VEHICLE-TO-GRID
- WHAT IS THE BENEFIT FOR A SUSTAINABLE MOBILITY?-

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Abstract

The demand for vehicles in industrialised countries is dropping and the growth rate in developing countries is slowing down rapidly. Driver of this evolution is evidently the current crisis but also the expectation that in the long run oil will not be sufficient and finally. Paper discus about that situation.

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Key words: vehicles, mobility

Introduction

The automobile industry is undergoing a deep recession. The demand for vehicles in industrialised countries is dropping and the growth rate in developing countries is slowing down rapidly.[1] Driver of this evolution is evidently the current crisis but also the expectation that in the long run oil will not be sufficient[2] and finally, one cause is a rise in oil costs.[3] Another argument for the change in the current paradigm is the environmental policy. Because of the expected external costs due to global warming and pollution,[4] politics are

[1] See e.g. Deutsche Bank Research: Automobilindustrie am Beginn einer Zeitwende, Beiträge zur Europäischen Integration, February 6th 2009

[2] The Chief Economist of the International Energy Agency declared "We should abandon oil before oil abandons us", cf. Schneider, A.: »Die Sirenen schrillen«, Interview Fatih Birol, in: Internationale Politik von April 2008, S. 34 – 45, p. 37

[3] The American Energy Information Administration (EIA) 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 186$ a barrel in 2030. Cf Energy Information Administration (EIA): International Energy Outlook 2008, Washington 2008

[4] See for more details for the cost expectation of global warming , Stern, N.: The Stern Review: The Economics of Climate Change, Cambridge 2006 and Stern, N.: Emissionsrechte zu verschenken ist eine ganz schlechte Idee, FAZ Nr. 229 from September 30th 2008, p. 14. To have a good estimation of the external costs in the European Union, see Nash 2003 p. 36. For

trying on all economic levels to internalise these costs. They think about new frameworks to change the incentives of the different economic actors. This can be observed with the Kyoto Protocol on the worldwide level, on the regional level with new environmental and automotive policy e.g. in Europe[5] and certainly, in several countries[6] (e.g. France[7], California or Germany) or even cities (Frankfurt am Main e.g. London, Stockholm, Paris etc.).
Uncertainties regarding the availability of oil and new legal requirements will deeply impact the future technological paradigm of the automotive industry. Which technical solution will be the most promising: optimized internal combustion motors powered with fossil or bio energy, Hybrid Vehicles, Electric Vehicles, Hydrogen Vehicles? Nobody can make a serious projection but because of the high energy efficiency and limited pollution on a well-to-wheel view[8], Electric Vehicles seem to have good chances on the future markets[9].
Electric Vehicles additionally offer synergies between several stakeholders like car drivers, electric power suppliers, employers and all parties which could be interesting to lower more energy consumption and environmental pollution and their related costs. This debate is discussed especially in the US and is called Vehicle-to-Grid (V2G) concept.[10]

Vehicle to Grid concept

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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 Infras 2004 p. 6 et seqq

[5] See for more details 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 CO2 emissions from light-duty vehicles (COM(2007)0856 – C6-0022/2008 – 2007/0297(COD)), http://www.europarl.europa.eu, Texts adopted

[6] To have an overview on the different taxes in Europe see for instance BMW (ed): BMW group Zeitung 9/2008

[7] Similar to the domestic appliance energy efficiency rating, France has e.g. devised a scheme „Bonus Malus“, which evaluates the 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 2600€. See for more details ://www.developpement-durable.gouv.fr

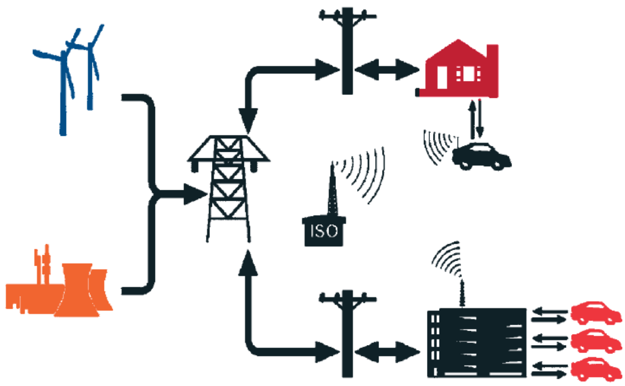
[8] The well-to-wheel approach is a systematic approach assessing energy consumption, greenhouse gas emissions and considers not only the CO_2 produced when the fuel is used in the vehicle, but also the CO_2 emitted in the fuel's production and distribution, whether from crude oil, biomass or other primary energy sources.

[9] See e.g. Deutsche Bank Research: Automobilindustrie am Beginn einer Zeitwende, Beiträge zur Europäischen Integration, February 6th 2009

[10] See e.g. Kempton, W.; Dhanju, A.: Electric Vehicle with V2G – Storage for Large Scale Wind Power, Windtech International 2006

The possibility to receive benefits for all the stakeholders described in a very brief way is seen as follows. The owners of cars with batteries (Electro Vehicles or Hybrid Vehicles) charge their batteries in times when power providers have to face a low demand (“valley filling”, see figure 1). 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 of this method is that it could make wind energy or other alternative systems more economically viable, more efficient, more stable and reliable.[11]

Figure 1: “valley filling” and “peak shaving”



Source: Kempton / Dhanju (2006)

Environmental benefits and new business models

Beside the mentioned energy efficiency and low pollution of electric vehicles by itself on a well-to-wheel view, a combination of it with power provider can raise additional synergies through “valley filling” and “peak shaving” and, in this way, benefit to the environment. Unfortunately, homogenous and detailed evaluations of the savings do not exist now.
In France for instance, first estimations expect that a percentage of 15% of electric vehicle in the entire car fleet would increase the energy by just 3 % and reduce the CO_2 emission by 90%.[12] The energy mix with a high part of nuclear

[11] Ibd.
[12] Gourevitch, A.; Lyon, L. (Boston Consulting Group Paris): La voiture électrique, rêve ou réalité ?, in: La Tribune du
07/10/2008).

energy explains a part of this result. Another Study in Germany projects that the entire German fleet could be powered with just 10% more electricity[13].

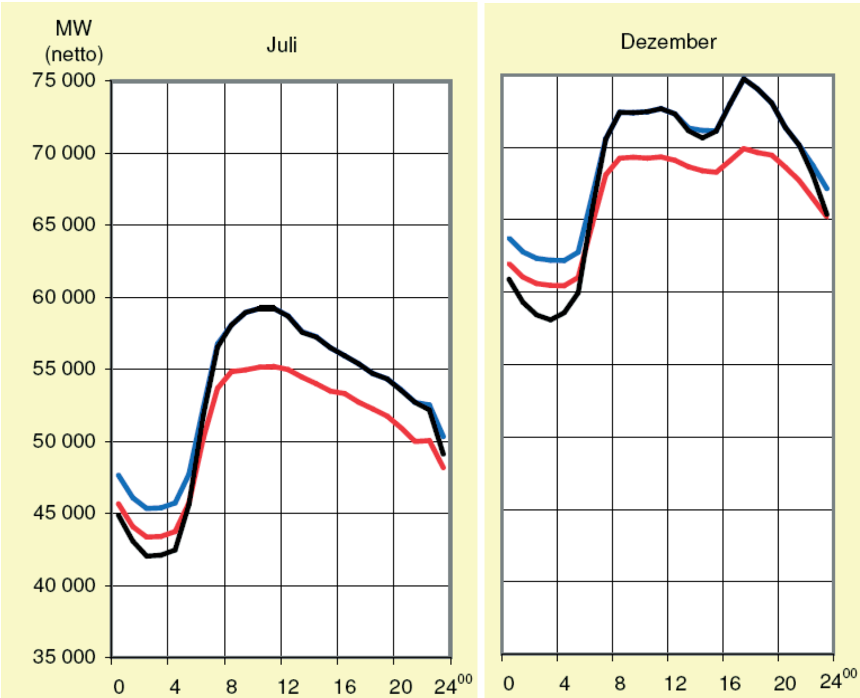
To develop such synergies, an agreement between power providers, the state and automotive industries should be investigated. Such agreements have been signed in Israel, Denmark, Australia, Hawaii (USA), San Francisco Bay (USA) or Canada with “Better Place”[14]. Other similar agreements have been signed 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 necessary conditions 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 mobile phone to transportation: instead of buying minutes, the customer buys a range extension through a battery exchange station (infrastructure).
In Denmark, the “better place” project will be introduced by 2011. The objective is “to help reduce CO_2 emissions and increase the consumption of sustainable energy by capturing and leveraging wind power more efficiently".[15]
Switching all vehicles to electric could effectively reduce the current emissions of CO_2 in Denmark by 17 percent. This project could help the goal of Denmark to reduce the emission of CO_2 by 21 percent by 2012.[16]

Benefits for the power provider

Thus, vehicle to grid seems to bring environmental benefits and raises interest in a lot of countries and, for companies furthermore provides a basis for new business models. The question now is to clarify if power provider can take advantage of this concept as well.
A specificity of providing energy is that the demand of electricity extremely varies during the daily 24 hours and over the year. The following graphs show exemplified the variety of produced and demanded electricity on the third Wednesday of July and in December 2007 in Germany.

[13] This is due to the high efficiency of electric vehicle 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
[14] See the global progress at http://www.betterplace.com/
[15] Anders Eldrup, CEO Dong Energy, cited from LaMonica, M.: Better Place Denmark to plug electric cars by 2011, http://news.cnet.com/8301-11128_3-10150716-54.html
[16] Better place: Dong Energy Close 103M Euro (770M Danish Kroner) Investment for Denmark Electric Car Network, press release from Jan 27th 2009

Figure 2: Output and load of German power plants of energy suppliers at the third of a month in 2007



Capacity and Load of Thermal Power Plants
Capacity of all Power Plants
Capacity and Load of all Plants minus Pumping

Source: Bundesverband der Energie- und Wasserwirtschaft e.V. (BDEW). (to be published 2009)

The minimum is around 42 GW and the maximum around 75 GW (see figure 2).[17] This makes a considerable difference of almost 79% between minimum and maximum!

Regarding the necessity of an uninterrupted service on a constant level, the electricity suppliers have two possibilities to meet the market requirements:

- Producing or buying the electricity just in the moment when needed

[17] Bundesverband der Energie- und Wasserwirtschaft e.V. (BDEW). (2009). Jahresdaten der Stromversorger 2007. VWEW Energieverlag GmbH. 1. Auflage, (noch nicht erschienen, in Vorbereitung). Frankfurt am Main.

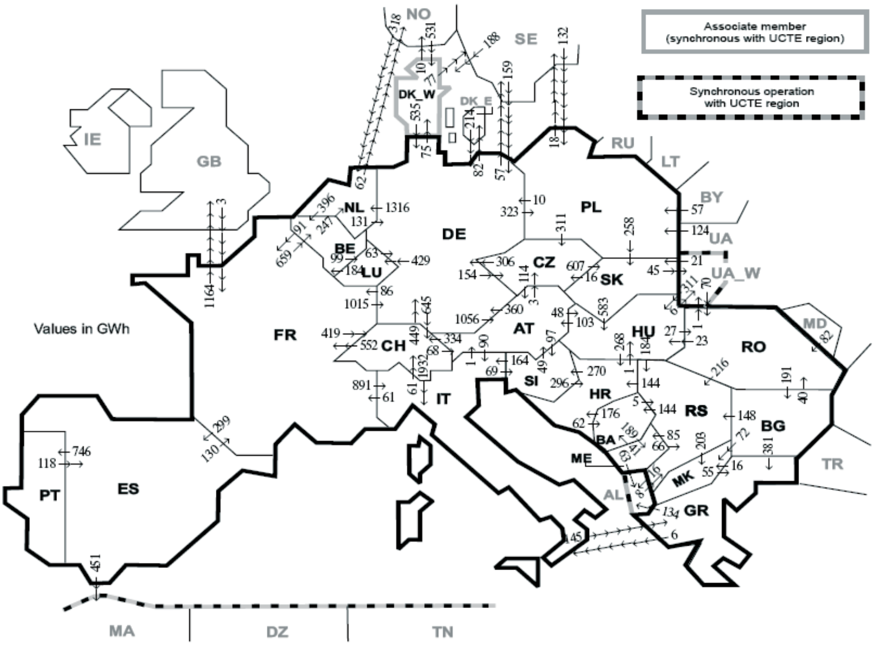
- “Storing” produced electricity during times of low demands to bring this electricity into the grids when needed during peak times of demand.

Both possibilities have technical and/or economical limitations:
To 1.: When production of electricity has to follow an extreme volatile demand, the capacities to produce electricity should be orientated at the theoretical maximum peak demand. Otherwise this demand, whenever it appears, could create a lack of electricity and a grid breakdown. This risk augments strongly with alternative energies like wind. To ensure the reliable production capabilities for the maximum peak means that during the rest of the time there is more or less unused capacity, since there is no demand for the electricity that could be produced. This creates fixed costs. In addition, the growing production of “unreliable” renewable electricity creates even more unused production capabilities. The wind and the sun will not necessarily provide power when demand needs electricity. Sometimes these wells of power even produce when the demand is low. This possibly reduces the utilisation of conventional electricity production capacities again. Buying electricity at a peak level is usually expensive selling at low demand brings only poor or no profits. For example: on Thursday January 29th 2009 the cost of one MWh at the European Energy Exchange Spot Market (EEX) varied between 37,10 € (between 04:00 am and 05:00 am) and 108,49 € (between 07:00 am and 08:00 am). The minimum and maximum price between January the 24th and January 30st was 8,84 €/MWh (2009-01-24; 06:00 – 07:00) and the above mentioned 108,49 €/MWh (2009-01-29; 07:00 – 08:00).[18]
To 2.: The available storing capacities for electricity are limited and expensive. Pumped-storage power stations need a lot of volume and a maximal vertical height. Both limit the geographical possibilities to build these storing capacities. Other storing possibilities like compressed air, batteries etc. are not used in a noteworthy volume. They are obviously too expensive and in the case of compressed air, they need a lot of energy which raises a lot of environmental questions and doubt about efficiency. [19]
As a result of the above described situation and, in order to keep the grid always stable, load management is very important for all electricity producing companies and countries as well as for companies that use very much electricity.
This is true for the course of a day but also for example between the needs of regions like in Europe where “...the (UCTE) coordinates the operation and development of the electricity transmission grid....” to provide “..a safe

[18] See for more details http://www.epexspot.com/en/
[19] See for more details Cyphelly, I.; Rufer, A.; Brückmann, Ph.; Menhardt, W.; Reller, A.: Usage of Compressed Air Storage Systems, Ordered by the Swiss Federal Office of Energy, Les Brenets 2004

electricity supply for some 430 million people..." (UCTE)[20]. The partners of UCTE try to help each other by selling or buying electricity to other partners. The idea is, the bigger the grid, the bigger the possibility to shape regional peaks or lacks of demand. This creates an enormous flow of energy between the partners as exemplary shown in figure 3. But even by using this international dealing for load- and production levelling, there is still the above shown volatility in capacity load and, therefore, in price.

Figure 3: Energy flow between UCTE countries in September 2008 in GWh



Source: UCTE, September 2008, Monthly provisional values, Page 3

Facing this background, thousands or even millions of V2G-batteries, paid or leased by the car drivers or a company like “better place” and used as flexible storing capacity, could be a major part of a smart grid and could create interesting new business opportunities for power providers. For Germany, by the year of 2020, one million electric vehicles (EV) are expected[21]. When each of these electric vehicle’s has a battery with a capacity of only 55 kWh (like today the electric vehicle Tesla Roadster) and only 92% of all vehicles are connected to the grid and the drivers allow a discharge of 50%, this gives an electric energy of 25,3 TWh.

[20] UCTE

[21] Cf. Herz, Carsten in Handelsblatt, 28.01.2009, S. 16

These electric vehicles could be used as buffers for peak shaving, valley filling, spinning reserve[22] or ancillary services[23].

Questions that are not answered yet are the following: How many electric vehicles are needed to provide the above mentioned services in a reliable and economical way to the electricity suppliers? The answer to this question depends on several variables.

a. Important is, for example, how many cars are connected to the grid at a time. For California, Kempton et al. 2001 calculated that in minimum 92%-95% of the electric vehicles should be connected to the grid at any time[24].

b. How much energy can an electric vehicle provide and in what given time can it be discharged? This depends on the further development of the batteries, the connection capacities and the range buffer the drivers need. Even when the capacities of the batteries increase, the volume of discharging per time is limited by technical reasons. The capacity of the grid connection could become another limiting factor since the maximal connection capacity in kw is limited. Range buffer means the minimum state of charge the owner of the vehicle requires to fulfil his or her transportation needs.

c. The technical needs for a reasonable metering and billing seem to be complex and to be corresponding to the level of flexibility for the driver and all other stakeholders. If the driver of an electric vehicle shall have the possibility to connect his or her car at home as well as on public or other private areas, the quantity and time of charging or discharging has to be counted and documented in detail. An identification of the car and the meter it was connected with has to take place and must be documented. Every kwh charged or discharged appears on two meters (car and local) and has to be stored and transported via IT to a clearing and billing unit. This IT-background (hard and software) has to work very reliable and secure at least nationwide, but better over the whole continent. The complexity could be reduced by using a business model like "better place" where just the used kwh are billed.

d. To meet the needed flexibility in connecting the car wherever the driver wants it to, a connection standard has to be established. Parts of this standard have to be for example the plug, the voltage and the clearing and billing software. These standards must be established between the automotive industry and the suppliers of electricity at least all over Europe.

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[22] Today spinning reserves are provided by immediately responding electrical generating equipment to respond when due to a shortly and heavy increase in demand more electricity is needed than produced. Cf. Kempton et al. 2001, P. 54

[23] Ancillary services that include more than spinning reserves are necessary to regulate the grid frequency by adding or subtracting power to or of the grid in response to slight changes in frequency. These services must be available every time since the response time must be extremely short to react to sudden and unanticipated loss of electricity supply. In Europe there is due to the UCTE less necessity for this kind of services than in the US. Cf. Kempton et al. 2001, P. 54

[24] Cf. Kempton et al. 2001, P. 28

e. The power providers have to install the infrastructure for a smart metering as far as this infrastructure is needed outside the cars.
f. The power providers have to create pricing models to meet the needs of the customers and their own needs.

Benefits for the customer of electric vehicles

The electric vehicles in the 1980s and 90s 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 the acceptance from consumers. Furthermore, new concepts are being designed to arouse greater interest by addressing the (non-existing) sound, the extraordinary acceleration, cutting-edge technology and the new lifestyle of 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".[25]
Different surveys are today confirming the newly founded 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 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 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 environmental friendly vehicle.[26] This shows that a substantial portion 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.[27] When comparing vehicle costs, an electric vehicle is currently more expensive than a car with an internal combustion engine. This is especially true concerning the purchase price mainly due to 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 a 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

[25] CCFA: CO2 Emissions – Mobilising road transport…, Paris 2008, p.21
[26] Compare Krogh, H.: Alternative Antriebe im Aufwind, Automobilwoche, 27th June 2008
[27] Compare WP Consulting: Elektrofahrzeuge-Endkunden-Marketingstudie, Bremerhafen 2008

affordable as cars with internal combustion engines: The lifecycle costs of an electric vehicle will be 20% cheaper than a car with an internal combustion engine.[28]
A vehicle to grid infrastructure could additionally bring some incomes with the car by connecting it as often as possible to the grid. This gives the electricity suppliers the possibility to use the “electricity buffers” as described above. Also, large companies may see benefits from V2G if their employees connect their cars to the company grid to shave peaks in electricity consumption. The employee as car owners then could receive a part of this benefit. By calculating the costs and benefits of an electric vehicle used with V2G the investments of the meter on board and the shortage of lifetime of the battery, as a result of the increasing number of charging and discharging cycles, have to be taken into account. This degradation of the battery may be 4 to 8 times higher than the costs for the recharging energy.[29]
Another problem related to electric vehicle is the range. Looking from the customer’s side, we should first note that since 2007, 50% of the world population lives in urban areas. In Europe and the U.S. the urban population is much higher at 72% and 81% respectively.[30] In developing countries the megacities will continue to grow steadily.[31] Furthermore, 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.[32] Looking at the daily travel needs of the customer, 75% of European drivers use their cars less than 40 km in one day. In Germany the average driver travels 38.5 km a day, in France it is 35.3 km and in the UK it is 29.9 km.[33] Therefore, the range of the car need not to be high. But even when a large range is needed, a vehicle to grid infrastructure could serve as a range extender.

Benefits for the automotive industry

As mentioned above, the automotive industry suffers from cyclical and structural problems. A lot of car makers see electric vehicles as one chance to overcome the actual struggles: GM created the Volt, Volkswagen the TwinDrive-System and it cooperates with E.ON, Daimler cooperates with RWE, BMW starts tests with a fleet of electric powered Minis and Renault

[28] See Valentine-Urbschat, M.; Bernhart, W.: Powertrain 2020: The future drives electric, in: Automotive Insights n° 02.2008, Munich 2008, p.6-13
[29] Kempton et al. 2001, P. 35
[30] 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
[31] See Weyman 2007
[32] Gourevitch, A.; Lyon, L. (Boston Consulting Group Paris): La voiture électrique, rêve ou réalité ?, in: La Tribune du 07/10/2008
[33] Europäische Gemeinschaften, Eurostat: Kurzstreckenmobilität in Europa, Brussel 2005

cooperates with “better place”. These examples may show the seriousness of the trend of the electrification of mobility. Questions like standardisation of connections to the grid for charging reasons occur with all these cars. The step from an electric vehicle to a V2G only adds questions of standardisation of on board metering and IT-connection. This is crucial to meet the synergies between customer, power provider, car maker and the environmental issues.

Conclusion

To conclude, the electrification of mobility and the implementation of V2G offer interesting benefits for the environment. It also brings attractive options and benefits for different stakeholders like the power provider, customer of electric vehicles, their employers and car makers.

We are just at the beginning of a transformation of different techno economic paradigms[34] in our modern societies which are based on energy and mobility.This means that a lot of technical and economical options are possible and can influence, enhance or lower the benefits. This transformation is an opportunity to raise benefits for all stakeholders and to open new business fields. State regulations as well as innovation will therefore be determinant. V2G is probably such an opportunity. Improving our energy efficiency and lowering the pollution will also clear the way for a sustainable development and for future generations.

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[34] 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 an Economic Theory, London / New York 1988, p. 39 – 66

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