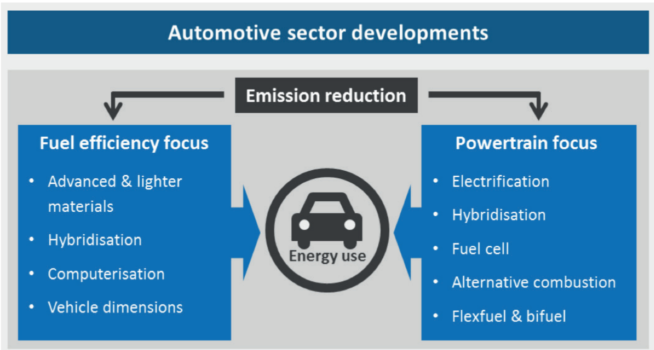

FIGURE 14. DEVELOPMENTS IN THE AUTOMOTIVE SECTOR THAT INFLUENCE ENERGY USE IN TRANSPORT

Clearly, developments in the automotive industry allude to further improvements in energy efficiency of conventional ICEs. In mature markets such as those of the EU, this very likely will translate into downward adjustments of energy demand in transport (see Figure 14). At the same time, the development and integration of alternative engine technologies will change the make-up of the vehicle fleet in Europe and consequently the demand for energy. These new engine technologies, moreover, have the potential to diversify the energy use within the vehicles themselves.

150 Pioneered by Volkswagen Brazil with the launch of the Gol 1.6 total flex in 2003. While flex fuel vehicles running on ethanol and gasoline mixes have been around since the days of the T-Ford, these vehicles were pre-set to drive on specified ratios. The total flex fuel vehicle of Volkswagen was the first mass market vehicle to overcome this limitation, as it can run on any given combination of the two fuels. (Volkswagen, 2012, 'Anuário de Responsabilidade Corporative 2012')

151 http://www.dlr.de/dlr/en/desktopdefault.aspx/tabid-10081/151_read-6318/year-all/151_page-2/#/gallery/8873

5 SUPPLY SIDE DEVELOPMENTS: THE ENERGY SECTOR

NATURAL GAS IN TRANSPORT

Spurred by the combination of horizontal drilling and hydraulic fracturing, the US has experienced a tremendous increase in domestic hydrocarbon exploration and production activity in the past decade, commonly referred to as the 'shale revolution'. In a new context, resulting from these advancements in drilling techniques and the ensuing E&P efforts, natural gas reserves[152] in the US grew by over 60% in the period between 2002 and 2013,[153] while production increased by approximately 30% over that period.[154] As the (potential) supply of gas increases, designated markets are not necessarily increasing concordantly. This is related to inter-fuel competition in electricity generation[155] and macro-economic developments. In response to these developments, natural gas producers seek to diversify their supply options, not just geographically but also in terms of exploring other product markets for methane. Growing the share of natural gas in transport energy demand is a prime example of the latter. Similar to the current impact of the shale revolution, the developments of natural gas in transport has thus far been much localized. The growing natural gas reserve and production volumes, combined with the development of truly global natural gas infrastructure, the diffusion of natural gas based fuels and compatible propulsion technologies, could catalyze the role of natural gas as a transport fuel on a global scale.

Natural gas has been a transport fuel for the past decades already, in the form of compressed natural gas (CNG). In an increasing number of countries the share of CNG in the transport fuel mix is growing, the lion's share of CNG fuelled vehicles being driven in Iran, Pakistan, Argentina and Brazil.[156] Currently, approximately 16 million of these vehicles are being driven around, a number expected to more than double by 2020,[157] most of which will be light-duty vehicles. The development of gas-to-liquids

152 "Quantities that geological and engineering information indicates with reasonable certainty can be recovered in the future from known reservoirs under existing economic an operating conditions" (BP, 2014, Statistical Review of World Energy)
153 In the same period global natural gas reserves have grown by just under 20% (BP, 2014, Statistical Review of World Energy)
154 BP, 2014, 'Statistical review of world energy'
155 Competition from growing shares of renewable energy sources, as well as from coal in various markets because of lower prices of the latter in comparison to natural gas
156 Citi, 2013, 'Global oil demand the end is nigh'
157 Navigant, 2014, 'Global Natural Gas Vehicle Sales and Refuelling Infrastructure Forecasts: 2013-2020'

(GTL) – various conversion processes exist, including methanol-to-gasoline, syngas-to-gasoline[158] and Fischer-Tropsch, the latter is most commonly used[159] – allows for another way in which natural gas can be marketed as a transport fuel. Because of its capital intensity, GTL production growth is limited. Global GTL production is currently at approximately 200,000 barrels per day.[160] To date, most GTL products are used in dedicated niche markets or are blended into other fuels as a means to improve fuel quality.

Technological developments relating to natural gas in transport have not ceased to develop, as natural gas in the form of liquefied natural gas (LNG) is entering the transport fuel mix both in land- and water-borne transport. The deployment of LNG trucks in the US has gained broad media coverage, although it seems that the pace at which fleet owners adapt to LNG has been more moderate than initially expected.[161] In China, LNG is making inroads, driven by top-down policy focused on diversifying energy demand as well as reducing tailpipe emissions.[162] Part of the attractiveness for LNG is the greenhouse gas reduction potential for heavy-duty vehicles (HDV). LNG trucks are generally associated with the characteristic of lowering GHG emissions by a significant percentage vis-à-vis conventional diesel powered trucks, through the estimations vary.[163] The variation relates to value chain emissions,[164] whereas in the tank-to-wheel part, the combustion of LNG is potentially 20-25% less emitting than that of diesel.[165]

The market potential for LNG in the road transport sector is commonly associated with heavy-duty trucks, "particularly along high-traffic corridors and including both long-haul and specific services (e.g., buses, waste management and utility vehicles)".[166] Estimates of LNG's potential fuel mix share still vary widely (see Figure 15).

158 Primus Green Energy, February 2013, http://www.primusge.com/press-room/white-papers/, retrieved: 5 March 2013

159 http://www.meed.com/supplements/2013/gas-to-liquids/lucrative-future-for-gtl-sector/3186989.article

160 In the year 2012 (Oxford Energy, 2013, 'Gas-to-Liquid: a viable alternative to oil-derived transport fuels?')

161 At a moderate pace, more moderate then perhaps was foreseen in the years immediately after the US shale boom. Reasons for this can be found in the easing of the oil-gas spread in the US; the relative fuel efficiency of LNG as compared to diesel trucks; the significant price premium between LNG and diesel trucks and the limited decrease in this difference; the fuelling infrastructure which is not yet up to par; and the improvements in fuel efficiency of diesel trucks (Reuters, 9 April 2014, 'Ride to lower costs for LNG-run trucks rockier than expected'; Wall Street Journal, 25 August 2013, 'Slow going for natural-gas powered trucks: premium prices and more efficient diesels leave sales in first gear')

162 Chen, 2013, 'Development Strategies of the Chinese Natural Gas Market', Clingendael Energy

163 The estimations vary from potentially 7% (RFF, 2010, 'Energy, Greenhouse Gas, and Economic Implications of Natural Gas Trucks') to up to 20% (CE Delft, 2013, 'Natural Gas in Transport') or even towards 30% (NGVA, http://www.ngvc.org/about_ngv/, accessed 18 November 2013).

164 This is partly related to methane emissions, which when regulated can be lowered, which would increase the likeliness of abatement towards 20% vis-à-vis diesel (CE Delft, 2013, 'Natural Gas in Transport').

165 Tank-to-wheel, supply chain emissions are not taken into consideration. (EIA, 2014, FAQ 'How Much Carbon Dioxide is Produced When Different Fuels are Burned?' http://www.eia.gov/tools/faqs/faq.cfm?id=73&t=11)

166 ExxonMobil, 2013, 'The Outlook for Energy: A View to 2040'

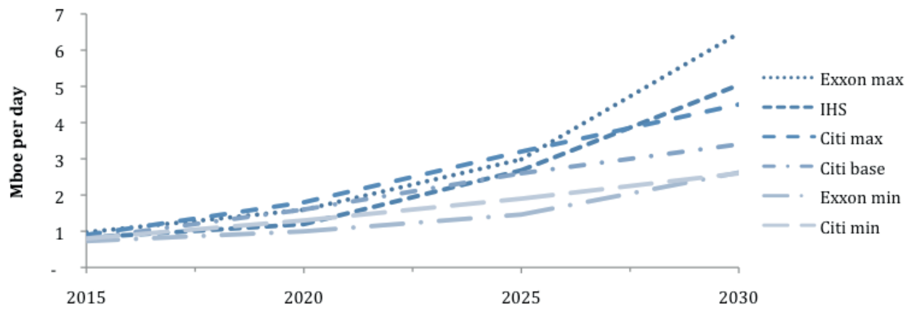

FIGURE 15. SCENARIOS FOR GLOBAL NATURAL GAS DEMAND IN TRANSPORT[167]

New potential for fossil fuels in EU transport: CNG and LNG

In the EU, diversification into the transport sector would be a welcoming development for sellers and producers of natural gas. Under current market conditions in the EU, gas-fired power generation is squeezed[168] and developments regarding the electrification of heat are likely to further erode the share of natural gas in the energy mix. In the European Union, currently one million CNG vehicles and 3000 filling stations[169] are already present, and this number is likely to increase. In several European markets, a push is being made for more use of gas in transport by way of CNG in LDV.[170] Italy boasts the largest and still growing market for gas in road transport in Europe,[171] with over 750,000 NGVs deployed.[172] While CNG is commonly regarded as best applied in light-duty vehicles, LNG is mostly considered to be an alternative for diesel in notoriously 'hard-to-clean' freight transport.

The commercialization of natural gas in transport, as CNG or LNG, requires the development of infrastructure, especially to support long-haul trucking. The EU seeks to stimulate the development of refuelling sites via the alternative fuel directive

167 Citi (2014, 'Global Oil Demand: The end is nigh'), Exxon (2013, 'The Outlook for Energy: A View to 2040'), Gazprom (2012, 'LNG as a Transportation Fuel: Potential for LNG bunkering and heavy-duty vehicles')

168 Groot, 2013, ´EU Power Utilities Under Pressure´, Clingendael Energy

169 EC, 2013, ´Clean Power for Transport: A European alternative fuels strategy´

170 In Spain, gas company Gas Natural Fenosa and automotive company Seat have entered a collaboration to develop CNG as a transport fuel, focusing on the development of infrastructure and vehicles (Volkswagen, 26 November 2013, 'Seat and Gas Natural Fenosa Boost the Use of Natural Gas in the Automotive Industry') In Sweden this is mainly a programme to stimulate biomass in transport, through bio-methane: 60% of total gas used in natural gas vehicles (NGVs) in Sweden is bio-methane (NGVA, 2013, http://www.ngvaeurope.eu/sweden).

171 In Italy, the number of NGVs increased by 16% from 2010 to 2012, as the government stimulated CNG in transport by providing fiscal advantages to CNG as compared to oil products, while vehicle manufacturers like Fiat have offered CNG vehicles at discounted price levels (Bloomberg, 17 September 2012, 'Gasoline Sticker Fuels Fiat Natural-Gas Auto Sales')

172 NGVA, 2013, http://www.ngvaeurope.eu/italy accessed on 20 September 2014

and Ten-T financing.[173] Part of the necessitated infrastructure roll-out can take place through IOCs building LNG refuelling facilities on their own truck refuelling sites. Apart from the fuel's economic viability from the perspective of the producer and distributor, the truck OEMs and transport companies need the commercial competitiveness of LNG trucks. Similar to the learning effects to be obtained with LNG refuelling infrastructure, the price of LNG-fuelled trucks is expected to decrease, potentially to the price of diesel-fuelled trucks. If and when LNG takes up as a transport fuel, cost reductions are expected, among others as the result of standardization. This latter process is taking place through various forums, such as at the International Standards Organization (ISO) for onshore refuelling and at the International Maritime Organization (IMO) for both LNG transporting and LNG fuelled ships. Meanwhile, truck manufacturing OEMs are seeking to establish common technological standards for the adaption of LNG in vehicles. However, as LNG in transport is an emerging technology, which requires customers to adapt their vehicle park, additional stimuli are likely to be needed. A decrease in the price of the infrastructure and the vehicles should contribute to a positive business case for switching to LNG. Fiscal policy is also likely to play an important part in viably marketing LNG as a transport fuel, at least in the pioneering stage.[174]

Another boost for the adoption of natural gas in transport might be the growing production of biogas, because of the lower CO_2 profile; bio-methane can be used as alternative feed gas for LNG (and CNG) in transport. Fuelling transport with natural gas by way of either CNG or LNG is certainly not limited to road transport; as both rail and waterway transport provide potential for the energy source. Investments in the development of CNG and LNG in other transport modes, combined with developments in required infrastructure, are likely to be accelerators for the continued development of CNG and LNG in road transport in the EU.

173 "Liquefied natural gas for trucks: The plans for LNG refuelling points installed at least along the existing TEN-T Core Network are to ensure that, by 2025, LNG heavy-duty motor vehicles can move throughout the EU, where there is demand, unless the costs are disproportionate to the benefits. The adequate distances for the refuelling stations will be defined taking into account the minimum range of LNG trucks. As an indication, the necessary average distance should be approximately 400 km." (Amended text of proposal for EC directive on the deployment of alternative fuels infrastructure http://www.consilium.europa.eu/uedocs/cms_data/docs/pressdata/en/trans/141906.pdf)

174 Given the (relative) high price of LNG trucks, investment stimuli, e.g. by way of reduced excise tax, can contribute to the adaptation of the fuel and related engine technologies in the sector. In the EU, a concerted effort is being made to overhaul the energy taxation rules, which might provide opportunities (http://ec.europa.eu/taxation_customs/taxation/excise_duties/energy_products/legislation/).

UTILITIES AND ELECTRIC MOBILITY

In recent years, major EU power utilities[175] have faced several significant changes in their external environment. Combined, these changes seriously affect the viability of their activities. The economic crisis has meant diminished demand for electricity, the subsidized rise of renewables has caused more competition in this smaller market, and the departure from nuclear generation in various Member States has caused significant set-backs to firms operating nuclear power plants. The ongoing developments culminate in a dire outlook for many EU power utilities. Profit margins of individual plants and entire generation portfolios are under pressure and, as a result, firms are retiring their generation assets – whether mothballing, wet-reserving, fully decommissioning or even putting up entire divisions up for sale.[176] Neither the current market conditions nor the prospects for the future seem to provide much relief. Going through corporate restructurings and strategic reorientations, these electricity firms are also focusing their attention on the transport sector, by means of electrifying road transport.

The business for electricity in transport

The European electricity sector is going through a phase of transformation, with substantial shares of wind and solar generators entering the market. The developments are most visible in Germany, where, in 2013, 13.7% of electricity was generated by solar or wind energy facilities.[177] In the EU-28, the share of non-hydro renewables was at 10%, a share that is increasing rapidly, whereas in 2011 the share was only 7.5%[178] (see Figure 16).

175 In the power sector of the European Union, seven firms stand out when it comes to size of installed capacity, electricity production and revenues. These are E.On, EDF, Enel, GDF Suez, Iberdrola, RWE and Vattenfall.

176 RWE discontinued the operation of 10 units of total 4.3 GW (RWE, April 2013); E.On decommissioned 30 units of total 11 GW by 2015 (Eon, 2013); GDF Suez mothballed 1.4 GW of generation assets in 2013 adding to the already 8.6 GW of decommissioned or mothballed units since 2009 (GDF Suez, 2013); EnBW and Statkraft take similar measures, shutting down respectively 0.5 GW of hard coal and gas-fired capacity (Enerdata, 10 July 2013, 'EnBW Plans to Shut Down 4 Power Units and to Mothball One') and 2.2 GW of gas-fired generation capacity (Enerdata, 20 August 2013); while Vattenfall has announced to look for investors to off-take its share in non-Nordic European power production at a total of approximately 19.5 GW (Vattenfall, 23 July 2013).

177 Fraunhofer ISE, 2014, 'Electricity Production from Solar and Wind in Germany in 2013'

178 Eurostat, 2014, http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/File:Electricity_Statistics_2013_%28in_GWh%29.png

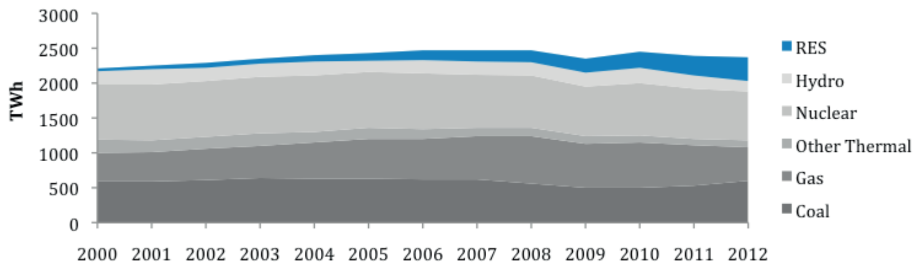

FIGURE 16. DEVELOPMENT OF THE EUROPEAN ELECTRICITY GENERATION MIX BY SHARE[179]

Though perhaps not ubiquitous yet, electric vehicles have become part of the fleet in Europe and, given aforementioned developments, their numbers will increase. By 2020, there should be at least 8-9 million electric vehicles on EU roads, according to policy aims of EU Member States,[180] up from a few hundred thousand today. For electricity companies, this rise of electric vehicles provides business opportunities in two ways: first, the electrification of transport constitutes a new source of electricity demand. This market can provide large potential to European utilities, especially given the new direction in which utilities have indicated to develop their business, namely towards more consumer-centred and service oriented propositions.[181] Catering to the needs of EV owners and providing enticing product offerings that include services aimed at the EV, this provides the utilities with an opportunity to interact more with their customers, whom they might otherwise be losing.

A second opportunity that arises out of the emergence of EVs is the growing demand for accompanying EV infrastructure and services that will need to be developed and provided. The market for EV charging stations is expected to grow rapidly from 7,250 EV charging stations in 2012, to perhaps 4.1 million by 2020, of which 60% will be installed in France, Germany, Italy, the United Kingdom and the Netherlands, resulting from the growth of the EV market in these countries.[182] The development of the EV, battery and charging technology as well as service offerings will play an important role in the further adoption of EVs. Electricity companies – integrated utilities and infrastructure companies – can play a facilitating role in this and thereby grow their business. Technological advancements that will reduce charging time while improving

179 Depicted data represents the situation in the area of Belgium, France, Germany, Italy, the Netherlands, Portugal, Spain and the UK (WoodMackenzie, 2013, 'The Role of Coal in European Power – One last push or a long-term player?'). Total generation in these countries in 2012 was 2370 TWh (WoodMackenzie, 2013), which accounts for 77% of total electricity generation in the EU-28 (3127 TWh in 2012; Eurostat, 2014, http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/File:Electricity_Statistics_2013_%28in_GWh%29.png)

180 EC, 2013, 'Clean Power for Transport: A European alternative fuels strategy'

181 Various utilities have proclaimed this in different occasions, e.g. RWE (Energy Post, 21 October 2013) or E.On (Energy Post, 3 December 2013).

182 Navigant, 2013, 'Electric Vehicle Charging Equipment in Europe'

reliability, safety and robustness of the electric charging system are expected to continue[183] and will thereby encourage EV adoption, potentially providing yet again more business to electricity companies. However, the technological advancements also pose a risk, as the various technologies used, moreover the combination in which this occurs, is still relatively new and many developments are taking place. This is very likely to result in new technologies (and technology combinations and services), which might result in earlier generations becoming obsolete.

What role EV might play in the (near) future will also depend on the local or regional power generation dynamics. This is to say, the way in which the electricity that fuels EV is produced is a determining factor in assessing the desirability of full electric vehicles and thereby the growth potential – at least from a carbon content and climate change point of view; for issues of local air quality this is less the case. The share of zero- and low-carbon generation technologies in power production will therefore be an important determinant in the success of the EV. This is a space where electricity-generating companies can play a decisive role.

BIO-ENERGY AND TRANSPORT

Not too long ago, corn-, sugarcane- and rapeseed-based biofuels were expected to play an increasingly important role in the decarbonization of transport. These first generation – food crop-based – biofuels have been on the market for as long as cars have been around[184] and in various markets contribute significant shares to the transport fuel mix.[185] In the past decade, these fuels have become a significant part of the EU transport fuel mix, primarily contributable to the policy push for biofuels through mandated blend-in requirements. On a world scale, the market for biofuels (mostly first generation) grew by 400% between 2004 and 2013, from 0.3 million barrels per day to over 1.3 million barrels per day (see Figure 17).

183 Frost & Sullivan, 2013, 'European Electric Vehicle Charging Infrastructure Market Becoming Increasingly Self Sustaining'

184 Both Rudolf Diesel and Henry Ford had envisioned vegetable oil as a fuel source for their engines. At the world exhibition in Paris of 1900 Diesel ran demonstrated his compression-ignition engine by running it on peanut oil, while Ford has expected his cars to run on corn-derived ethanol (Discovery Company website accessed on 30 July 2013, http://auto.howstuffworks.com/fuel-efficiency/alternative-fuels/biodiesel2.htm).

185 Fifteen percent in Brazil (IEA, 2013, 'World Energy Outlook'); 14 billion gallons biofuels out of total billion gallons is 4.5% in the US (EIA, 2014, International Energy Statistics, http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=5&pid=5&aid=2; for year 2011Annual Energy Outlook) and 5% in the EU (USDA, 2014, 'Biofuels Annual'; input from Eurostat and EC Publication 'EU Energy Trends to 2030')

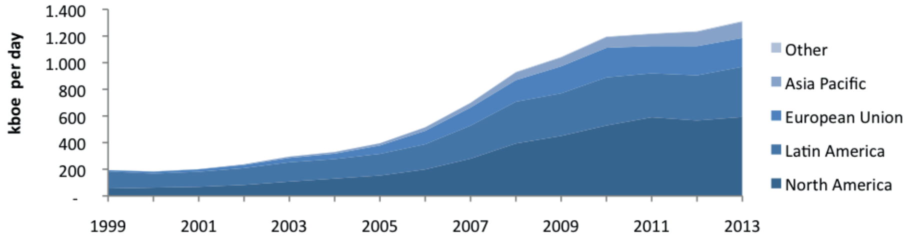

FIGURE 17. DEVELOPMENT OF BIOFUELS PRODUCTION[186]

In the current debate on biofuels, much attention is paid to the competition of biofuel-crop acreage with acreage for food crops and to the risk of GHG emission displacement – rather than abatement – as the result of indirect land use change (ILUC).[187] In response to these issues, the blend-in requirements for first generation biofuels have become heavily debated in the EU.[188] Regardless of the political outcome in the EU, the future for first generation biofuels is unlikely to be characterized by growth, given these issues of ILUC and food competition.[189] For the growth of biomass in the transport fuel mix, major advancements in the commercialization of so-called second and third generation biofuels have to be made.

The future of biofuels is expected to be largely in cellulosic products[190]. The potential for growth is expected to be derived from the commercialization of these biofuel types, to be possibly supplemented further on by algae-based biofuels, although this is hard to predict. As the source of biofuels shifts away from food crops, the financing structure of the production process is changing. In the case of first generation biofuels, most expenses are related to operational costs. In the case of advanced biofuels, operational costs are relatively low, because the feedstock is often abundantly available as waste or residue.[191] Advanced biofuels do, however, require substantial upfront investments, in contrast to first generation biofuels. Driven by various developments, the production volumes of advanced biofuels are growing. This growth comes from traditional biofuel production companies pairing their facilities

186 BP, 2013, 'Statistical Review of World Energy'

187 The ILUC issue could be abated by making more efficient use of land and crops; apart from investing in advanced biofuels, much attention is focused on developing the most energy efficient and land-use efficient fuels, by doing research into process improvement.

188 Among others reported by Euractive (18 November 2013, 'Lawmakers Vote to Block EU Biofuels Bill')

189 See Transport & Environment, 2012, 'Biofuels: Dealing with Indirect Land Use Change (ILUC)'

190 Biofuel produced from the inedible (parts of) plants (Huber and Dale, 9 April 2009, 'The Fuel of the Future is Grassoline', in Scientific American)

191 Bloomberg New Energy Finance, 2012, 'Moving Towards a Next-Generation Ethanol Economy'

with new-generation technology to use the waste[192] and from dedicated advanced biofuel production companies.[193] Nevertheless, government policy is regarded a necessity to stimulate advanced biofuels towards economic viability.[194]

The business for biofuels in EU transport

In the EU transport fuel mix, biofuels currently have a market share of 4.4%.[195] The production of biofuels in the EU seems to have stabilized since 2010 at around 0.12 million barrels of oil equivalent per day,[196] while on a global level production is increasing.

Policy drives the market for biofuels. Because of the limited cost competitiveness, especially for advanced biofuels, the mandated blending prescriptions determine the market size. In the US, policy is in place that mandates the use of 36 billion gallons of biofuels by 2022 (up from 9 billion in 2008). In the EU, the Renewable Energy Directive requires a mandatory share of 10% renewable energy in transport by 2020, to be achieved largely through biofuels. The 10% target of renewable energy in transport will not be fulfilled solely by using first generation biofuels; 7% percent[197] is estimated to be attained by (first generation) biofuels, the other 3% percent by other sources, i.e. advanced biofuels, renewable electricity and biogas.

The companies active in the investment in the biofuel value chain hail from different industries; such as agriculture, energy, biotechnology and chemistry. All firms have different drivers; however, some might be able to manoeuvre more easily than others. Biotech companies, for one, are adamant investors in especially newer generations

192 E.g. Raizen (the Shell and Cosan joint-venture), with plans to invest in eight cellulosic ethanol plants up to 2024 (Bloomberg, 13 March 2013, 'Raizen to Spend $102 Million on Brazil Cellulosic Ethanol Plant'); POET-DSM Advanced Biofuels, a cooperative effort between the two companies (POET and DSM), which saw its first commercial scale cellulosic ethanol plant begin operation in early 2013 (POET-DSM website, http://poet-dsm.com/liberty, accessed on 5 August 2013).

193 On a large scale, firms invest in advanced biofuel production technologies, e.g. Abengoa, Beta Renewables. In 2013, in Italy, the first of such facilities opened, capable of producing 75 million litres annually (Financial Times, 6 November 2013, 'Italy Leads Biofuels 'Revolution' Hopes')

194 See e.g. ICCT, 2014, ICCT responses to 'Advanced Fuels: Call for evidence'; or 'Transport and Environment, 2013, Biofuels—At What Cost? A review of costs and benefits of France's biofuel policies'.

195 EC, 2013, 'Clean Power for Transport: A European alternative fuels strategy'

196 BP, 2013, 'Annual Statistical Review of World Energy'

197 "After more than a year of talks, the Energy Council says it wants to limit the amount of food-based biofuels to 7% of petrol and diesel sold. Without policy change, around 8.6% would likely come from such biofuels; the Commission proposed a stricter limit of 5%. The deal also further weakens the reporting of biofuels emissions resulting from indirect land-use change." (Transport & Environment, 13 June 2014, 'Ministers Seal a Modest Reform of EU Biofuels Policy, Energy Ministers Today Finally Agreed to Change the EU's Biofuels Policy')

of biofuel production.[198] Recent years, have also seen a wave of investments in new generation biofuels by chemical companies[199] as the production process of these new generation biofuels requires technologies more akin to those in the chemical industry. Further integration of biofuel production into the (bio) chemical value chain can bring a new competitive dynamics to the sector.

Much will depend on the commercial viability of the various biofuel production technologies,[200] as well as the ability of biofuel producers to deal with ILUC issues and other aspects that decrease the sustainability and GHG abatement potential of these fuels. For at least the short-to-medium-term future, however, the market potential for biofuels will mainly be determined by policy and policy instruments.

OIL AND TRANSPORT IN EUROPE

Oil demand is largely related to the transport sector. In the EU, this is even more pronounced than at a global level (see Figure 18). The second half of the 20th century saw the economic development in North America, Western Europe and Asia's Far East flourish. This contributed to significant increases in wealth and translating into perpetual demand growth for the transport of goods and persons. As such, global oil demand increased from 30.1 million barrels per day (mb/d) in 1965 to 91.3 mb/d in 2013.[201] While in the late 1990s, the countries of the OECD still consumed 65% of oil produced,[202] the share of oil consumed in the developed economies has declined steadily since and was overtaken in 2013 by the non-OECD countries.[203]

198 Novzymes, for one, has conveyed the intention to be involved in the establishment of 15 to 25 second-generation biofuel plants by 2017, together with Italian chemical company Mossi Ghisolfi chemical group (Financial Times, 6 November 2013, 'Italy Leads Biofuels 'Revolution' Hopes')

199 E.g. DSM through its POET-DSM Advanced Biofuels joint venture; and Dupont through its Biofuel Solutions business unit.

200 These are tracked at the website of the European Biofuels Technology Platform (www.biofuelstp.eu/); NER 300 financing has also been rewarded to various biofuel projects, which allows for more technology development tracking.

201 Numbers refer to oil consumption data by BP (2014, 'The Statistical Review of World Energy') on total demand for oil products, including biofuels, GTLs and CTLs

202 BP, 2014, 'Statistical Review of World Energy'

203 In 2013, the OECD countries consumed 45.55 mb/d, whereas total non-OECD countries consumption reached 45.77 mb/d (BP, 2014, 'Statistical review of world energy')

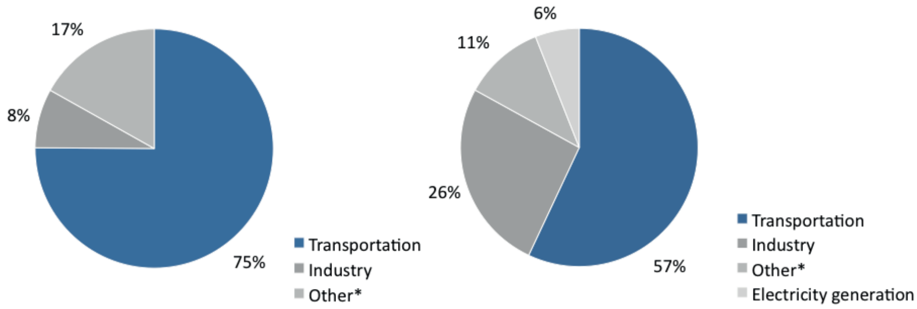

FIGURE 18. OIL DEMAND BY SECTOR (2012) GLOBALLY[204] AT 91.3 MB/D (LEFT) AND IN THE EU[205] AT 12.8 MB/D (RIGHT) I *HOUSEHOLD, SERVICES AND AGRICULTURE

In the past 50 years, the majority of oil production has taken place in the countries of OPEC and the Former Soviet Union,[206] although the US and the EU also boasted significant production provinces. The shale revolution seems to have reinvigorated oil production in the US, allowing it to reaffirm its position in the top three of global oil producers. Contrarily, oil exploration and production in the EU has been in steady decline since the late 1990s.

The past decade has seen many developments indicating a pivot of the oil value chain from the old demand centres towards the new. The expanding investments in large-scale refinery complexes in the Middle East, India and China are particularly illustrative of this trend. The reorientation of Russia's oil industry towards Asia is another example.[207] In the US, the shale boom has enabled the oil industry to catch on to these developments, by transforming into an exporter of oil products to emerging economies throughout the Western Hemisphere and in Africa; as well as by increasing exports to the EU.[208]

The lack of significant upstream developments, combined with the maturation of the product market, has made the oil industry in the EU another example of the pivot. The EU market for oil products is still the largest single market for oil products after

204 Based on OPEC data (2013, 'World oil outlook', figure 2.1) providing sectoral division of demand for the year 2010; which the graph combines with BP data (2013, 'Statistical review of world energy') on total demand for oil products, including biofuels, GTLs and CTLs

205 Based on European Environmental Agency data (EEA, 2010, http://www.eea.europa.eu/data-and-maps/indicators/final-energy-consumption-by-sector-2/final-energy-consumption-by-sector-7) providing sectoral division of demand for the year 2009; which the graph combines with BP data (2013, Statistical Review of World Energy) on total demand for oil products, including biofuels, GTLs and CTLs

206 Between 1965 and 2014, at least 50% of oil production always took place in the countries of OPEC and FSU; on average 58,1% of production in the period took place by OPEC and FSU countries

207 Wood Mackenzie, 2013, 'Russia's pivot east: the growth in energy trade with China'

208 Six, 2013, 'US Refining Dynamics', Clingendael Energy

the US, making up 14% of global oil product demand. As mentioned before, most of this pertains to energy use in the EU transport sector, which has grown biased to diesel. European refineries, however, are skewed to gasoline production[209] and as a result have had to compete in export markets for a substantial part of their business. The competiveness of European refineries has deteriorated as the result of the mounting competition from US light distillates exports and middle distillates exports from refineries in Russia, India and the Middle East. Instigated by the developments in the competitive environment the EU refining sector is undergoing restructuring, a wave of refinery closures and divestitures in the EU started some years ago[210] and has continued in 2014.[211]

A new competitive environment for oil products in transport

Apart from the dynamics in the oil market, oil companies are faced with a changing competitive environment for their products in the transport sector, the result of the emergence of new competitive forces in the market for energy in transport (see Figure 19). Where in Europe, the already mature market for oil in transport is pushed into decline, as mobility consumption patterns change and the availability – accessibility and affordability – of alternatives to oil in transport grow.

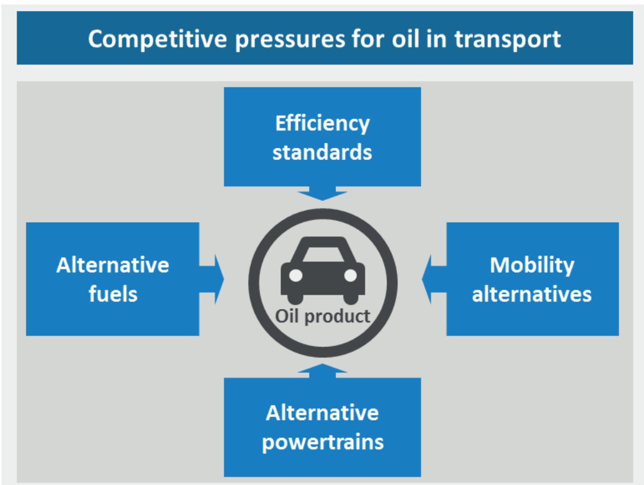

FIGURE 19. EFFECT OF COMPETITIVE PRESSURES IN VARIOUS DOMAINS ON OIL PRODUCT DEMAND IN TRANSPORT

209 Meijknecht, 2012, 'A Cinderella Story', Clingendael Energy

210 Since 2008, a total of 1.7 million barrels in refining capacity has been closed already in Europe (FT, 2013, 'Refining Overcapacity Hits Oil Majors')

211 E.g. Shell divesting/closing downstream capacity, in Rotterdam (NRC, 28 April 2014, 'Sanering bij Raffinaderijen in Nederland'); and ENI reducing its refining business by more than half (Reuters, 8 August, 2014, 'Eni cutbacks bring welcome relief to Europe's oil refiners').

In order to comply with more stringent emission regulation, oil companies focus on the production of less polluting and more efficient oil products such as high-octane gasoline and ultra-low sulphur fuels. Most companies active in the oil value chain are also active in the natural gas value chain, which in a low-carbon and reduced emission world provides opportunities – so too in transportation. Apart from the upstream overlap in oil and gas exploration and production, there is also overlap in the downstream part of the oil value chain, between activities that are related to oil products and other (transportation) fuels. As such, companies active in the downstream part of the oil sector also play a role in the business of some of the alternative transport fuels. This is especially the case for GTLs and biofuels, which are mixed and blended into oil products and as such distributed to filling stations before reaching to end-user.

However, what stands out most from the European push for low carbon mobility, is its contribution to the emergence of new competitive forces in the market for energy in transport, creating competition with oil in transport.

6 CONCLUSION

In the EU, policymakers have initiated a number of policies aimed at reducing oil consumption and carbon emissions in transport. These interventions include the imposition of biofuel mandates, the support for alternative fuels and alternative fuel vehicles, and the introduction of higher fuel efficiency requirements for new vehicles.

This demand pull – and the anticipation thereof – seems to resonate in the market. In the EU, the share of alternative energy carriers in transport is increasing, whether this be biofuels, natural gas or electric batteries. The biggest impact of the fuel saving and emission reduction strategies, however, might be taking place in the automotive industry. There, in order to meet the increased fuel efficiency requirements, automobile manufacturers have made major investments. As a result of these efficiency strategies, their vehicles will very likely be able to fulfil the fuel efficiency requirements of the years to come, slashing energy demand in new vehicles.

Nevertheless, the dominance of oil products in the transport fuel mix is unlikely to change in the near future. Transport energy consumption, however, will become more diverse as the alternatives compete for market share. Specialization might be a very likely outcome of the competition in the transport fuel sector, since the fuel mixes of urban, interurban and long-haul road transport each have their own characteristics.

The diversification of energy use in road transport goes beyond the diversification of the mix in macro terms. While the vast majority of vehicles today are powered by oil-product-fuelled internal combustion engines only, this will no longer be the case in the future. Developments underway allude to this in vehicle fuel diversification. Most alternative fuels and associated propulsion technologies provide the ability to combine various fuels, even if this design has come about for different reasons, whether to benefit from price arbitrage, to alleviate range anxiety or to provide fuel flexibility. As a result, the future of the vehicle fleet is likely to lie in hybrid, multi-fuel vehicles.

Meanwhile, consumer preferences are changing, too. Virtual mobility through information and communication technologies seems to become a formidable competitor of physical mobility. Influenced by these technologies and by the increasingly dense living environments resulting from continued urbanization, vehicle ownership seems to be on the decline, at least among European urbanites.

On the back of these developments, it indeed seems safe to state that oil demand in the EU is in long-term decline – at least the share that is related to road transport energy demand. The same message that has become commonplace in reports of energy companies and research institutes. The argumentation usually employed in these reports includes the aging population in Europe, the maturity of the European market and the introduction of biofuels in the EU. Structural developments that characterize the EU market, however, are hard to extrapolate to other parts of the world.

While all the above is the case, this paper has explored other elements to the long-term demand decline in the EU. These are related to changing demand patterns of consumers, technological developments in the automotive sector and the shifting emphasis of energy companies to supply the transport market with natural gas products, hydrogen and electricity. Whereby the EU push for low carbon mobility has contributed to the unleashing of new competitive forces in the market for energy in transport. European boundaries might prove to be rather permeable when it comes to the potential effects of these new competitive forces on markets in other parts of the world. Most of the companies involved in catering for this low carbon mobility, are international in nature, companies with business activities and supply chains that extend beyond Europe. Considering that various of the factors that facilitate the shift towards low carbon mobility are already present in other parts of the world – and are likely to continue to spread – it makes sense for these international companies to bring the products and services triggered by the European demand to world markets. That way, a particularly regional dynamic, which contributed to the development of transnational value chains, may have a global impact.

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