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# HOW TO COPE WITH DISTANCE IN THE FUTURE? THE IMPACT OF GLOBALISATION AND ECOLOGICAL REQUIREMENTS THE DESTINY OF THE AUTOMOTIVE INDUSTRY AND ITS SUPPLIERS<sup>+</sup>

GUY FOURNIER\*

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**ABSTRACT:** *Mobility is essential to life, human needs, and economic development. Diminishing oil reserves, a growing dependency on oil and global warming will all strongly impact on mobility. However, innovative solutions exist. To keep mobility affordable it is likely that fossil-oil-based mobility will not be substituted by just one technology. Second- and third-generation biofuels and electric vehicles are some of the best ways to be energy and CO<sub>2</sub> efficient in a well-to-wheel view. In contrast, fuel cells do not seem to be an alternative. Original equipment manufacturers (OEM) and suppliers will be firmly impacted by this evolution. The fastest and most innovative of them can take advantage of these challenges and find new interesting business opportunities.*

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**Keywords:** *Sustainable Mobility; Global Warming; Peak Oil; Biofuel; Alternative Propulsions; Electric Vehicle; Vehicle to Grid (V2G); Car-Sharing; Automotive Industry*

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**UDC:** 629.33:005.44:502/504

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**JEL classification:** L90, Q57

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## 1. INTRODUCTION

Mobility is a fundamental need of all societies and is an important part of our social cohesion. Further, it is also a prerequisite for the economic development of a company, town, country or region. With the growing scarcity of resources and rise of environmental issues, the recent path of development cannot continue for future generations. This raises the problem of whether mobility can remain affordable for individuals or other economic actors?

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To find new paths towards future developments an interdisciplinary approach combining economics, technology and business strategies will be adopted in this paper.

First, the phenomenon of globalisation and its impact on wealth and the automotive fleet will be defined and explained. In the second stage the consequences of globalisation, with regard to the scarcity of oil and how regulation is affecting the automotive sector, will be analysed and evaluated. Afterwards the culmination of these factors will challenge the traditional techno-economic mobility paradigm in place. Finally, we will explore how the market will be impacted in relation to the customer, producer, infrastructure and projected estimations for the future.

## 2. GLOBALISATION AND THE AUTOMOTIVE INDUSTRY

Globalisation is a result of the international division of labour. This division is likely regarded as one of humanity's greatest innovations. The division of labour<sup>1</sup> enables both countries and companies to specialise in what they do best. Within this framework, it enhances productivity and thus economic growth. It encourages wealth at all levels of the economy, including companies, towns, regions, countries and continents.

The transport of goods, energy and new information technologies as well as the economic framework are fuelling this development by facilitating the division of labour. The mobility of goods and services can therefore be seen as a determinant creator of wealth and prosperity.

Prosperity first came with the industrial revolution in Western countries. The integration of more states of the world into the international division of work has accelerated globalisation and today brings wealth into developing countries. The first need of a developing nation is to fulfil individual mobility. Today, the United States has about 800 vehicles per 1,000 people. Other mature markets such as Japan, the United Kingdom, Germany and France have about 600 vehicles per 1,000 people. In the BRIC countries, Russia has 230 vehicles per 1,000, Brazil has 130, while two of the most populated countries in the world – India and China – have fewer than 50 vehicles per 1,000 people.<sup>2</sup>

The figures quoted above indicate there is vast potential for growth and opportunities for a vehicle manufacturer and an original equipment manufacturer (OEM). At the same time, new competitors are emerging from these countries and are augmenting the competitive environment, forcing the OEMs to specialise in what they do best. This reduces the vertical range of manufacturing and gives the supplier the opportunity to enlarge its

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<sup>1</sup> Cf. Smith, A.: *An Inquiry into the Nature and Causes of the Wealth of Nations*, London 1776, p.13

<sup>2</sup> Cf. Japan Automobile Manufacturers Association: "World Motor Vehicle Statistics Vol.7 2008", p. 95C

part of value added. The 'Fast Study'<sup>3</sup> expects that the automotive market will grow from USD 645 billion in 2002 to USD 903 billion in 2015. The suppliers' share of value added will at the same time rise from 65% to 77%. The vertical range of OEMs will therefore continue to decline in the future.<sup>4</sup>

New growth opportunities for suppliers are connected with greater pressure from OEMs.<sup>5</sup> This is because OEMs are receiving an increasing amount of pressure from end-users. The main factors driving the pressures from end-users are caused by: stagnation in demand from the triad markets; increasing price sensitivity; growing awareness of environmental issues; and a decrease in brand loyalty. Also, suppliers are facing industry pressures that include continuous price rises of raw materials and the growing bargaining power of suppliers as a result of the consolidation of suppliers. An example of this is seen in the cases of Arcelor in the steel industry, and Rusal and Sual in the aluminium industry. The supplier is therefore increasingly finding himself in a 'sandwich position' and will have to react swiftly to ensure that it limits any loss of market share or decline in profitability.

As mentioned, the first need of any developing country is to ensure that it fulfils its individual mobility needs with its new wealth. Developing countries have more groundwork to cover in this regard compared to developed nations, which have reached saturation point. That is the main reason why an increasing dichotomy exists between established mature markets and emerging ones, which are forcing the industry to adopt diametrically opposing strategies. This dichotomy is further borne out when reviewing the global light vehicle figures between 2000 and 2007. They show that emerging markets (in light blue) are growing at a rate of 12.40%, while mature markets (in dark blue) are declining by -0.56%.<sup>6</sup> This trend will continue in the future (see Figure 1): the mature markets will stagnate with an annual growth rate of -0.10%. In contrast, emerging countries will grow by 6.74% each year.

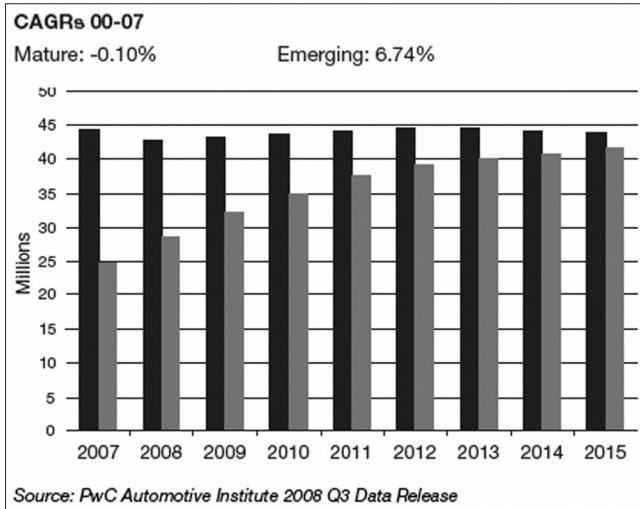
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<sup>3</sup> Also see the following: Mercer Management Consulting; Fraunhofer-Instituten for Production Technology: 'Future Automotive Industry Structure (FAST) 2015', 2004

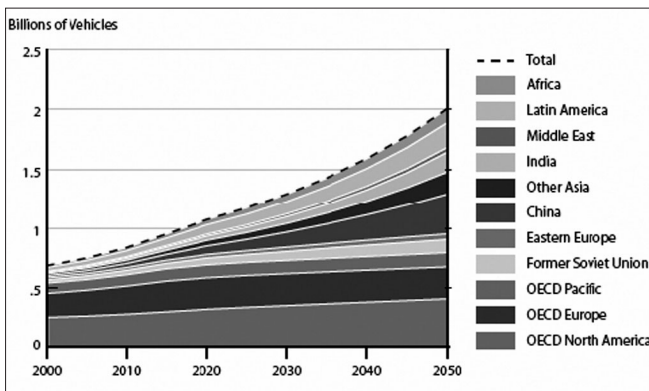
<sup>4</sup> It is expected that the automotive region of Eastern Europe will be the winner of this evolution, its market share is expected to grow from 3.5% to 7.5% in 2015. For more details, see Sihm, W.: Automotive Region Eastern Europe – AREE Opportunities and Risks of the "Detroit of the East" for Automotive Vienna 2006.

<sup>5</sup> For more details, see Roland Berger: Automotive suppliers procurement study – Main success levers to master the procurement challenges are not exhausted, February 2008

<sup>6</sup> Cf. PWC (2008)

FIGURE 1: *Global Light Vehicle Assembly 2007–2015*

The continuous growth in light vehicle assembly has of course also had an impact on the number of vehicles on the road; in the 1950s the world had about 50 million vehicles on the road and currently there are 600 million. The World Business Council for Sustainable Development (WBCSD) 2004 expects about two billion cars by 2050.<sup>7</sup> However, the IMF estimates a figure closer to three billion by 2050.<sup>8</sup>

FIGURE 2: *Projected Total Stock of Light Duty Vehicles by Region*

Source: World Business Council for Sustainable Development (WBCSD) 2004

<sup>7</sup> World Business Council for Sustainable Development (WBCSD) (ed.): *Mobility 2030: Meeting the challenges to sustainability*, Geneva 2004

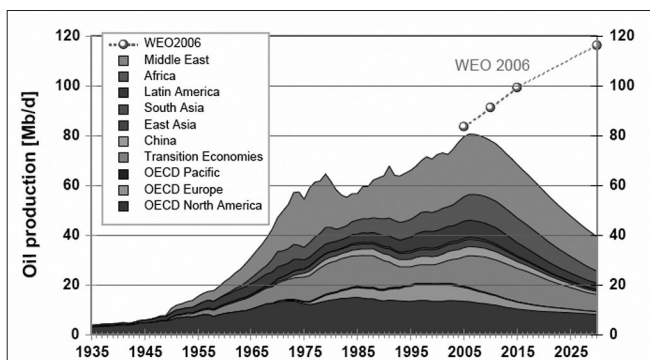
<sup>8</sup> [www.imf.org/external/index.htm](http://www.imf.org/external/index.htm)

For fuel growth in general, and for the fleet of vehicles in particular, more energy is needed. International Energy Outlook 2008 projected that world market's energy consumption will rise by 50% between 2005 and 2030. Looking particularly at liquid fuels, the world is expected to increase more rapidly in the transportation sector than in any other end-use sector.<sup>9</sup> The demand for fuels is thus growing very fast. Now, the objective is to examine how the market offer will appear in the future.

### 3. GLOBALISATION AND SUSTAINABLE DEVELOPMENT: THE NEED TO CHANGE THE ECONOMIC FRAMEWORK

The offer of oil grew steadily between 1935–2005 facilitating economic growth and providing a valuable source of energy for the ever-expanding car fleet. However, more recently oil stocks have been showing signs of depletion.<sup>10</sup>

FIGURE 3: *Oil Production*



Source: [www.energywatchgroup.org](http://www.energywatchgroup.org)

A report from Energy Watch (see Figure 3) declares that 'peak oil' production has been reached in the world. ASPO<sup>11</sup> is more optimistic and predicts that 'peak oil' production will happen within the next decade. The IEA has forecast that 'peak oil' production will occur around 2030. Beside these geological facts, a lack of investment in exploration and production could slow future oil production down. Consequently, costs would increase until the point is reached where the industry is unable to bring a sufficient number of new fields into production quickly enough. Investment is critical to compensate for the depletion of oil. The current financial crisis could aggravate the situation further in the long run. Finally, the production policies of the key regions (politics) could reduce the offer. An argument in support of this point is that those regions with vast oil stocks want to protect their future generations' revenues. The

<sup>9</sup> Energy Information Administration (EIA): International Energy Outlook 2008, Washington 2008

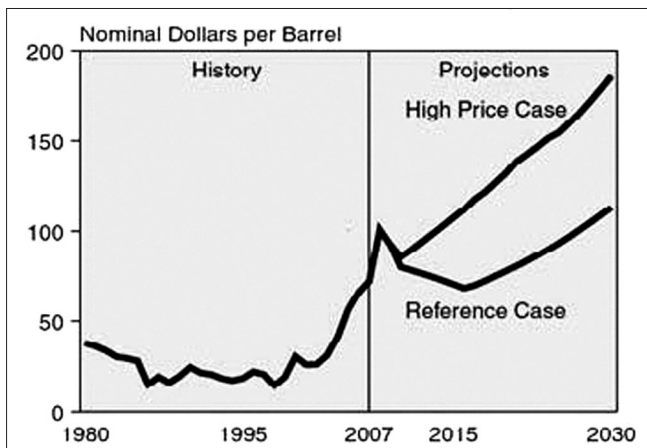
<sup>10</sup> <http://www.eia.doe.gov/oiaf/ieo/highlights.html>

<sup>11</sup> <http://www.aspo-usa.com/>

conclusion from the above sources strongly indicates there is a high risk of a supply crunch.<sup>12</sup>

The differences between supply and demand are reflected in price levels that rose consistently from 1999 to August 2008. As an example, the price of oil in summer 2008 in France was so high that demand dropped 10.6% in June and by 12.3% (gasoline and diesel) in August. In the USA a similar occurrence was observed.<sup>13</sup> Interestingly enough, the US Energy Information Administration actually predicted the recent downturn (see Figure 4). It still expects different scenarios for the future, but forecasts that a higher projection will be more likely. In this case, the price of oil would reach USD 186 a barrel in 2030. The International Energy Agency has projected that supply could fall by 4% while demand could increase by 3% by 2015. That is why M. Birol, the Chief Economist of the IEA, declared 'We should abandon oil before oil abandons us.'<sup>14</sup>

FIGURE 4: *World Oil Price in Two Cases, 1980–2030*



Source: EIA (Energy information Administration): Energy Projection 2008

### 3.1 Global Warming

The scarcity of oil is not the only problem that individual mobility will have to face in the future. Since energy fuels the division of labour and globalisation, most of that energy has a fossil provenance. A number of growing human activities emit carbon dioxide, methane and other fossil compounds back into the atmosphere. Cars alone emitted approximately 2.6 billion tonnes of carbon dioxide (CO<sub>2</sub>) in 2000, which is equivalent to

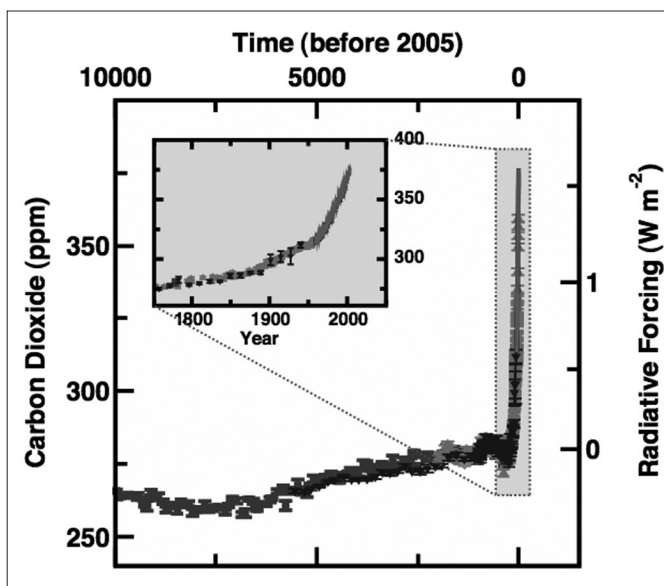
<sup>12</sup> Compare Schneider, A.: "The Shrill Sirens", Interview with Fatih Birol, in: International Politics on April 2008, S. 34 – 45, p. 36

<sup>13</sup> For more details, see Le Figaro 16.9.08, challenges 16.9.08

<sup>14</sup> Compare Schneider, A.: "The Shrill Sirens", Interview with Fatih Birol, in: International Politics on April 2008, S. p. 37

6.1% of overall global CO<sub>2</sub> emissions. This figure could reach 6.8 billion tonnes or 8.1% of overall emissions by 2050<sup>15</sup>.

FIGURE 5: *Changes in Greenhouse Gases from Ice-Core and Modern Data*



Sources: IPCC 2007; Stern 2006, 2008

The emission of carbon compounds back into the atmosphere is considered to be one cause of global warming. There has been a sharp increase in these emissions since the industrial revolution. This marked increase takes the shape of a hockey stick<sup>16</sup> (see Figure 5). Since the publication of the IPCC<sup>17</sup> report and the Stern Review 2006,<sup>18</sup> it is now more apparent that emissions from economic activity, in particular the burning of fossil fuels for energy, are causing the earth's climate to change. According to the Stern Review 2006, the overall financial costs of climate change will be equivalent to losing 5% of global Gross Domestic Product (GDP) each year. The costs of stabilising climate change are also significant, but is currently estimated at less than 2% of global GDP.<sup>19</sup>

One aim of the aforementioned studies is to furnish politicians and economic actors with the arguments needed to change attitudes and to reduce greenhouse gases. However, since 2000 anthropogenic CO<sub>2</sub> growth has been four times faster and no decoupling of growth

<sup>15</sup> PWC (2008)

<sup>16</sup> Mann/Bradley/Hughes 1998

<sup>17</sup> INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE: Climate Change 2007: The Physical Science Basis, Paris, February 2007, p. 3

<sup>18</sup> Stern, N.: The Stern Review: The Economics of Climate Change, Cambridge 2006.

<sup>19</sup> Stern, N.: Emission Rights Are a Bad Idea, FAZ Nr. 229 vom 30. September 2008, p. 14



from greenhouse gas emissions (2008) can be observed.<sup>20</sup> That means that the carbon intensity, meaning carbon emitted per unit of GDP of the global economy, rose especially in the 2003-2005 period. This change was largely attributed to China's rapidly growing share in economic output and carbon emissions. In order to reverse this evolution, more and more politicians are trying to define new rules for globalisation and human activities. On the international level there are discussions on the Kyoto Protocol. The aim of these discussions is to stabilise greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.

The European Union is currently investigating a realistic target for its member countries to reduce their CO<sub>2</sub> emissions by 20% by 2020,<sup>21</sup> or 30% if a broader international agreement is reached. The objective for cars in 1997 was that by 2012 CO<sub>2</sub> emissions should be reduced to 120 g/km. However, after a long dispute between the European Commission, governments and the automotive industry a final decision was reached in parliament at the end of 2008.<sup>22</sup> The European Parliament took a strong stance on this regulation despite vigorous lobbying from the automotive industry.

Beyond the abovementioned costs and regulation ambitions, the European Commission is also working on a proposal to internalise the external costs of transportation. Currently, these are estimated at 1.1% of GDP (€100 billion) for global warming, noise and air pollution and another 1.1% GDP (€100 billion) for traffic congestion.<sup>23</sup> Suggested incentives for people to adopt less costly behaviours include tax reductions, charges and emission trading schemes.

Parallel to this, countries are setting up their own individual regulations to combat climate change and the external costs. Many European countries have started to introduce a one-off tax or a yearly tax based on CO<sub>2</sub> emissions. Similar to the domestic appliance energy efficiency rating, France has e.g. devised the 'Bonus Malus' scheme which evaluates carbon dioxide emissions from cars. A carbon dioxide exhaust of less than 130 g/km gives a bonus (tax break) from €200 to €5,000. The tax on new cars with a carbon dioxide exhaust emission of more than 161 g/km is between €200 and €2,600. It is expected that the revenue from these taxes will finance the tax breaks. In reality, this has profoundly changed demand: sales of cars with less than 131 g/km jumped from January 29.6% in

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<sup>20</sup> See Canadell JG, Corinne Le Quéré, Michael R. Raupach, Christopher B. Field, Erik T. Buitehuis, Philippe Ciais, Thomas J. Conway, RA. Houghton, Gregg Marland (2007): Contributions to accelerating atmospheric CO<sub>2</sub> growth from economic activity, carbon intensity, and efficiency of natural sinks, Proceedings of the National Academy of Science

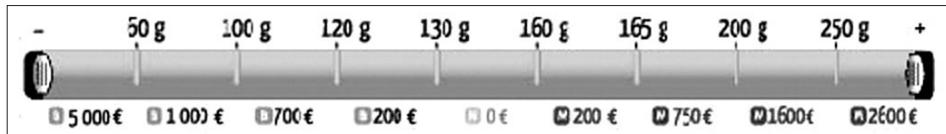
<sup>21</sup> [http://ec.europa.eu/energy/energy\\_policy/](http://ec.europa.eu/energy/energy_policy/)

<sup>22</sup> For more details, see the European Parliament legislative resolution of 17 December 2008 on the proposal for a regulation of the European Parliament and of the Council setting emission performance standards for new passenger cars as part of the Community's integrated approach to reduce CO<sub>2</sub> emissions from light-duty vehicles (COM(2007)0856 – C6-0022/2008 – 2007/0297(COD)), <http://www.europarl.europa.eu>, Texts adopted

<sup>23</sup> See Nash 2003 p. 36. For further detailed information about external costs in the transport sector, please refer to European Commission 2008. A study by INFRAS, IWW, Universität Karlsruhe estimates the external costs of transport without traffic congestion to be 650 billion €. See Infrass 2004 p. 6 et seq

December 2007 to 46% in August 2008. The average sales CO<sub>2</sub> exhaust dropped from 149g/km (2007) to 140g/km in only 10 months.<sup>24</sup>

FIGURE 6: *The Bonus Malus System in France*



Source: <http://www.developpement-durable.gouv.fr>

Previously we have looked at the world level, Kyoto, followed by the European and country level, but even on the city level transportation regulation can and is being implemented. In 2003 London became the world's first major city to introduce a congestion charge<sup>25</sup> to reduce the flow of traffic into and around the centre from Monday to Friday. Currently this charge is GBP 8. This was followed by some other cities like Stockholm<sup>26</sup> where a daily congestion charge of €7 was introduced. Traffic passing into the congestion zone decreased by nearly a quarter (22%); traffic accidents involving injuries fell by 5-10%; CO<sub>2</sub> emissions have been reduced by 14% in London, and by 2-3% overall in Stockholm just as a result of this one policy. Public transport use increased by about 6%, although around 1.5% of that is credited to the higher fuel prices in this period.

In Germany green zones have been implemented, meaning that traffic is regulated by pollution from vehicles. In Paris a self-service car ('Autolib') will be launched to reduce the number of cars in the city.<sup>27</sup>

#### 4. CHALLENGING THE TRADITIONAL TECHNO-ECONOMIC MOBILITY PARADIGM

Mobility is essential to life and human needs. As we have seen it is also fundamental to economic development. The diminishing oil reserves combined with the growing dependence on them, along with global warming, will highly impact on mobility. The question is whether mobility will remain affordable, or whether these changes trigger creativity and innovation which could result in a new techno economic paradigm.<sup>28</sup>

<sup>24</sup> Katchagourian, R.: Bonus-Malus. A measure that starts on the ground wheel, in *France Soir*, 10 Oct. 2008

<sup>25</sup> [www.tfl.gov.uk/roadusers/congestioncharging/6717.aspx](http://www.tfl.gov.uk/roadusers/congestioncharging/6717.aspx)

<sup>26</sup> [http://www.sweden.se/templates/cs/Article\\_\\_\\_14227.aspx](http://www.sweden.se/templates/cs/Article___14227.aspx)

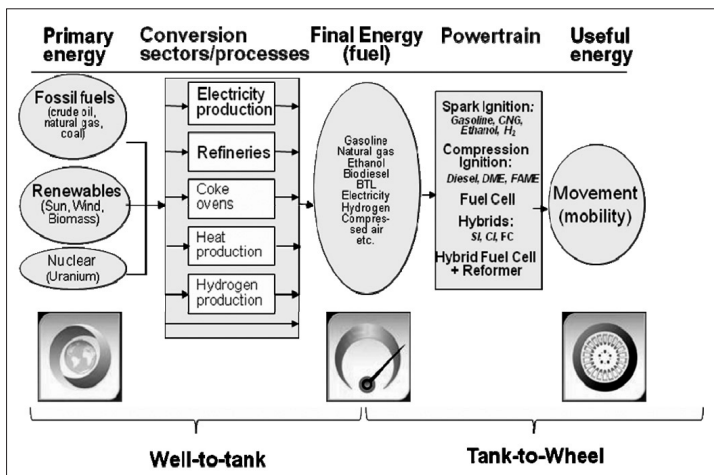
<sup>27</sup> For more information, see [www.paris.fr](http://www.paris.fr)

<sup>28</sup> For more about the techno-economic paradigm, see Perez, C.: Structural change and the assimilation of new technologies in the economic and social system, in: *Future* Nr. 4 from October 1983, Bd. 15, S. 357 – 375; Freeman, C.: Die Verbreitung neuer Technologien in Unternehmen, Wirtschaftsbereichen und Ländern, in: Heertje, A. (Hrsg.): *Innovation, Technik und Finanzwesen*, Oxford 1988, S. 34 – 63; Freeman, C., Perez, C.: Structural crises of adjustment, business cycles and investment behaviour, in: Dosi, G., Freeman, C., Nelson, R., Silverberg, R., Soete, L. (Hrsg.): *Technological Change and Economic Theory*, London / New York 1988, pp. 39 – 66

Most ideas about the new mobility concepts discussed today are in fact not new. The Otto motor was developed in 1860 and uses ethanol. The diesel motor was run on nut oil at the World Exhibition in 1900. At the same exposition, the Lohman Porsche, the first hybrid car, was demonstrated in Paris. At the end of the 19th century there was fierce competition to make the fastest car and history shows that electric vehicles were the most successful. The 1899 *jamais contente* car then achieved more than 100 km/h. Twenty years later, Ford designed his Model T to run on Ethanol, yet gasoline was to be imposed by Rockefeller with the help of prohibition in the USA.<sup>29</sup> This paradigm remains to the present day.

In order to gain a better understanding from the technical point of view and to better evaluate the different possibilities regarding fuel mobility, it is best to analyse the energy path from primary energy to the wheel (see Figure 7). First, one has to distinguish primary energy that can be classified as fossil fuels (crude oil, natural gas, coal), renewable (sun, wind, biomass) or nuclear (uranium). Primary energy is then transformed into final energy (gasoline, natural gas, ethanol, biodiesel, biomass to liquid, electricity, hydrogen, compressed air etc.). This final energy is then transformed by a powertrain into movement (useful energy). Powertrains propel a vehicle using: a spark ignition (gasoline, compressed natural gas, ethanol or hydrogen), a compressed ignition (diesel, dimethyl ether (DME), fatty acid methyl esters (FAME or biodiesel), a fuel cell (an electrochemical device that continuously changes the chemical energy of a fuel (hydrogen) and oxidant (oxygen) directly into electrical energy and heat without combustion or by a hybrid (using multiple propulsion devices) or the pervious options.

FIGURE 7: *Energy Technology Perspectives Model*



Source: own, based on Concawe, Eucar, JCR – Well-to-Wheels Report, Version 2c, March 2007; Daimler Optiresource tool

<sup>29</sup> [www.rockarch.org/publications/resrep/dighe.pdf](http://www.rockarch.org/publications/resrep/dighe.pdf)

Usually, when a carmaker speaks of a zero-emission vehicle they tend to focus on a tank-to-wheel view. In reality, the manner in which electricity is produced should also be taken into account. When taking this 'well-to-tank' view into consideration, zero-emission vehicles can still be produced if the primary energy is wind. In contrast, the use of coal instead of wind as the original energy source would give a worse CO<sub>2</sub> balance than the internal combustion engine. The well-to-wheel approach is thus a systematic approach assessing energy consumption and greenhouse gas emissions. It considers not only the CO<sub>2</sub> produced when the fuel is used in the vehicle but also the CO<sub>2</sub> emitted in the fuel's production and distribution, whether from crude oil, biomass or other primary energy sources.

In the next step, primary energy (1) especially of liquids like biofuels will be analysed. Some years ago this source of energy was seen as a solution to substitute oil in the long run. This will be followed by an analysis of final energy (2), focusing on Li-ion batteries which could launch the mass production of the electric vehicle. Accordingly, the final step will be to break down the different powertrains to conclude with an evaluation of useful energy (3) according to a well-to-wheel view.

Primary energy, and especially the efficiency of biomass, can be evaluated in comparison with how far an average car can drive with one hectare of cultivated area. The most efficient biomasses today are the biomass to liquid (BtL) and biomethan (see Figure 8), the second-generation biofuel. The 1<sup>st</sup> generation biofuel competes with the food chain and thus has a high negative impact on the price of food. By contrast, second-generation biofuels are not in competition with the food chain. They offer greater efficiency because, beside the fruits, the energy of the leaves and the stem can be used. That is the main reason why the distance to drive with one ha of cultivated area is much higher with BtL and biomethan than with the first generation of biofuel. However, biomethan and BtL may be constrained in scale as the surface of land is limited.

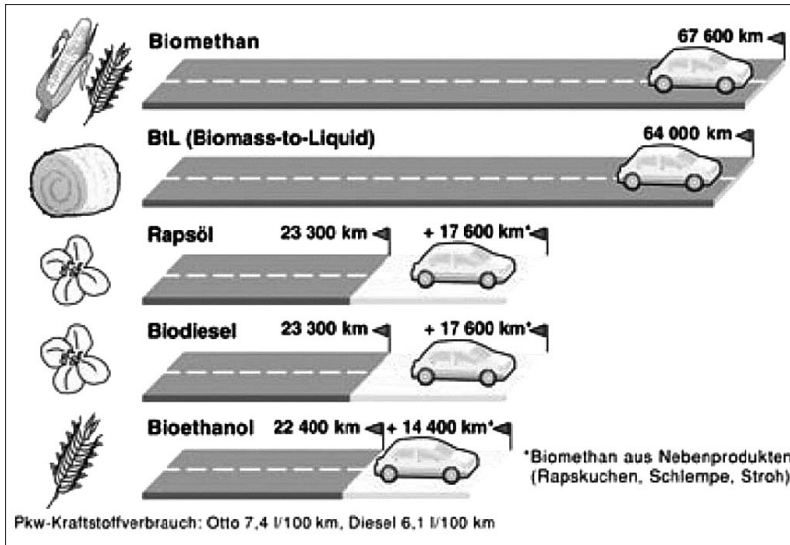
There has recently been the development of third-generation primary energy namely in the form of microalgae. Currently there are about 200,000 different types of microalgae. The annual productivity and oil content of algae is far greater than with seed crops. Algae can yield more than 100 times more oil than a hectare of soybean.<sup>30</sup> Another advantage is that cultivated areas are not required. Algae can grow in places away from farmlands and forests, thus minimising damage caused to eco and food chain systems. In addition, purified water is not needed. Finally, this is an improvement in the yield of oil due to working on a vertical rather than horizontal plane. That is why the yields of oil from algae are higher than those for traditional oilseeds. The only problem is that it will not be commercially available before 2020.<sup>31</sup>

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<sup>30</sup> For more details, see Campbell, M.N.: Biodiesel: Algae as a Renewable Source for Liquid Fuel, Guelph 2008, p. 4 and also US Department of Energy: Algal Bio fuels, Washington 2008

<sup>31</sup> See e.g. the algal project in UK: Jha, A.: UK announces world's largest algal bio fuel project, in: The Guardian: 23 October 2008.

FIGURE 8: Distance to Drive with 1 Hectare of Cultivated Area



Source: FNR 2008

Looking at final energy, traditional gasoline, diesel or biodiesel, hydrogen or electricity can be used. Electricity has gained in importance over the last years as lithium-ion batteries have opened up new opportunities for electric vehicles and hybrid vehicles. The reason why lithium-ion batteries have gained in importance is simple: they offer the best weight-to-energy ratio (important for the range), the best specific power (important for acceleration) of any battery and a slow loss of charge when idle.<sup>32</sup> The weight-to-energy ratio is especially promising. Limitations are present; however, especially in comparison with gasoline or diesel, the energy density of gasoline is 12,000 Wh/kg, about 100 times better than batteries. One reason for this gap is that internal combustion engines (ICE) burn fuel and oxygen, but the weight of oxygen does not have to be transported. This is also why the exhaust of CO<sub>2</sub> is higher than the weight of gasoline (burning one litre of diesel produces 2.65 kg CO<sub>2</sub>, while one litre of burned gasoline emits 2.32 kg CO<sub>2</sub>).<sup>33</sup>

Another limitation of batteries is the price. According to Avicenne<sup>34</sup> these prices will decline quickly with mass production, but will still be high. Today the costs are about USD 1800-2000 / kWh, in 2010 they are expected to decline to USD 700-800 / kWh and to USD 500 / kWh in 2015. The availability of lithium or cobalt could also be a problem, but statements on this topic vary. As primary energy and final energy have been discussed, the next step is to analyse which powertrains can transform the best final energy into useful energy to aid mobility.

<sup>32</sup> Kromer, M.A.; Heywood, J.B.: Electric Power trains: Opportunities and Challenges in the U.S. Light-Duty Vehicle Fleet, Publication No. LFEE 2007-03 RP, Cambridge, Ma., p. 19

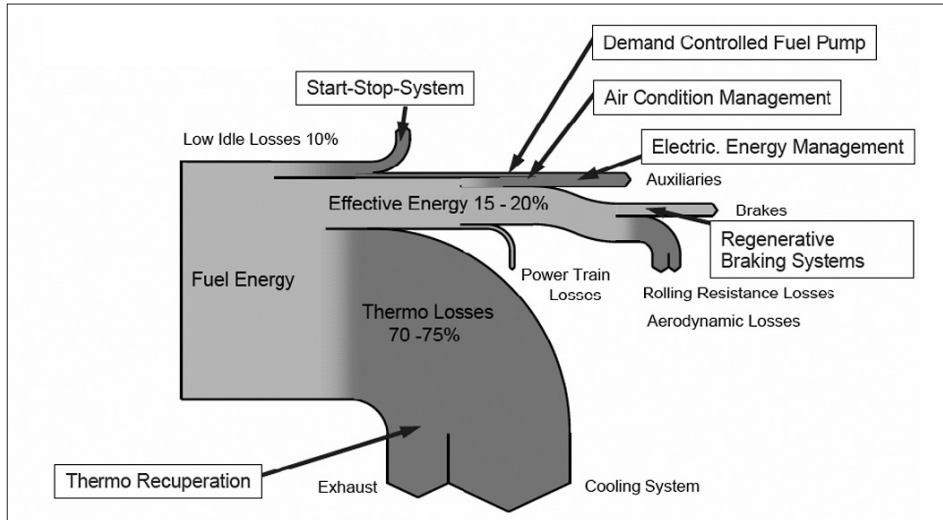
<sup>33</sup> Baden-Württemberg (ed.): Energy-saving Drive, Stuttgart 2006, p. 20

<sup>34</sup> AVICENNE, The Rechargeable Battery Market 2005-2015, March 06

Historically, consumers have been motivated by performance, comfort and safety and been willing to pay a price premium for it.<sup>35</sup> Accordingly, producers have reacted to these demands and offered these features at higher prices. That was the success and the reason for the high margins of carmakers in Europe and the USA. With growing energy prices and environmental constraints, these business models are not viable today. To solve this problem, car producers can choose between keeping and improving the traditional technology or choosing a new energy path like hybrid power, electricity or fuel cells.

Keeping the conventional powertrain strategy can bring huge benefits. An easy way to adapt it could be to reduce the vehicle's weight and thereby reverse the tendencies of the last 20 years whereby the car became about 70% heavier. Another possibility would be to downsize cars or develop new combustion engines like the DiesOtto (a combination of Otto and Diesel technology). Even conventional combustion technologies and engines could decrease fuel consumption to just 15-20% of the fuel energy that is used for movement (see Figure 9).<sup>36</sup> The first energy flows of the 1920s show similar effectiveness compared to today! These improvements are of course possible only if the enhancement in vehicle technology is used to improve fuel consumption rather than to power larger, more powerful cars.

FIGURE 9: *Energy Flow*



Source: Bosch 2008

Analysing the energy flow of a car can be very helpful in developing energy saving strategies: The Start-Stop-System can save 10% of energy and avoid low idle losses (see Figure

<sup>35</sup> Kromer, M.A.; Heywood, J.B.: Electric Powertrains: Opportunities and Challenges in the U.S. Light-Duty Vehicle Fleet, Publication No. LFEE 2007-03 RP, Cambridge, Ma., pp. 19, 135

<sup>36</sup> Kallenbach, R., Bosch: Trends in Automotive Electronics, Steinbeis Symposium, Stuttgart 8.4.2008

9). Energy used for braking can be regenerated as occurs with hybrid cars (see Figure 9). The rolling resistance and aerodynamic losses can be reduced through improved wheel design and aerodynamics.

To evaluate the different improvements in fuel economy and CO<sub>2</sub> emission reduction strategies the CO<sub>2</sub> savings must be divided by the costs. In this way the most cost efficient savings can be seen. Investing in reduced mechanical friction will cost USD 50 and improve the CO<sub>2</sub> efficiency by 4%. Investing in a dual clutch transmission will cost USD 2,000 but will improve the CO<sub>2</sub> balance by only 7%.<sup>37</sup> Even though significant improvements can be achieved, the considerable increases in fuel economy required by the consumer and regulator will be difficult to achieve using conventional internal combustion engines alone, which further enhances the need for hybrid vehicles, electric vehicles and/or fuel cell vehicles.

A hybrid vehicle is a vehicle with more than one power source such as a small internal combustion engine and an electric motor. There are different types of hybrid vehicles: micro hybrid, mild hybrid, full hybrid and serial hybrid. Micro-hybrids have the capability of turning off the ICE when it is not needed. Mild hybrids not only turn off the engine but also provide supportive power when starting up and accelerating at low speeds. Full hybrid systems have a much more powerful electric drive system in addition to an internal combustion engine. The electric drive remains active in the upper speed range, making it possible to cruise without the combustion engine for a limited period of time. The range of the full hybrid vehicle on electricity is still limited to a few kilometres. Serial hybrid vehicles are only driven by an electric engine and run purely on electricity from on-board batteries. The conventional gasoline engine is used to drive a generator and to extend the vehicle range from 60 km with batteries alone to about 600 km. The battery pack can be recharged by the onboard engine and can also be recharged by plugging the car in. Pure electric vehicles (EVs) have one or more electric motors for propulsion.

Full hybrid cars are complex as they have two engines to be managed simultaneously (parallel hybrids). The advantages of these vehicles are that they are energy efficient but as yet still not as efficient as the electric car. They do, however, have low CO<sub>2</sub> emissions. Serial hybrid vehicles are complex vehicles because two engines must be installed, but not as complex as the parallel hybrid vehicle. They have a lower level of efficiency when the range extender is needed. Another disadvantage is the high cost of the batteries. The advantages are that there is a high range of operation through the range extender, and also when in battery mode the vehicle is efficient and environmentally friendly.

Battery powered electric vehicles also provide solutions in terms of alternative vehicle concepts. The negative aspects of the electric vehicle are that even with lithium-ion batteries they still have a limited range of operation, and require lengthy charging periods. The cost of batteries is also an issue, as well as the performance and durability since they are temperature-related. However, the vehicles have lower operating and maintenance

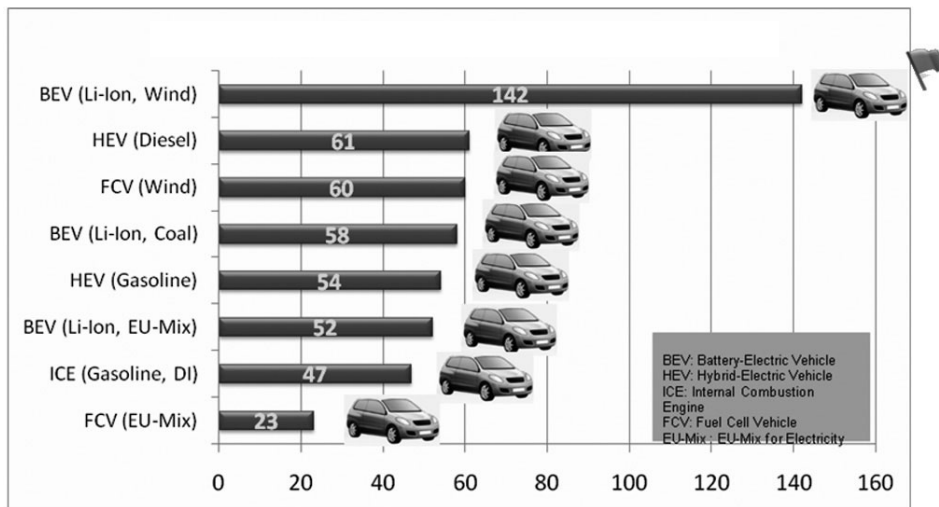
<sup>37</sup> Compare FITT Research: Electric Cars: Plugged In - Batteries must be included, New York 9th June 2008, p. 7



costs. They have an efficiency factor of up to 90% on a tank-to-wheel basis. Further, they are durable and utilise resources efficiency as no gearbox or clutch is necessary. Finally, electric vehicles produce no noise or emissions on a tank-to-wheel view. A problem could be the availability of lithium carbonate and cobalt for the batteries (see above) and of copper and rare-earth<sup>38</sup> for the power trains. On a macroeconomic level, electric vehicles have the best flexibility for being fuelled as all primary energies can be transformed into electricity.

Another alternative concept is the fuel cell. The market is due to see the launch of a new fuel cell vehicle in 2010, but at an extremely low level. Currently, the fuel cell vehicle is less efficient than the electric vehicle<sup>39</sup> (see below). The range of operation is lower than with an internal combustion engine (ICE) and the price of the car is high due to the use of expensive materials. As there is currently no supporting infrastructure, the price of setting up and fuelling this development would be extremely high and is unlikely to be carried out. Further research should be conducted regarding the amount of water vapour the car emits as it is suspected that these emissions could be as damaging to the environment as CO<sub>2</sub>. On a positive note, there is no tank-to-wheel pollution and the driving range is greater than that of the electric vehicle. It has low maintenance costs and the technical fascination is arousing the interests of many parties.

FIGURE 10: *Km travelled on 100 MJ on a Well-to-Wheel view*



Source: own, based on data from Concawe, Eucar, JCR – Well-to-Wheels Report, Version 2c, March 2007; Daimler Optiresource tool

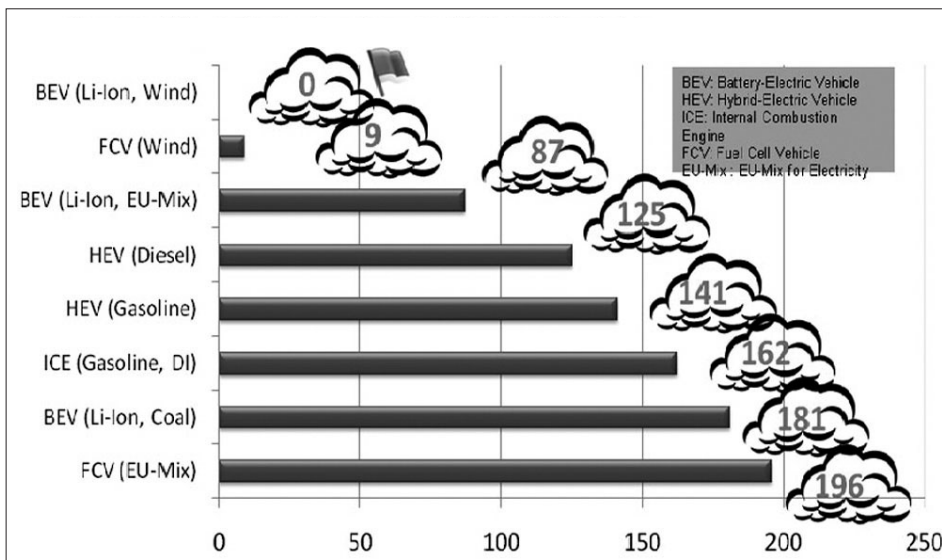
<sup>38</sup> For more details, see Kruse, J.: Chinese Key-controlled raw materials, in: Automobileweek, 6 October 2008, p. 23

<sup>39</sup> See below, the efficiency of a fuel cell vehicle operated on compressed gaseous hydrogen will be in the vicinity of 22%. Using liquefied hydrogen will worsen the efficiency in the vicinity of 17%. For more details, see Bossel, U.: Efficiency of Hydrogen Fuel Cell, Diesel-SOFC-Hybrid and Battery Electric Vehicles, Oberrohrdorf 2003



We have previously seen different powertrain alternatives and evaluated them individually. Now we will compare these different solutions on a well-to-wheel view from the energy efficiency and the CO<sub>2</sub> emissions point of view (see Figures 10 and 11). The summary shown above highlights various fuel/powertrain combinations as estimated by the European Well-to-Wheel project.<sup>40</sup> Competition between the different energy paths is quite enthralling. Technology will provide different solutions for different requirements in the future. Which powertrain concept will be imposed? Nobody knows, but the electric vehicle seems promising. With 100 MJ of wind energy an electric vehicle can drive at 142 km. A fuel cell car, in contrast, can drive just 23 km, which is on the macroeconomic view is very energy inefficient. The Hybrid Electric Vehicle (HEV, Diesel) is very efficient too, with a range of 61 km. A normal ICE Gasoline car can drive 47 km.

FIGURE 11: Gramme CO<sub>2</sub> equivalent per km on a Well-to-Wheel view



Source: own, based on data from Concawe, Eucar, JCR – Well-to-Wheels Report, Version 2c, March 2007; Daimler Optiresource tool

Turning our attention to CO<sub>2</sub> emissions<sup>41</sup>, the BEV with wind is clearly the best solution with nearly 0 g/km. Using the EU Energy mix is still very interesting as the emissions are estimated at 87 g/km. By contrast, the electric vehicle with coal as an energy source is the second worst in this league with a high 181 g/km. However, coal power stations with this level of CO<sub>2</sub> emissions are unlikely to be constructed in Europe today. The hybrid electric vehicles have relatively low CO<sub>2</sub> emissions. The fuel cell here has the highest amount of CO<sub>2</sub> at 196g/km on a well-to-wheel view.

<sup>40</sup> Concawe, Eucar, JCR – Well-to-Wheels Report, Version 2c, March 2007; Daimler Optiresource tool

<sup>41</sup> Ibid.

## 5. SHAKING THE MARKET

We have previously seen the potential growth in world markets. This potential growth means more cars on more roadways in more countries (3 billion in 2050) (Chapter 1) whilst everyone is watching the impact of oil availability and future pricing together with the impact of CO<sub>2</sub> emissions (Chapter 2). There is a perceived conflict between the demand for more cars with better performance and a cleaner planet. Recognising the different technical solutions and their evaluation stressed in Chapter 3, the question now is how will the individual mobility market develop. Will the needs of the customer be met? What about the infrastructure required to create new markets? Will there be a shift towards other mobility modes?

From the customer perspective it should be noted that, since 2007, 50% of the world population has been living in urban areas. In Europe and the USA the urban population is much higher at 72% and 81%, respectively.<sup>42</sup> In developing countries the megacities will continue to grow steadily.<sup>43</sup> Further, 75% of future travelling will be done in urban areas. In France 15-20% of the cars never leave towns and 30% of the vehicles are second cars. Looking at the daily travel needs of the customer, 75% of European drivers use their cars for less than 40 km in one day. In Germany the average driver travels 38.5 km a day, in France the figure is 35.3 km and in the UK it is 29.9 km.<sup>44</sup> Therefore, the range of the car does not need to be high. On the other hand, single parent households are increasing<sup>45</sup> which has an impact on the vehicle size needed.

The second question to answer is how accepting are customers of new technologies. The EV in the 1980s and 1990s did not arouse emotion or passion. The offer was based on light utility ICE (internal combustion engine) vehicles. Today's design is being successfully used to enhance acceptance by consumers. Further, new concepts are being designed to attract greater interest by addressing the (non-existing) sound, the extraordinary acceleration, cutting-edge technology and the new lifestyle of the electric vehicle. Besides these new arguments, 'a little good sense and public-spiritedness can be just as effective as a large amount of technical development'.<sup>46</sup>

Presently, different surveys confirm the newfound interest of customers in electric and hybrid vehicles. An international survey conducted by Continental came to the conclusion that 45.8% of participants would take the purchase of an electric vehicle seriously into consideration and, on average, 36% of the customers are prepared to buy a hybrid vehicle. Comparing the attitudes of different countries, China is the country with the

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<sup>42</sup> United Nations: Urban Population, Development and the Environment 2007, New York 2008, p. 90,92. For a better overview for the growing urbanisation see Weyman, O.: 2015 Car innovation, Innovationsmanagement in der Automobilindustrie, Düsseldorf 2007

<sup>43</sup> See Weyman 2007

<sup>44</sup> Europäische Gemeinschaften, Eurostat: Kurzstreckenmobilität in Europa, Brüssel 2005

<sup>45</sup> Statistisches Bundesamt: Datenreport 2006, Zahlen und Fakten über die Bundesrepublik Deutschland, Bonn 2006

<sup>46</sup> CCFA: CO<sub>2</sub> Emissions – Mobilising road transport, Paris 2008, p. 21

highest disposition to buy hybrid cars. Also, it has been proven that tax incentives increase the disposition to buy as the consumer can overcome the initial cost disadvantage of an electric vehicle or hybrid vehicle. Looking at the price, 50.8% are not prepared to pay more for a hybrid car. The other half is disposed to pay a €2,781 more for an environment friendly vehicle.<sup>47</sup> This shows that a substantial proportion of the population has a sense of public spiritedness. A German study comes to a similar result with 37% of the participants saying they would buy an electric vehicle, 15% would choose a hybrid vehicle and 48% would opt for a vehicle with a conventional engine.<sup>48</sup>

When comparing vehicle costs, as mentioned before, an electric vehicle is currently more expensive than an ICE car. This is especially true concerning the purchase price mainly because of the cost of batteries. As the operating and maintenance costs of an electric vehicle are low, it is interesting to see if the life cycle costs are still higher. Considering usage over 12 years, and taking into account the evolution of battery costs, gasoline and electricity price, as well as improvements in ICE consumption, an ICE vehicle will have lifecycle costs of €38,604 in 2010. The electric vehicle is 6% more expensive at €40,887. In 2020 the situation will probably be different. Progress in battery technology and mass production will make electric as affordable as ICE cars – the lifecycle costs of an electric vehicle will be 20% cheaper than an ICE car.<sup>49</sup>

We have discussed the customer requirement and now our attention will turn towards the offers available. Western car manufacturers have until recently failed in their marketing communication and brand positioning to address the trend toward more sustainable behaviour by the customer. They have previously focused on performance, comfort and safety to achieve a higher price. With the changing paradigm, American OEMs and European premium market OEMs have had to bear drops in sales in the segments of trucks, SUVs and also the premium market. In contrast, sales in the segment of small and medium cars have risen substantially.

In the mid-range market segment, high performance cars of the traditional paradigm will appear. The Golf 6 blue motion, for instance, will achieve 99g/km of CO<sub>2</sub> emissions. This is better than the second generation of the Prius from Toyota (104g/km). Toyota, the precursor of the hybrid system, will launch the next generation of the Prius in mid-2009. It will have a very low CO<sub>2</sub> emission of 89 g/km. GM has announced the launch of plug-in hybrid electric vehicle with a range extender. This project has top priority and will come on to the market in 2010. This serial hybrid car will be able to drive more than 60 km on batteries.<sup>50</sup>

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<sup>47</sup> Compare Krogh, H.: Alternative Drives on the Rise, *Automobilweek*, 27 June 2008

<sup>48</sup> Compare WP Consulting: Electric vehicles retail-marketing study, Bremerhafen 2008

<sup>49</sup> See Valentine-Urbschat, M.; Bernhart, W.: Powertrain 2020: The future drives electric, in: *Automotive Insights* n° 02.2008, Munich 2008, pp.6-13

<sup>50</sup> These data of course change often and depend on the advancement of different projects. For more details, see the following e.g. *Automobilwoche*, *Automotive News*, *Japan Automobile Manufacturers Association* or *Comité des Constructeurs Français d'Automobiles*.

The growing small car segment has many newcomers penetrating the market. There is latent demand, but no substantial offers for the new concepts<sup>51</sup>. The Norwegian Th!nk company currently offers the 'City'. A bigger 'Ox' will follow. Heuliez is the biggest electric vehicle producer in the world and was recently bought by the Indian company Argentum. It has planned to provide the 'Will' in 2010: The drivetrain, electric suspension system, brake and tyres are integrated into an active wheel. Also, Pininfarina will launch the new B-0 in 2009. The group Bolloré developed the car. In addition to being equipped with lithium-ion batteries this car will integrate super-capacitors, which are known for their sophisticated energy storage components. They allow for greater acceleration, increased range and a longer battery lifespan.

In order to make mobility more affordable for developing countries and for some segments in developed countries, the low-cost concept is constantly evolving. The very successful Logan has sold more than 1 million vehicles since mid-2004. Volkswagen will launch the 'Up' in 2011 and Fiat will perhaps use the Serbian Zastava brand to launch its own range of low-cost cars. This low-cost concept has not only been copied, but also developed further in order to save weight and fuel. The new and improved idea is to renounce superfluous features. The aim of the C-Cactus from Citroen is to come back to the rapport of dimension and weight of vehicles seen in the 1970s. A new Logan will be launched in 2010 and will emit 97g/km of CO<sub>2</sub>. This shows that mobility can be environmentally clean and also affordable.

Beside these developments, new OEMs in developing countries are developing their own low-cost solutions to accommodate the demand for affordable mobility. They extend the low-cost idea and have designed ultra-low-cost cars like the Nano from Tata, which is priced in the realm of USD 2,000. Recognising the demand for sustainable mobility, some OEMs will compete in other higher segments. This will mean they will come into direct competition with Western OEMs and use this opportunity to close the gap faster in powertrain engineering. An interesting producer could be BYD – Build Your Dreams. BYD is the second biggest Li-Ion battery producer in the world. BYD is currently developing new electric and hybrid vehicles, which will be soon available in the US. The BYD Strategic Plan received an excellent reception from Warren Buffet, who subsequently invested USD 0.25 billion in 2008 in the company.<sup>52</sup> Tata, an Indian company, has a stake in Pininfarina and also bought Miljøbil Grenland (Norway) in order to further develop an EV on the basis of the Indica. At the moment, Tata is the only company that has also invested in air-compressed cars from MDI, a French company.

The suppliers of OEMs have different possibilities for adapting: they can follow the OEM, help the OEM (innovator), become a competitor to the OEM or diversify and change branches. To summarise, the slow OEM reactions to the new paradigm seen in recent years have brought a number of new players to the market such as Th!nk for city cars, Tesla, Fisker and Mindset for sports cars, Pininfarina (Bolloré) and Heuliez (Argentum)

<sup>51</sup> So e.g. Carlos Ghosn the CEO of Nissan and Renault in: Nissan (ed.): Nissan GT 2012 and Fiscal Year 2007 Results, Tokyo May 13, 2008

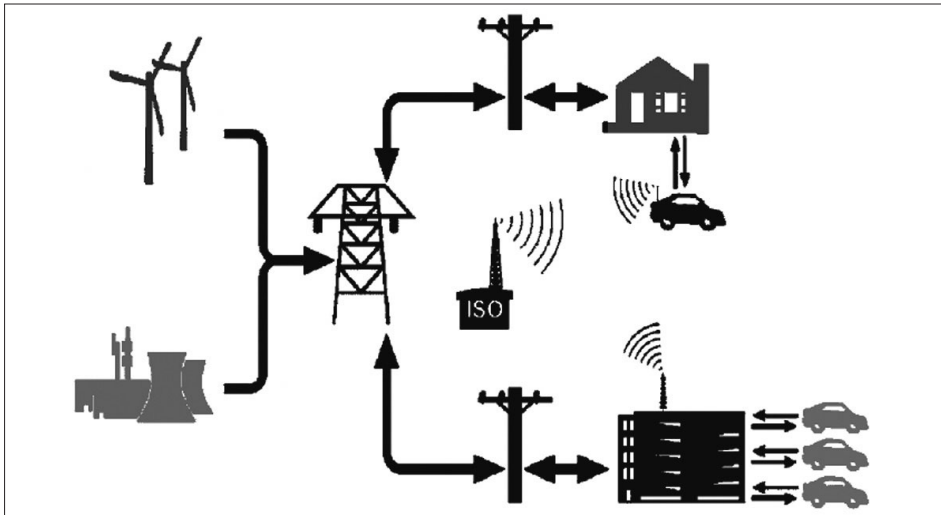
<sup>52</sup> See e.g.: Zeller, J.: Buffett Buys BYD's Battery Brain Trust, in: The New York Times from September 30, 2008

for small cars. New Chinese and Indian car manufacturers, notably BYD (China) and Tata (India), regard electric and hybrid vehicles as a major opportunity to close the gap in propulsion technologies vis-à-vis their global competitors and are preparing to penetrate the US and European markets.

A prerequisite for launching the new vehicle concepts is the development of a supporting infrastructure. Substituting oil for biofuel would not necessitate large investments in new distribution channels. Clean solutions can be implemented within the existing fuel infrastructure. In contrast, the introduction of the fuel cell would necessitate a cost-intensive hydrogen distribution infrastructure.<sup>53</sup> Further, the current fuel cell technology is expensive and extremely energy and CO<sub>2</sub> inefficient. The build-up of such an infrastructure is thus unlikely in developed countries.

With regard to electricity, the extension of the existing power grids to allow for the development of electric vehicles might not be very expensive<sup>54</sup> and would enable new synergies. These synergies would come through valley filling and peak shaving (see Figure 12). Valley filling is charging at night when demand is low. The valley filling strategy is just one opportunity to raise synergies with power providers. Another possibility is to use the batteries of electric vehicles for 'peak shaving'. This means that electric vehicles would send power back to the grid when demand is high. The advantage is that it could make wind energy systems more economically viable, more efficient, more stable and reliable. Of course, further research in this field is necessary.

FIGURE 12: 'Valley Filling' and 'Peak Shaving'



Source: Kempton / Dhanju 2006

<sup>53</sup> A hydrogen infrastructure must be built from scratch. See for more details Zyga L.: Why a hydrogen economy doesn't make sense, Physorg.com 2006

<sup>54</sup> The electric power grid only needs a modest extension in most parts of the world, *ibid.*

In France for instance, having 15% of electric vehicles in the entire car fleet would increase energy use by just 3% and reduce CO2 emissions by 90%. Another German study expects that the entire German fleet could be powered with just 10% more electricity.<sup>55</sup> To develop such synergies an agreement between power providers, the state and automotive industries should be investigated. Such agreements have been signed in Israel, Denmark, Australia, Hawaii (USA), San Francisco bay (USA), and in Canada with the 'Better Place' programme.<sup>56</sup> Other similar agreements have been signed in Portugal, Kanagawa (Japan), Tennessee (USA), Switzerland, Monaco and France.

'Better Place' is an initiative to bring the public and private sectors together to create the conditions needed to make zero-emission vehicles on a tank-to-wheel view. The aim is to provide a viable and attractive solution for consumers and to create and operate a nationwide network of charging stations for electric vehicles and related infrastructure. The idea of the business model is to transpose the business model of the mobile phone to transportation: the customer buys a range extension through a battery exchange station (infrastructure) instead of minutes.

Another evolution of the individual mobility market could be a shift to other travel modes. The first solution could be 'car sharing'. This model still uses vehicles and is promoted at the moment by several cities including Paris and Lyon, but also by private companies like Mercedes in Germany, which has launched 'Car2Go'. In Paris the idea is to adapt the successful public bicycle rental model ('velib,' vélo libre) to cars. One-shared car should replace six cars. The cost amounts €15 to €20 per month and €4 to €5 for half an hour. This could provide an answer for growing town pollution and congestion (parking and driving). However, its effectiveness has yet to be proven.<sup>57</sup> A second solution could be a change in travel habits and a shift to other travel modes. In France a survey on the impact of growing fuel prices observed that 41% of the participants drove less, 60% walked more, 36% used public transportation more, 31% rode a bicycle and 12% a moped.<sup>58</sup> Japan is another example of shifting travel modes. Most of the population lives in urban areas and most of their travel needs can be fulfilled by walking or public transport. Therefore, young people are becoming more and more indifferent to vehicles and their consumer preference diversifies. This can be observed with car sales which dropped from 7.7 million in 1990 to 5.4 million in 2007.<sup>59</sup> In a shorter term view, the price of gasoline was also an important argument in explaining the buying resistance.<sup>60</sup>

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<sup>55</sup> This is due to the high efficiency of the EV and the raising of synergies with energy providers. Cf. Leuhold, J.: Antriebs- und Fahrzeugkonzepte für die Mobilitätsanforderungen der Zukunft, VDI Tagung Innovative Fahrzeugantriebe from 6th to 7th November, Dresden 2008

<sup>56</sup> See the global progress at <http://www.betterplace.com/>

<sup>57</sup> See Les Echos from 7 October 2008, The launch of self-service cars in Paris postponed to the end of 2010

<sup>58</sup> Compare Institute CSA (ed.): REPORT OF THE FRENCH AL'AUTOMOBILE A RESULT OF THE INCREASE IN THE PRICE OF FUEL - Survey Institute CSA THE PARISIEN / TODAY IN FRANCE /-TF1, Paris October 2008

<sup>59</sup> Compare Nagashima, S.: A LOOK AROUND THE WORLD, Japanese OEMs' desperate attempts to fight flagging domestic demand, in: Automotive Insights n° 02/2008, p.3.

<sup>60</sup> See Handelsblatt: Auto sales in Japan sink auf 35-Jahres-Tief, 07.01.2008

Previously, the evolution of the mobility market was looked at from the customer point of view: the offer and the infrastructure. The question now is at which speed will the recent mobility model be transformed. The speed will depend first on the price of crude oil and environmental regulation (federal and local) and incentives. It will also depend on the availability of raw materials like lithium carbonate, cobalt, copper, rare earth<sup>61</sup> etc. as well as technological evolution. Last but not least, the customer perception and acceptance of the new lifestyle, new technology (with a growing range, growing potential customers), new business and finance models ('Better Place', leasing) and cost savings (cost of use, maintenance) will be the determinants.

According to research by Roland Berger (2008), 25% of future vehicles will be electric or plug-in electric hybrid.<sup>62</sup> Similarly, a study by the Centre of Automotive Research<sup>63</sup> expects that by 2025 conventional cars will disappear and only hybrid (micro-, mild-, full and serial-hybrid cars) and electric vehicle will remain. Carlos Ghosn (CEO Renault Nissan) expects 10 million electric vehicles to be on the road in 2016, with two million of them in Europe.<sup>64</sup> The fastest development will probably be in China. China has strong growth potential, high acceptance of the electric vehicle and is open to investments in new infrastructures because currently it has few gasoline stations to compete with the new electric car infrastructure.<sup>65</sup>

Even the future of the electric vehicle is very promising. It is also apparent that in the long run it will not be possible to replace oil with only one substitute like electricity or biofuel. The energy content in oil is unique. On the other side, lithium, cobalt, rare earth or copper, which are required for electric vehicles, are scarce and biofuels of the first and second generations need cultivated areas that are also limited. Nevertheless, the third generation of biofuel like microalgae could play a significant role after 2020. In this case, the internal combustion engine could experience a revival.

## 6. CONCLUSION

The issues surrounding global warming and the scarcity of oil and other valuable resources are very challenging for all economic actors (state, business, customer), each of which has a responsibility to recognise the other's limits. No economic actor should live beyond its means, which has been done in the past as seen in the recent financial crisis. The disturbance of our natural systems would cause an ecological crisis and be much more difficult to manage than the financial crisis.

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<sup>61</sup> For more details, see Kruse, J.: China Key-controlled raw materials in: *Automobileweek*, 6 October 2008, p. 23

<sup>62</sup> Compare Moch 2008 who in his model is expecting similar results. More scenarios are taken into account. Therefore it is more precise. For more details, see Moch, P.: *Fuel cell and battery vehicles – Short-term trend or hype?* VDI Tagung Innovative vehicle propulsion from 6 to 7 November, Dresden 2008

<sup>63</sup> Compare 2025 the car has run out of petrol, *FAZ* 26.6.2008

<sup>64</sup> Compare Ghosn, C.: in *Autojournal* n° 761, from 9-16 October 2008, p. 37

<sup>65</sup> world business council for sustainable development

<http://www.wbcsd.org/plugins/DocSearch/details.asp?type=DocDet&ObjectId=MzE4NTY>



Innovative solutions exist to maintain affordable mobility. Competition between different technical solutions (different energy paths on the well-to-wheel view), as well as legal regulation, will determine the new techno economic paradigm. It is likely that fossil-fuel-based mobility will not be substituted by just one new technology like biofuel or the electric vehicle. Instead, there could be a mixture of gasoline/diesel, ethanol, rape oil, BtL, biomethan, microalgae in the future, hybrid or electric vehicle depending on the market segment or the distance.

In the market it is highly likely we will see a further downsizing of cars even though a premium market will still exist. As a large majority of customers is prepared to buy alternatives vehicles, the mass production of hybrid cars for long distances and electric vehicles for short distances will emerge. In addition, low-cost and ultra-low-cost cars will gain importance in emerging and in developed markets. These cars must not necessarily have poor energy or poor CO<sub>2</sub> efficiency.

The OEM and supplier can both find vast new business opportunities. However, if they are not fast enough they will lose market share to new competitors from outside their industrial segment or from China or India as customers are not willing to sacrifice their mobility.

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