Hydrogen Transport Economy for the North Sea Region

HyTrEc - policy paper on the distribution of the driving substance

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1. Theoretical foundations

This section deals with a brief presentation of the theoretical foundations that are behind the introduction of a new (and innovative) technical solution or service. In essence, it consists of a short discussion of

- Innovation
- Adoption and diffusion of innovations, and
- A presentation of the relevance for HyTrEc

1.1 Theoretical bases for innovation

Based on the Latin word "innovatio" the term innovation means renewal or new, what is also clear from the reference to the adjective "novus"(new). [1] As de facto many areas of life have the potential for innovation, the excessive use of the term innovation in recent years is not surprising. Thus, the term finds its use in business, politics, science and society, and this in quite differing ways. This may also be an explanation for the fact that to date, neither a closed innovation theory nor a uniform definition of the term innovation is to be found. [2]

Below follows a selection of commonly available definitions in this context:

- "An innovation is an idea, practice, or object that is perceived as new by an individual or other unit of adoption." [3]
- "Creativity is the thinking process that helps us to produce ideas. Innovation is the practical application of such ideas to achieve the company's objectives more effectively. " [4]
- "The innovation is a significant change in the status quo of a social system, which, based on new insights, social practices, materials and equipment, encompasses a direct and / or indirect improvement within and / or outside of the system. The system targets themselves may also be subject to innovation. " [5]
- "Here, innovation is to be understood as the entire process of research, development and application of a technology. This process consists by definition of several logical, ie successive phases (sub processes), which can be distinguished analytically. " [6]

[1] Vahs, D / Burmester, R.. Innovation management, 1999, p 43
[2] Hensel, M / Wirsam, J.:. Diffusion of Innovations, 2008, p 8
[3] Rogers, EM: Diffusion of Innovations, 5th edition, 2003, p 12
[4] Majaro, S.: success creativity: yield through management ideas, 1993, p 6
[5] Aregger, K.: innovations in social systems - Introduction to the theory of innovation Organization, 1976, p 118
[6] Uhlmann, L.: The Innovation Process in Western European industrial countries, Vol 2 - The ex-continuous industrial innovation processes, 1978, p 41

As the mentioned definitions already indicate, the term innovation is used in a variety of scientific disciplines. A comprehensive examination of the various definitions underpins that an amount of novelty [7] appears to be attached to any innovation. [8] In other words, innovation can be described as qualitatively new products or processes, which differ significantly from the status quo. [9]

However, a mere invention or the knowledge of a renewal option is no innovation just yet. Considered economically, the term "invention" differs from the concept of innovation through an aspect of market or internal use. [10] In this respect, the R & D process is a subset of the innovation process, since it refers only to the emergence of an invention (eg development of possibilities for the use of space). [11]

According to the specifications by *Roberts* an invention describes all efforts geared to generate new ideas and to implement them. In contrast, the innovation includes the further aspect of a mandatory use or commercialization of the innovation. Therefore, it can be stated simplistically, that an innovation consists of an invention and its introduction, implementation or application. It represents a qualitatively new product or process in use, with a marked distinction from the status quo. [12] The problems in the process from invention to innovation are according to *Hauschild / Solomon* in the presence of barriers to innovation. These must be overcome for the successful introduction of an innovation. [13] Thus, the mere knowledge about the feasibility for achieving an innovation is insufficient. Accordingly, an energy carrier like hydrogen needs an implementation in context, proving a concept, regardless whether use is made of existing solutions or completely new solutions are applied. Consequently, an implementation strategy must always address existing and potential barriers and how to overcome them (see Figure 1).

[7] Novelty can be divided into objective and subjective novelty. Objective novelty describes new features, for the first time, which can only occur once. Innovations are subjective when they are new from the perspective of the relevant group of persons, i.e., that the innovation is independent of the existing implementation by other parties. The subjective novelty applies to "producers" and consumers (for a new, e.g. geographical or regional market), so they can be applied for use on a limited sustainable energy strategy like in a municipal context. Cf Hübner, H.: Integrative Innovation Management, 2002, p 10

[8] Hensel, M / Wirsam, J.:. Diffusion of Innovations, 2008, p 11

[9] Heger, G / Schmeisser, W.:. Introduction into innovation management in Heger, G / Schmeisser. W.: Contributions to Innovation Marketing, 2007, p 5

[10] Steinhoff, F / Trommsdorff, V.:. Introduction to marketing innovation, p 5, in: Heger, G / Schmeisser, W.: Contributions to innovation marketing, 2007, pp. 4-17

[11] Hauschildt, J / Solomon, Innovation management, 2004, p 30 and Hensel, M / Wirsam, J.: Diffusion of Innovations, 2008, p 18

[12] Graper, Ch: From invention to innovation, 2003, pp. 2 and Rogers, EM: Diffusion of Innovations, 5th edition, 2003, p 170

[13] Hausschildt, J. / Solomon, p. Innovation Management, 5 Edition, 2011, p.37

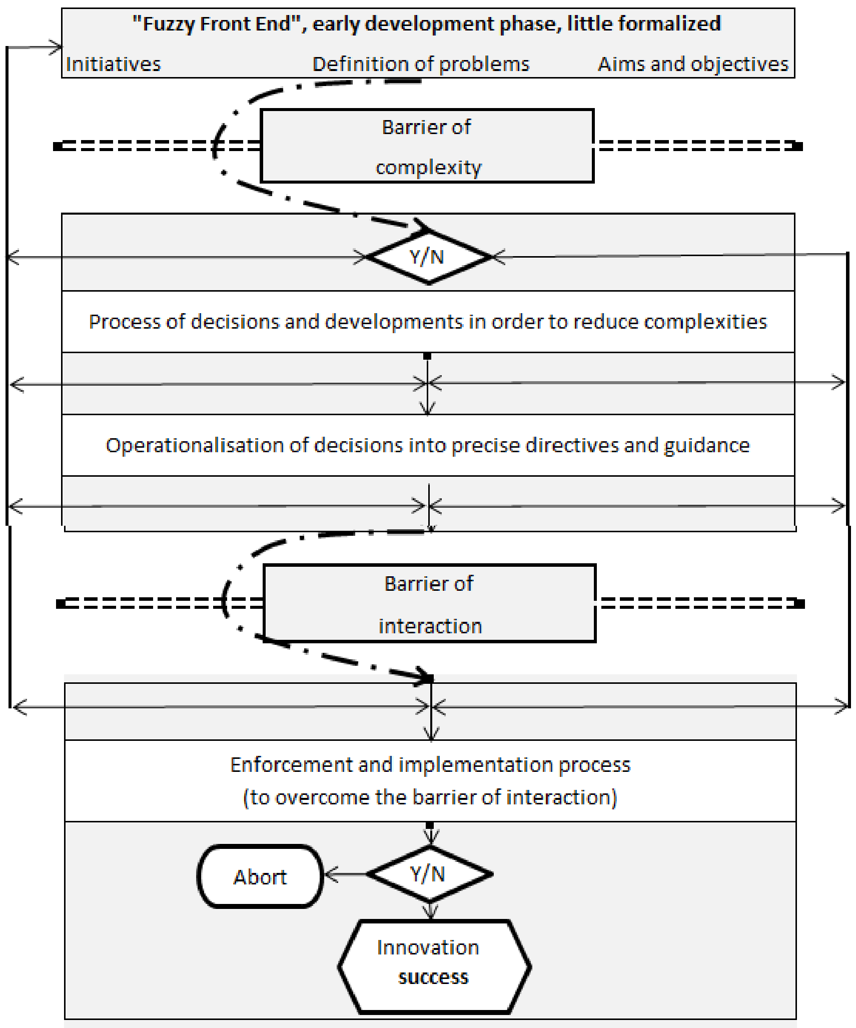

Figure 1: Innovation as a decision-making and enforcement process
Source: Own representation based on Hauschildt, J / Solomon, p. Innovation Management, 5 Edition, 2011, p 37

Accordingly, the transition from a mere invention to an innovation is associated with obstacles. *Rogers* dedicated his theories on diffusion to this circumstance, as is being explained in detail in the following section.

1.2 Theoretical basis for the adoption and diffusion

In principal, the decision of a consumer to acquire an innovation is referred to by the term adoption. Therefore, it affects the primary, decisive act of the demander (adopters), purchasing or acquiring an innovation. Derived from this the subject of the adoption theory is to determine key factors which ultimately lead to adoption or rejection of an innovation at the individual level. [14] In contrast, the acceptance of innovations describes a step before adoption and can be defined as an expression of an individual and subjective opinion towards a situation that implies a positive readiness or a positive behaviour. Consequently, an adoption of an innovation has been preceded by an overcoming of acceptance barriers (see Figure 1). [15]

The diffusion theory as founded by *Rogers* in his masterpiece *diffusion of innovations (*now published in the fifth edition) in this context looks at the spreading and diffusion of innovations in social systems. [16] According to him, the diffusion is defined as follows:

"Diffusion is the process in which an innovation is communicated through certain channels over time among the members of a social system" [17]

Each diffusion in this context bears the following inherent characteristics: [18]

- Innovation and
- communication of innovation between individuals
- in a social system
- during a course of time.

In this respect, the diffusion theory sets a special focus on communication within a social system. According to *Rogers,* the diffusion forms a particular type of communication, since it spreads information about a new idea. [19] Within this framework of innovation research as well as within the one of the marketing theory, an understanding of communication is applied that puts information first. Information is traditionally known as “fit-for-purpose knowledge” (Wittmann 1959:4), ie a resource whose supply contributes to the reduction of uncertainty, enables decisions and steers opinions and behaviour." [20] Here, the communication in the business context is understood is a process of purposeful and task-related information exchange. [21]

[14] Hensel, M / Wirsam, J.:. Diffusion of Innovations, 2008, p 21
[15] Steinhoff, F: Customer-related market research for innovation in Heger, G / Schmeisser, W.:. contributions to innovation marketing, 2007, p.22
[16] Karnowski, V.: Diffusion Theories, 2011, p 12
[17] Rogers, EM: Diffusion of Innovations, 5th edition, 2003, p.5
[18] Schidt, S: The diffusion of complex products and systems, 2008, p 18
[19] EM: Diffusion of Innovations, 5th edition, 2003, p 6
[20] Zerfaß, A.: Communication as a constitutive element in the innovation management in Zerfaß, A / Möslein. communication as a success factor in innovation management, 2009, pp. 27
[21] Rich forest, R / Hensel, J.: Communication as part of the management task in Piwinger, M / Zerfaß. M.: Handbook of Corporate Communications, 2007, S.650

Already the definitions lead to the conclusion that a substantial prerequisite for overcoming barriers to innovation and acceptance are the targeted identification, processing and communication of information to facilitate the acceptance of a potential innovation adopter and thus innovation itself. For a more detailed explanation of this hypothesis, the diffusion and adoption process will be detailed further, starting as in the illustration (fig. 2) below.

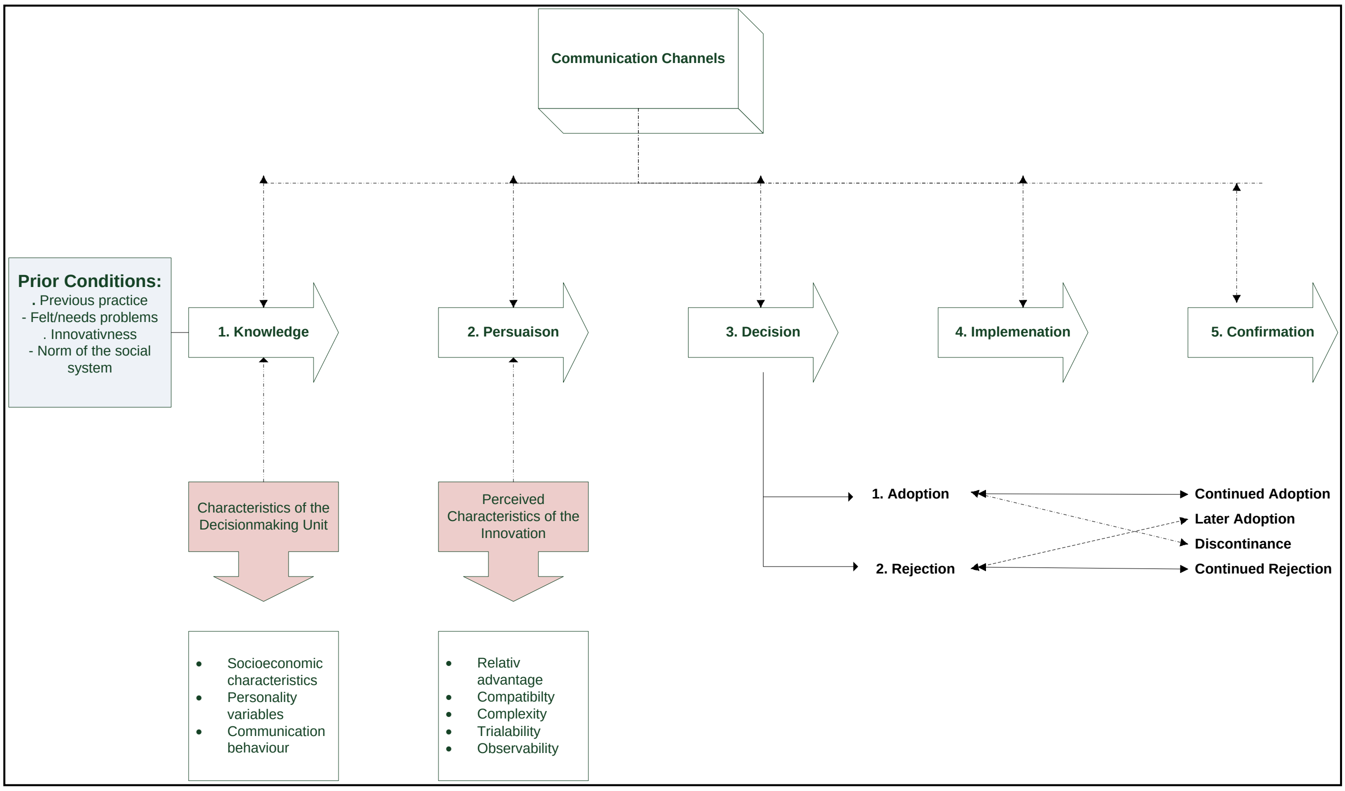

Figure 2: Innovation and diffusion process
Source: Own representation based on Rogers, EM: Diffusion of Innovations, 5th edition, 2003, p.170

The innovation diffusion, ie the diffusion and commercialization of innovation, is an essential part of the innovation process. Simply put, the aim of the diffusion is to make a product known to the customer and to make it accessible. At the customer, it is the adoption process, or in other words the process of using information to foster the decision-making and trigger the adoption, e.g. by purchase. This phase is however different in duration for individual customers. The aim is to shorten this process, for example from a customer perspective to reduce risks through active information. [22]

[22] OV: An innovation created in the minds of customers, 2013
http://www.inknowaction.com/blog/2012/05

According to *Rogers,* the adopters (customers) can be divided into different categories, as shown in the following figure.

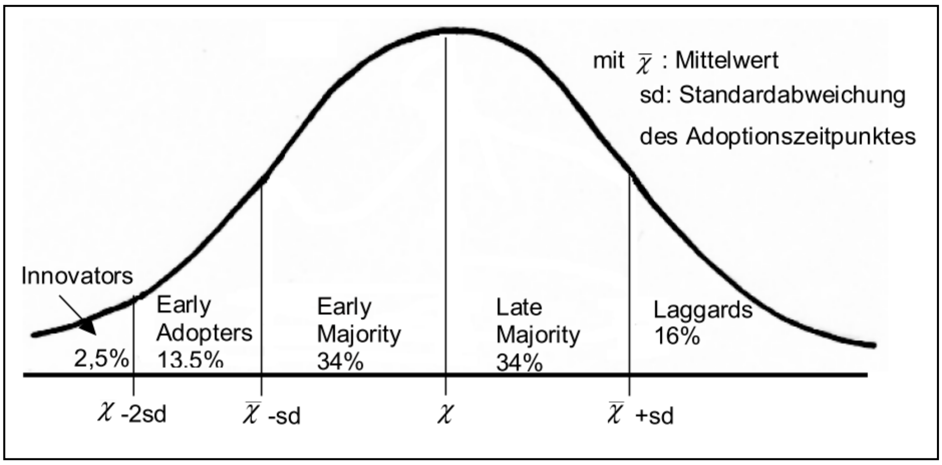

Figure 3: Adopter categories
Source: G. Hofbauer: Success factors for the introduction of innovations, Issue No.3 Work Reports Working Papers, 2004, p.11

This rough representation of the buyer behaviour of individual groups implies the fact that especially the innovators and early adopters are the driving force in the diffusion of innovation. In other words, they are the key in the communication system between potential customers and the suppliers of product innovation and must be identified and specifically addressed by the innovation management. [23]

As a logical consequence of this principle situation, the question of the basis for decisions of an individual adopter or adoptergroup is to be asked next. When the influence on the diffusion process is shown schematically, then according to *Rogers* five factors emerge concerning the adoption rate (in terms of number and speed): [24]

1. Perceived attributes of innovations
2. Type of innovation-decision
3. Communication channels
4. Nature of the social system
5. Extend of change agents' promotion efforts

Factors one, three and four of this list are typical elements of the diffusion processes, factors 2 and 5 are rather accompanying factors, namely because they can slow down or speed up the diffusion of innovation, but are (as many practical examples show) not among the necessary conditions for the adoption as such. Finally, the following graph shows the contents of the basic elements of a diffusion system:

[22] An innovation created in the minds of customers, 2013 http://www.inknowaction.com/blog/2012/05,
[23] G. Hofbauer: Success factors for the introduction of innovations, Issue No.3 Work Reports Working Papers, 2004, p.11
[24] Rogers, EM: Diffusion of Innovations, 5th edition, 2003, p.222

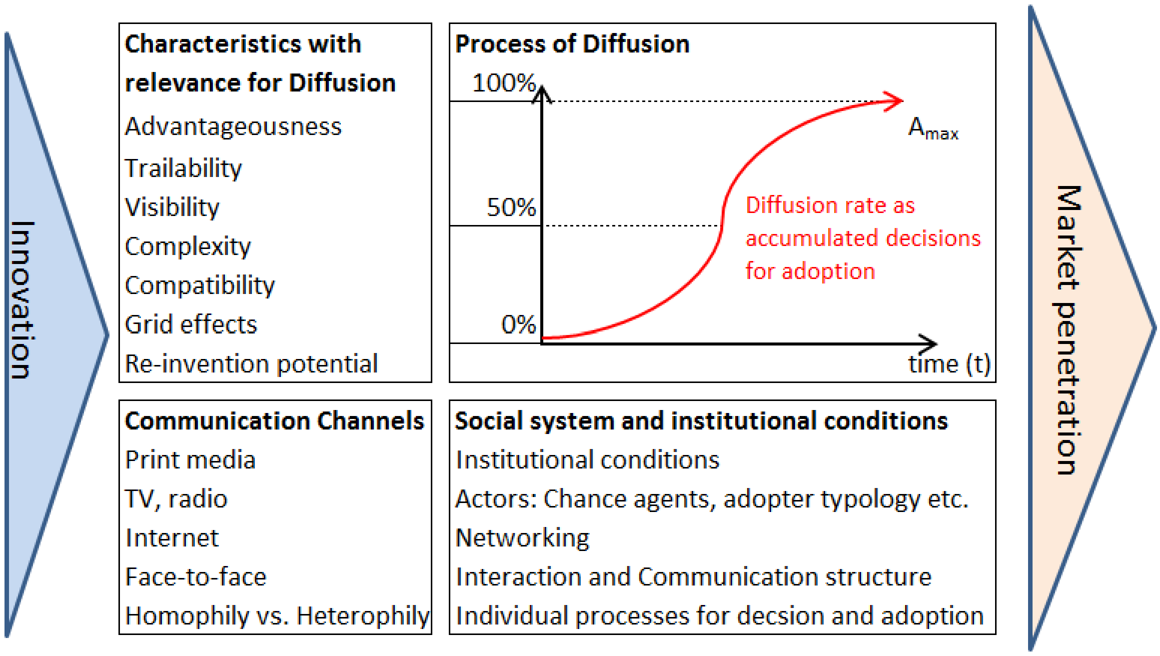

Figure 4: Typical elements of a diffusion system
Translated from source: Paech, N.: Research project Gekko - research framework and theoretical basis for the second baseline study, 2007, p 17

1.3 Relevance to the project HyTrEc

Around the middle of 2013, press articles appeared in major magazines presenting the first on the market hydrogen car from *Hyundai.* These described, how Hyundai after 15 years of innovation research as the first car maker introduced a hydrogen-powered car (Hyundai ix35) on the end-user market, after Mercedes had shifted its planned introduction to the year 2015. According to the product management of Hyundai, the basic idea was finally to dare the first step. Thus, by the year 2015, the number of 1.000 cars pieces of this car will be built with the target markets of Europe (mainly Scandinavia) and California. However, these markets have their limitations. Due to lack of infrastructural facilities, the vehicles are only available to corporate or government customers with e.g. mostly common routes and respective refuelling facilities within a certain vicinity. In addition, the vehicle is very expensive at estimated costs of € 100,000 each. Last but not least also Hyundai admits that at this moment, the economic gain is not a dominating aspect. [25]
The above-mentioned articles also indicate a range of interesting topics for further research on sustainable hydrogen power, some of which can be grouped as follows:

- Obviously, the automotive industry is on the verge of overcoming the first barrier to innovation (cf. Fig. 1), although some carmakers are more advanced than others. The technical implementation of the Hyundai hydrogen drive appears to justify a six years unlimited mileage warranty.
- In contrast to conventional electric motors some of the typical weaknesses do not apply here, so the potential of the hydrogen based electric drive seems much larger. Also a range of 600 km and refuelling performance close to petrol or gas draw a positive picture. However, a number of historical examples show that the better solution is not always what prevails in the market. One of the most striking examples

[25] Gomoll, W.: Hydrogen propulsion ventures into everyday life, into time-online, June 11, 2013, and Greenway, T: The first step it is, Spiegel-online, 2013

documented is that of the technically inferior VHS video recording standard (by JVC) initially competing against the Betamaxx (Sony) and later Video 2000 (Philips). [26] The technical performance of an innovation can therefore not be the sole factor for the rate of market penetration of an innovation.

- According to descriptions and experiences, adoption takes place in the event of a perceived benefit or advantage for the potential customer, which is to be communicated to him, adequately to his socio-cultural background. In this context, the question of the benefit dimensions of a sustainable drive arises. Related to sustainable development a technical solution is potentially based on ecological, economical and socio-cultural value dimensions. The decisive factor is the difficulty of combining and aggregating the individual levels and values for one total single marker. [27] It remains a fact that a potential customer requires a recognizable advantage, whether quantitative or qualitative, that clearly characterises the new solution to be more attractive than other existing options.

Based on the described theoretical and practical basic situation around the diffusion of technological innovations, the next chapter will discuss a selection of fuelling substances regarding their distribution and further details.

[26] This Brim, M / Lischka, K.: million-failure, power mirrors online world, 2008, np
[27] de Groot, RS et al.: A typology for the classification, description of valuation of ecosystem functions, goods and services, pp. 394 in: Ecological Economics, No. 41/2010, pp. 393-408

2. Presentation of the development of selected fuelling substances

2.1 Actual situation of consumers in Germany in 2013

According to a survey carried out by the German vehicle monitoring organization of freelance automotive experts (KÜS e.V.) the consumer interest in alternative fuels has been in continuous decline ever since the year 2008, despite persistently high fuel prices.
Regarding the interest in purchasing considerations and expected future opportunities perceived by consumers the sae survey provides the following results:

Concrete interest in purchasing	*Numbers from the previous year in brackets*
Compressed natural gas (CNG)	21% (24%)
Electric vehicles	20% (26%)
Hybrid drive	18% (23%)
Biofuels	18% (22%)
Liquified petroleum gas (LPG)	17% (19%)
Fuel cell	9% (12%)
Hydrogen power	9% (12%)

Largest future chance expectations	*Multiple scoring admitted*
Hybrid drive	72%
Electric vehicles	62%
Liquified petroleum gas (LPG)	50%
Compressed natural gas (CNG)	47%
Fuel cell	34%
Hydrogen power	31%
Biofuels	31%

Figure 5: Consumers' interest and estimation regarding alternative drives
Source: Alternativ Fahren-de: Alternative drives: Consumers show little interest, May 2013

From another survey, it should be noted that out of 1000 randomly surveyed consumers 52% favoured a ban on biofuels and their admixture to certain final refuelling products (E10). In addition, the willingness to spend more money increases with a decreasing CO_2 exhaust. [28] The fuels mentioned by the consumers will be examined further in the following paragraphs.

[28] Alternativ Fahren-de: Alternative drives: Consumers show little interest, May 2013

2.2 Petrol and diesel fuels

Basically the traffic in Germany accounted in 2010 for around 28.2% of the primary energy consumption (being the largest sector), while it represented only 20.1% (road traffic 19%) of the CO_2 emissions thus staying significantly behind the energy sector (45.7%). It has to be stated however, that the CO_2 emissions reduction rate since 1990 was with 5.6% (road traffic 3.3%) much lower than the other sectors, arriving on average at around 28%. [29]

Regarding the availability of oil, the experts still argue, but while making use of latest, rather not environmentally friendly extraction methods the end of the oil age appears not yet at hands. With prices upwards of US$100 per barrel of crude oil the industry still has a business case with using the most advanced technology, thus postponing the last quantum of oil to be extracted into the far future. More important will be the so-called peak-oil, the point in time when the extraction maximum will be passed. From that moment onwards, the obvious decline in resource will counter-match the rising demand (with at present about 90% of motorized vehicles and goods transport dependent on oil). [30] The impact on the economy and the human race would thus be significant and consequences could be as devastating as in the scenario sketched by *A. Eschenbach* in his science-novel “Burned-out”.

Despite these constraints the third largest carmaker in the world, Volkswagen, envisages the future to remain positive for combustion engines, and also according to the leading German sectorial think tank, the “Mineralöl-Forum”, petrol and diesel fuel will remain the market leaders among fuels far into the 21st century. As key reasons there is the combination of user-friendliness, efficiency and improved environmental friendliness. Subsequently, the alternative drives are still given the character of niche opportunities, of which the fuel cell is seen as the main option for the future. [31]

In this context, the two general types of the combustion engine still pose further potential for optimisation. With on-going technical evolution of the engines, both processes will continue to converge (for example, the Disotto, a development from Mercedes for its prototype F 700, a diesel that works just like a petrol engine, with a homogeneous fuel-air mixture also at part load conditions). This should reduce the emission of soot particles and oxides of nitrogen and reduce fuel consumption. With a similar objective petrol engines are under development, that aim at igniting the mixture of fuel and air throughout the combustion chamber simultaneously and by the heat of compression only. At least in the partial load range, the spark plug may become obsolete. This process is called HCCI (Homogeneous Charge Compression Ignition) or CAI (Controlled Auto Ignition = controlled self-ignition). While the developments based on petrol engines from Mercedes and GM run with conventional petrol or E85, the so-called CCS (Combined Combustion System) process promoted by VW = Combined Combustion System) requires a tailored, synthetic diesel, preferably from biomass. [32]

[29] Federal Environment Agency - Emission of traffic, November, 2012 http://www.umweltbundesamt-daten-zur-umwelt.de/umweltdaten/public/theme.do?nodeIdent=3577
[30] Rost, N.: Peak Oil, 2011, pp. 9
[31] Petroleum Forum: Fuels of the Future, 2000, 3
[32] Auto Motor Sport: Alternative drive: Concepts Overview, 19 Sept. 2010, p.1.

At this year's Geneva Motor Show, VW has presented the XL1 and will manufacture this is in a small (50) serial production in Osnabrück, for a retail price of € 40,000 - € 50,000. The 1-liter car uses a combined drive, consisting of the special two cylinder TDI engine (35 kW / 48 hp) and bears an additional electric motor (20 kW / 27 hp), to allow another up to 50 km of completely emission-free mobility. [33] These developments and the expected general reduction of consumption of vehicles clearly indicate that the future of the combustion engine will foster vehicles with increasingly minimised fuel uptake.

Regardless of the technological advancements of engines and similar solutions to reduce consumption the comparison to global markets reveals an interesting phenomenon. While in Europe nowadays almost every second newly registered vehicle is equipped with a diesel engine, in the USA this ratio is just at 2% (and Asia provides a similar picture). This situation is accompanied by several unsuccessful attempts from French and German manufacturers to demonstrate a decisive technological advantage with diesel in the USA. One reason is to be found in an affinity for hybrid vehicles - if a US citizen wants to save, he will resort to this technical option. [34] Also regarding other factors there are relevant differences and discrepancies between the European and especially the US habits and markets, as the following paragraph is to illustrate.

Historically, the USA had a very active diesel market in the 1970s. Mercedes sedans were delivered to almost 100% as diesel. Discussions concerning the carcinogenic effect of soot particles from diesel engines banned them from the shopping lists. A counter-offensive by Mercedes by a specific filter mounted as a standard failed in 1985 due to technical problems. The filter clogged and caught fire. Linked to this, the then share of six per cent fell even further, from which it has not yet recovered. In addition, the diesel fuel is more expensive than petrol in the the USA (up to $ 1.50 difference) because it is not "subsidized" by means of a tax advantage. The US car makers also complain about a modern diesel from another perspective as they claim it being too expensive to produce and thus unprofitable in comparison for the manufacturers. All in all, despite 25% lower fuel uptake than a petrol engine, a diesel drive does not pay off for the US citizen. [35]

In addition, in the USA diesel is subject to a problem known in Germany to apply to natural gas. Only 42% of service stations in the USA deal with the correct, because low-sulphur diesel fuel for new the new generation of engines (For example, on an interstate highway, only one in three stations provide the required quality, and in congested areas and cities even fewer). Even if a pump is found, there is another problem. Diesel is either unknown or unpopular in the USA, it is rather associated with truckers. Despite a marketing campaign and bonuses, especially the opinion leaders in California, including Hollywood stars, much rather tend to hybrid models, mainly from the US and Japanese manufacturers.

As a further condition there is a dependency on some specific framework prerequisites to be mentioned. German manufacturers were struggling for years to overcome obstacles and technical hurdles related to the US jurisprudence. Also, in conjunction with the oil price shock of 2007 and 2008, a significant market share rise for diesel was predicted for 2015. But with cost-reduction for petrol in the USA (about half of the price level since 2007), the interest in saving fuel waned further. Without the financial and credit crisis, US citizens would

[33] Volkswagen: The XL 1, Feb / March 2013, p.3.
[34] Doll, N: The German author drivers rely fully on diesel, The World Online, 29.08.12
[35] Becke, J: diesel remain a marginal phenomenon, Süddeutsche Zeitung Online, 25.01.2013

probably much sooner have returned to consider the supposed benefits of large SUVs. [36]

In spite of all protestations also the European market hears voices that predict the diesel to "squander its advantages" and thus a significant decline in share and spread. This would be partly due to the increased sensitivity of the engines with their new and more sophisticated technology, but also due to their higher price compared to a petrol one (on average € 2,000 per vehicle). Toyota, for example, has already drawn his own conclusions and will pull out of the diesel engine development almost entirely. One of the reasons for this is that cars with a diesel engine confront the company during the warranty period with five times the costs of comparable hybrid models. This circumstance is suspected to apply to other manufacturers in a corresponding way. But there are still further barriers for the diesel, such as:

- Declining lifetime of the technically complex units, high maintenance costs make these vehicles economically less attractive.
- The diesel price increased in comparison to other fuels significantly higher, so the cost advantage decreases. So diesel vehicles tend to “break even” with their higher purchase price only from mileages of at least 30,000 km per year.
- New environmental regulations (European exhaust norm #6) can be reached by a diesel only with highest technical efforts, which makes the production even more expensive (ratio 3:1; diesel: petrol) and the vehicle even more vulnerable.
- The number of attractive diesel substitutes at affordable prices grows. Smaller and more powerful petrol, LPG or (as especially spread in the USA) hybrid drives the are currently the most popular competitors.

Even taxi companies think about the option to switch their fleet to natural gas, which is understood to be the first warning of the end of an era. [37]

In summary it can be said that the discussion on future fuels for combustion engines runs partly controversial and driven by different motives. VW for example is according to an article in “Der Spiegel” willing to follow and monitor the diesel technology advancements closely while other manufacturers like Toyota will leave the segment almost completely. However, there is a common belief in future potentials of diesel. The recent developments on the oil market and the heralded extension of the oil age will also support a longer lasting supremacy of the combustion engine be it sustainable or not.

In particular, the details regarding the comparison of diesel in the USA and Europe already, ahead of presenting the situation with respect to other technologies, provide some indication on the roll-out of certain individual technologies. In almost all the articles on the topic the factor price and respectively the cost advantage is mentioned. Obviously, the economic aspect seems to be a major reason for choosing between technological solutions. Decisive relevance has the fact that this applies to both sides of the market – the supply side (eg: cost of production) as well as the demand side (fuel costs, acquisition, maintenance). The statements imply a direct relationship between achievable benefits on the economic side and the motivation to support a technology.

[36] Werb, H.: diesel tank in America? No Way, The World Online, 05.01.2009

[37] Rees, J.: The rise of the diesel engine comes to a close, Business Week online, 05.06.2012, pp.1-4

But the recent history in the USA also shows that in addition to the economic factor other, sometimes irrational reasons can cause whether a product is accepted or rejected,.Thus, the Audi brand has struggled in 1986 with "ghost tours" of their automatic driven vehicles. [38] The subsequent campaign and the resulting loss of image barred Audi for decades from setting foot on the US market again. A similar effect of images on the market can be seen today with the diesel. In conclusion it can be said, that the attractiveness of a product is associated with its image and the underlying marketing success.

The history of the diesel engine also shows that trust and security has an impact on the spread of technology. This clearly shows the cancer discussion and the subsequent drop in sales in the diesel segment in the USA. The customer's uncertainty about a health impact of a product / technology and his confidence in a safe (for health) function can affect the decision as well as economic factors.

Finally, two other factors indicate a certain interdependence between their sheer existence or absence and the spread and diffusion of a technology or product. Firstly, it is the access to the required fuel. This point will be found again in the descriptions for compressed natural gas and apparently has a major impact on the choice of the driving means. With increasing ability to replenish a particular item or substance, i.e. with increasing day-to-day practicality of a product, the consumer's acceptance seems to grow. Secondly, differences arise also in cultural terms, which have their adequate influence on the regional distribution of technologies. For example, the US customer differs in its socio-cultural background from German consumers. The emerging likes and dislikes are always to be taken into account as part of a product development. It is to be accepted that a product / technology usually achieves a specific regional success with the satisfaction of regional needs. The diesel e.g. shows clearly that what is successful on one market, may as well not be on a different market - it is completely banned in Brazil, insignificant in Japan, and of an extremely strong presence in India.

The following paragraphs are to detail the other fuel options stated under bullet point 2.1 in the context of these first clues.

[38] Hawraneck: lesson Audi, Spiegel Online Archive, 03.11.1997

2.3 Hybrid drive

"Hybrid technology related to the automotive sector really only describes that two different drive systems are available. A striking example was since the beginning of 2004 the revised Toyota Prius. " [39] "Hybrid cars combine the benefits of petrol engines and electric motors and increase the drive efficiency [...] The most common hybrid is the so-called parallel hybrid engine. In this case, the transmission may be driven by either an electric motor or a petrol engine. The batteries for the electric motor will be recharged when the engine is idling and during deceleration. Where appropriate, both motors can propel the car at the same time. " [40] Historically, the development of this form of propulsion goes back a long time. Already by 1900, Ferdinand Porsche invented the pure electric driving, with the formerly extreme disadvantage of a very short range. For this reason, the concept was further developed and transformed into a hybrid drive. The first drives were used in buses before they were displaced again by the world's dominant petrol engine. 1969 GM rediscovered this technological approach again and some of the other manufacturers (Mazda, Audi) continued to develop it further. The world's first serial production individual vehicle was then just The Toyota Prius in 1997, which has a 33 KW electric motor with a 53 kW petrol engine and is today the world's most popular hybrid vehicle. [41]

Toyota is thus also the most important producer with 4.6 million units sold worldwide, 15 models with hybrid drive and 14% share in the global production of such vehicles. Hybrid propulsion has however, compared to petrol-powered vehicles, only a very limited market share (In a current survey, 69.6% of all newly registered cars in Germany run on petrol, only 1.5% are representing alternative drive technologies, less than half of which or 0.7% are equipped with a hybrid engine) [42]

As with many technological developments also within the hybrid segment different solutions can be found that are prioritised by different manufacturers. A brief description of the existing variants with some significant aspects is provided in the following illustration:

Hybrid concepts overview

Concept	Advantages	Disadvantages	Examples
Micro hybrid	1st step of hybrid; effort, additional weight and costs moderate	Limited savings on fuel in comparison to other alternative drive concepts	BMW Efficient-Dynamics; Smart Fortwo mhd
Mild hybrid	Good ratio of effort and benefit, apart from electric drive all hybrid functionalities provided, recognisable reduction of consumption, improved driving capacities	Currently rather expensive; batteries, e-motor and power management require space and reduce payload	Mercedes S 400 Hybrid; BMW 7 series hybrid
Full hybrid	Very good driving capacities, high potential for savings vs. similarly powerful petrol engines, especially in urban areas, locally emission free possible	High technical ad financial effort, savings vs. diesel moderate, especially on long distance trips, additional weight	Lexus LS 600h; BMW X6 Hybrid; Mercedes ML 450 Hybrid
Plug-in hybrid	Only limited additional effort for existing hybrid systems, high conventional reach, may avoid city centre bans and tolls	No recharging infrastructure available yet, reach less than pure electric vehicles, additional battery weight	Toyota Prius (large scale test running); market launch 2012
Two-mode hybrid	Higher savings potential than the "Prius solution", on demand optional support between modes	Comparable to the full hybrid	Chevrolet Tahoe; GMC Yukon; Cadillac Escalade

Figure 6: Overview of hybrid concepts
Source: Auto Motor Sport: hybrid, 09.01.2008,

[39] LTB Special: alternative drive technologies, 09.2004, p 7
[40] EN monitor fuel: hybrid & electric motor - from toys to series model
[41] Hybridinf
[42] KFZMarkt.Info 43.4 million cars registered in Germany, 21.02.2013.

Regardless of the specific technical solution the hybrid slowly but surely paves its way out of the niche, and it is assumed that especially the plug-in hybrid vehicles will play a significant role in the long term for the car industry. The status quo in 2012 in Germany with 21,483 registered vehicles and a market share of 0.7% is forecast to expand depending on the price of petrol on a global market to a share of 16-24%.

The advancement of the hybrid share can be described on the basis of a number of different factors. First, the distribution of the drive type in Japan is based on a dense urban infrastructure especially transport, accompanied by a strong public interest in alternative technologies, such as hybrid and electric vehicles. Also, this type of drive is encouraged by the Japanese Government since December 2011. The approach appears rather similar to the subsidisation of diesel in Europe. This means that the market penetration of hybrid models in Asia and the USA will be promoted through governmental subsidising while it is supported also through a much wider access to the required alternative fuels (especially in the USA) and this is at the same time reducing fuel consumption by up to 30% . [43]
In addition the hybrid of the same model may well be more expensive than the comparable diesel model (e.g. Porsche Panamera € 25,000 difference - on average € 8,000) [44] but for comparable models from different manufacturers (especially in the middle class segment), this discrepancy leverage is annulled.. (e.g. Toyota Auris Hybrid vs. BMW 1 diesel). [45] Under current conditions in the USA and Asia, this means that the consumer receives a car with better access to alternative fuels, almost identical savings and at a competitive price level, which on top bears the image of an urban solution.

Besides these purely quantitative and tangible comparisons the hybrid drive is designed to illustrate the distribution process of a technology. In 2006, in Germany only about 30% of consumers were familiar with hybrid technology. From that year on, the popularity grew rapidly, so that today, this technology is known to almost every car driver at least by name. In this context, the hybrid is attribute with an image as suitable particularly for urban traffic, eco-friendly and fuel-efficient. Negative perceptions relate to little fun and high costs. Regarding upcoming purchase decisions, in the meantime at least 63% would at least consider the hybrid. As already described, the market shares are still low, which at the time of the survey in 2011 may also relate to the small number of hybrid vehicles available. [46]

For the future, experts estimate that the pure combustion engine will lose its meaning after 2025. Hybrid is seen in this context as a link between the combustion engine and the electric drive. Thus, a gradual development is expected to unfold that will ultimately result in the pure electric motor (see fig.7). [47]

[43] Borgmann, MM / Lossie, H: Hybrid or Diesel, Daily Mirror Online, 18.01.2013, p and o greenmotorsblog.de: Hybrid and Fuel Cell Cars - The Future Outlook, 19.07.2013
[44] Falk, A: Porsche Panamera - price and consumption better than the hybrid model, automotive-en, 02.05.2011
[45] AutoBild.de: Which is right for you? , 13.05.2013
[46] Topic-Q market research: Tema of the month 08.2011, p 2
[47] Dudenhöffer, F., battery-art technology for automotive applications, in Ifo Quick Service 11/2010 Asg. 63rdVol 22-23 KW 11.06.2010. S 20

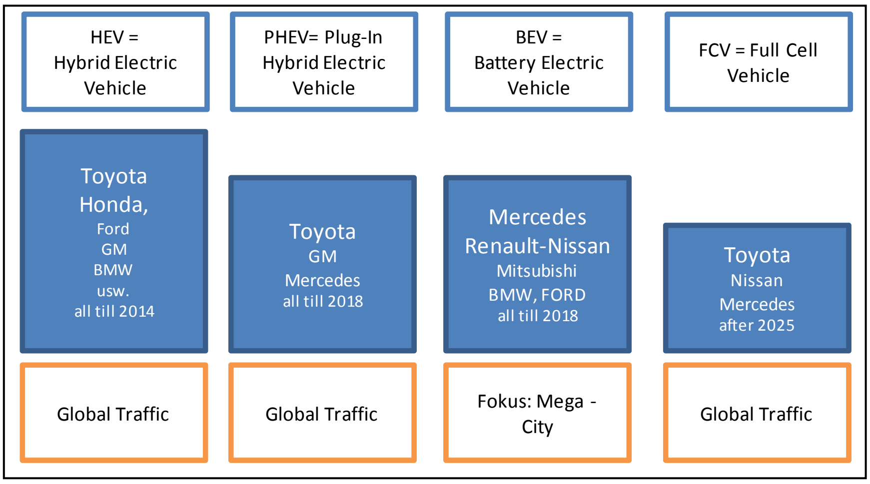

Figure 7: Important stations on the way to electric cars
Source: CAR University of Duisburg-Essen in Ifo Quick Service 11/2010 Asg. 63rd Vol 22-23 KW 11.06.2010. S 20

Currently, the hybrid drive is commonly spreading out, so that almost all the manufacturers offer a vehicle with this technology and gradually equip their fleets with the drive. With the plug-in drive, this change takes a special technological turn as the electric drive provides propulsion for a certain range all by itself.

Also the hybrid drive roll-out and diffusion shows, similar to that in the combustion engine context, some aspects worth observing along the development of a technology. Further to the detailing of section 2.2 is the level of awareness the first to mention. According to current market research in Germany, the awareness and thus the dialogue with the consumers on the technology increase. This implies a connection between knowledge about the technology and its dissemination.

A further condition appears in the form of a pressure from the market demand. The German manufacturers, although specialised in diesel technology, bow to the development of hybrid drives and regional developments in the growth markets in Asia and the USA. Diesel remains a niche product there quite overshadowed by flourishing hybrid markets. Obviously, the widespread implementation of a technology requires a certain and strategic market setting and penetration across all providers in the considered market upfront, which then results in the so-called critical mass. [48] This means in the long run that a technology will be substituted by another one, once the demand is correspondingly large.

Finally the quoted market research provides another important aspect and that is emotion or emotionality. In addition to high cost the other negative attribute mentioned was low driving fun. This purely emotional aspect, similar to the design, demonstrates that consumers act rationally only in little parts and are guided by their personal and emotional preferences. Also this aspect should be considered in the development of innovation.

[48] Critical Mass is here understood as the sales volume threshold, that moves consumers to “jump on a presumably accelerating train” in order not to miss it, so without the providers to need further incentives or marketing activities, as known from e.g. Facebook - many users pulling a lot more users to it.

2.4 Electric drive

The development of hybrid technology and the pure electric drive are difficult to separate because the hybrid drive is seen as a sort of "helper" for the transition to bridge to the purely electrically powered vehicles. An essential criterion of demarcation is the present focus of the developers on the operation within urban contexts and traffic whereas the concept of a hybrid drive is geared to facilitate the wider ranges. Another criterion would be the type of fuel used dominantly, preferably or by default. [49]

Historically, the application of electric motors is clearly the most intensive one in the rail-bound mobility sector. It has been growing especially fast in high-performance locomotives with electric drive since around the 1960ies. Nowadays the railway traffic is not conceivable without electric motors and corresponding high-speed trains such as the Shinkansen, TGV or ICE. However, also in another area of mobility the electric motor is becoming increasingly important - in the automotive industry. Here, experts see the greatest growth potential in the future for electric motors. Even if electric cars are still a rare exception, it will be in the next very few decades that more and more cars will be propelled by non-synchronic AC motors. [50]

The topic of electric mobility in passenger cars and light commercial vehicles is seen with so much potential that e.g. the German federal government has clearly positioned itself towards it with a “National Development Plan for Electric Mobility” back in August 2009. [51] According to an inaugurating evaluation report, a new technological era begins with the electric mobility and the electrification of transport is seen as an important parameter for a whole sustainable mobility. [52] With regard to the policy pursued by the Federal Government the concepts are shown together with their characteristics in the following table:

Type of vehicle	Acronym	Ratio of using the electricity grid for recharging the	In the German NEP (Nationaler Entwicklungsplan)	Typical features
Electric vehicle	BEV (Battery Electric Vehicle	100%	yes	Electric motor with a battery rechargable via the grid Typically a car, but also "two-wheelers" High potential for CO_2-reduction if electricity is
Electric vehicle with extended range	REEV (Range extended Electric Vehicle)	partial, depending on battery capacity and use	yes	Electric motor with a battery rechargable via the grid Modified combustion engine of smaller power or fuel cell
Plug-in hybrid vehicle	PHEV (Plug-in Hybrid Electric Vehicle	partial, depending on battery capacity and use	yes	Electric motor with a battery rechargable via the grid Combination: classical combustion engine + electric motor
Hybrid vehicle	HEV (Hybrid Electric Vehicle)	No grid connection	no, but important con-dition for the develop-ment of	Combination: classical combustion engine + electric motor Recharging battery using deceleration for energy
Fuel cell vehicle	FCHEV (Fuel Cell Hybrid Electric Vehicle	No grid connection	no (using synergies in exchange with the NEP)	Electric motor with a fuel cell for energy supply

Figure 8: Comparison of electric vehicles and other vehicle types
Translated from source: The Federal Government: National Electromobility Development Plan of the Federal Government, 2009, p 2

[49] The Federal Government: National Electromobility Development Plan of the Federal Government, 2009, p 6
[50] Electric - Engines: The applications of electric motors
[51] Fox, K: Fraunhofer Institute - Surveys for electric mobility, 2010
[52] The Federal Government: National Electromobility Development Plan of the Federal Government, 2009, p 2

In this context for pure electric vehicles the storage capacity of the battery has been a limiting factor for a century. The lithium-ion battery appears as a beacon of hope, but technicians are still facing challenges to be overcome expectedly only in six to fifteen years. First and foremost, the cost of a battery is extremely high. The technology already used in many electrical devices today is estimated at between €1,000 and €3,000 per kWh. [53] For a Renault Fluence, the manufacturer states a fuel consumption of 14 kWh per hundred kilometres, which correspondingly makes the battery one of the most expensive components used in electric vehicles. [54] But that's not the only obstacle on the way to widespread market penetration of electric vehicles. The German federal government ranks the challenges in this context for the future as follows:[55]

- Reduction of battery cost
- Increase in energy density and / or power density: for future generations (from 2015), beyond 200 Wh / kg, a battery today has a typical 100-200 Wh / kg.
- Achievement of ranges that are comparable to today's petrol or diesel vehicles, requiring an increase of the specific energy density (possibly up to 1000 Wh / kg), for which, however, a long-term basic research is needed.
- Extension of lifetimes and cycle resilience. Toyota and other manufacturers aim at developing batteries with a lifetime of 15 years at a maximum capacity loss of 15%. [56] This corresponds to 3,000-5,000 charge cycles without a significant loss in parameters. At the present stage predictions regarding the possible charging cycles are to be handled with care, but existing batteries manage prototypically around 1000 cycles of dis- and re-charging under current conditions. [57] Related to this are also the improvement of charging behaviour, part charging times and thus higher mobility.
- Increase of safety and reduction of weight, volume, re-charging time, dependency on temperature and use of toxic components.

In summary it can be said that the development of the battery is the critical node in the whole concept of electric vehicles, and that the car manufacturers worldwide are working to resolve the technical problems. The following figure shows the stress field of battery technology

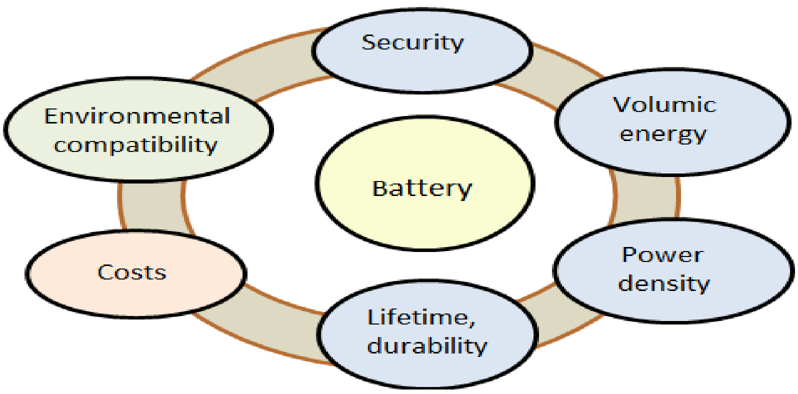

Figure 9: tension battery technology
Source: Rennhak, C / Grooving, G.: The battery is a key technology for the future Elektomobilität in Reutlingen contribution to the discussion about Marketing & Management No. 2012-3, p 8

[53] Blumenstock, Klaus-Ulrich: Vision electric car, car racing online, 13.01.2009, and
Fox, K: Fraunhofer Institute - surveys for electric mobility, 2010,
[54] High consumption dampens the joy, 16.03.2012,
[55] The Federal Government: National Electromobility Development Plan of the Federal Government, 2009, p 10
[56] Blumenstock, Klaus-Ulrich: Vision electric car, car racing online, 13.01.2009
[57] Mobile Power info: Lithium-ion batteries

In addition arises in the context of the overall concept the problem of supply. The re-charging times via the conventional (German) power grid are too long, so that the mobility is limited. In this respect, the market penetration depends on a combination of fast re-charging and sufficiently available re-charging stations, which appears comparable to the aspect of availability of diesel in the USA. A thorough technology assessment thus must screen the entire value chain and its side-effects in order to be successful. [58]

Finally, there needs to be a public debate leading to a broad consensus on the usefulness of the technology. On the one hand side, car manufacturers are working feverishly to develop appropriate battery technologies (including the exploration of alternative solutions such as the solid-state battery, as the performance improvement of lithium-ion batteries appears to be limited). [59] Naturally, and similar to the hybrid technology, this is expected to lead to different concepts identified that will then run through a homogenisation process. On te other hand, the consumer still demands to be convinced of the actual sustainability of electric mobility. According to eco-tests done by the German motorists club ADAC, electric vehicles are just not completely emission free, when considering their entire life cycle. Based on the current German electricity mix (563 kg / kWh CO_2 emissions) and the example previously mentioned for the Renault Fluence power consumption of 14 kWh per hundred kilometres, this results in a CO_2 emission of 79 g / km. In addition, the ADAC doubted the consumption values and determined in "more practice oriented" tests a power consumption of 25.7 kWh, which increases the CO_2 emissions to 145g/km, this being next to the level of a modern diesel engine (e.g. Audi A4 2.0 TDI Ambition) with its 156g/km. [60] At this stage, moreover, the price for the consumer is to be taken into account. Starting from a power consumption of 25.7 kWh per hundred kilometres and a current average electricity price of 28.73 cents / kWh [61] costs arise to 7.38 € per 100 km. In comparison, the current average cost of diesel in 2013 around €1.42 [62] , and a comparable diesel vehicle will state a fuel consumption of about 5.2 litres per 100 kilometres. According to the rather comparable equivalent of costs for driving the electric drive in short entails little incentive for the consumer in the present situation and from an economic perspective, since the costs are still too high.

All in all, it is not surprising, that the goal of the German government (1 million electric vehicles on German roads by 2020) are seriously challenged (in 2012, of the 40 million vehicles with a license for public roads, only 3,438 battery-powered and plug-in hybrid vehicles were registered). According to Daimler CEO Dieter Zetsche, although it is for the companies to advance the technology, but the customer scepticism still remains persistent. By saying so, he also pointed to the need for enticing market incentives in the form of benefits for consumers and producers. [63]

To summarise, the distribution of the electric drive has to cope with almost congruent problems as the diesel in the USA. Issues, such as cost / benefit, adequate supply, image, knowledge of the technology, safety, and by that ultimately the acceptance and adoption of a technology play an equally important role here. As a supportive framework for electric mobility, the broad and almost global consensus regarding the need for policy changes appear to foster mobility (e.g. substantial stimulus programmes in China).

[58] The Federal Government: National Electromobility Development Plan of the Federal Government, 2009, p 9
[59] Cattle man, S: The risk of battery live time, in time-Online, 20/01/2013, p 2
[60] including Der Tagesspiegel: High consumption dampens the joy, 16.03.2012
[61] bdew: BDEW current price analysis 2013, 27/05/2013, p 6
[62] ADAC.de: Monthly average prices of fuels since 2000, 2013.

In addition the spread might be accelerated, if, as in the USA, manufacturers were regulated to provide a fixed quota of emission-free vehicles within their fleet. In this context, the fuel cell is then often mentioned as an alternative. In consequence, this means that the electric mobility, similar to the example of private video-taping, is undergoing a technology development process, at the end of which the actual market penetration of one or more refined practical solutions will be available. Which one of the technological combinations will prevail or even dominate remains largely dependent on the adoption of consumers. [64]

2.5 Gas drives

The gas drives looked at in this paper represent the two types most commonly found in our hemispheres and probably worldwide, using compressed natural gas (CNG) and liquefied petrol gas (LPG, also referred to as “Autogas”). [65]

Natural gas has a special position among the alternative fuels, as in Germany it enjoys special fixed subsidies until 2020. Almost every conventional petrol vehicle can be retrofitted, but meanwhile also a wide range of new cars can be ordered accordingly. More than 20,000 vehicles drive on German roads - in addition to low fuel costs local energy providers help to promote the dissemination of this technology. Natural gas vehicles are distinguished by being gas-run only (monovalent, possibly with an emergency tank for petrol) or using two alternative sources as a concept (bivalent, gas and standard petrol tank). [66] However, natural gas, like crude oil, is a fossil fuel and thus represents a finite resource. In 2000, a survey estimated the gas consumption against the predictable supply and forecasted replenishment availability for 66 more years. For the purpose of developing a sustainable mobility, natural gas is therefore a poor alternative, as it is considerably more environmentally friendly than combustion engines (e.g. no SO_2 and soot particles are produced), but is also a finite resource. [67] Purely focusing on CO_2 emissions, the natural gas has advantages, which strongly resemble the situation of a biogas plant. It is the most advantageous variant of carbon burning schemes for this purpose, but still harms the environment along its lifecycle total balance. [68]

In Germany, natural gas for driving is a rather marginal phenomenon with 0.2% market share. Forecasts agree that in 2020, the one million natural gas vehicles (NGV) will have been surpassed, although at the beginning of 2013 only about 97,000 NGVs had been issued with a road license. [69] Natural gas as a means to public road transport sells with a certain difficulty in Germany, as possibly in many other countries too. A much higher penetration is to be observed especially in emerging countries (with Iran and Pakistan in the lead).With the shale gas boom in the USA, this could change. [70] In Germany, currently a manufacturers’ initiative for a range of models contributes to the further spread, so that in 2014 a doubling of NGVs is possible.

[63] Mortsiefer, H.: market share of electric cars "up upgradable", 31.05.2013
[64] Auto Motor Sport: Alternative drive: Concepts Overview, 19 Sept. 2010, p.1.
[65] Petroleum Industry Association: Mineral Fuels of the Future Forum, 2000, S 34 and Auto Motor Sport: Gas mileage - An overview of the alternatives, 2008
[66] BDK Special: alternative drive technologies, 09.2004, p 3
[67] Petroleum Industry Association: Mineral Fuels of the Future Forum, 2000, p 35
[68] Menz, T / Milentijevic, S: Research appraisal model, North-Sea-Sep-Interreg Project, 2012
[69] Gas 24.de: News, figures are based on Federal Motor Transport Authority, 11.09.2013, oS
[70] Schmidt, N: Affordable and Green - Now come the natural gas cars, Wall Street Journal Online, 2013

However, similar to the electric drive, the concept would only work in combination with a sufficiently deployed natural gas filling station network As of today, there are around 900 stations, th tendency is increasing. However, this is still by far not sufficient to guarantee an unlimited mobility. [71]

Regarding the additional costs, different sources vary considerably. On average, costs for an NGV compared to a respective petrol model range largely around € 2,500 higher. [72] In this case, the payback time (i.e. the economic advantage) for the user is essentially dependent on the model size. The conversion of small cars barely pays of within average mileage (Fiat Punto 1.2 8V 77,000 km), whereas in high class vehicles (e.g. BMW 740 i 43,000 km) with a different typical usage profile, this may takes place relatively quickly. [73] In a previous study the German motorists' club ADAC also proved that the more often an NGV drives by conventional fuel due to lack of gas stations, the longer the return of Investment would have to be awaited. [74]

A similar picture emerges for LPG vehicles, while slight differences can be seen. LPG in comparison to natural gas initially acquired great importance especially with the German neighbours - in Europe in 2004 more than 1.3 million vehicles with LPG drive were on the roads. Especially Poland, Italy and the Netherlands were strongholds of this technology. LPG has a different composition than natural gas. The mixture of propane and butane gas only needs a pressure of up to eight bar – correspondingly simple are the special requirements for additional installations like tanks and valves in the vehicle. This lowers the costs of upgrading compared to NGVs. [75] LPG is thus also much more common in Germany, represented with about 450,000 vehicles already back in 2012 - and also the filling station network is significantly better (about 6,000 filling stations in 2012). LPG is also cheaper than petrol (as of 13.09.2013 € 1.568 for a litre of 95 octane vs. € 0.746 LPG) [76] , while consumption is on average about 10-15% higher. From an environmental perspective LPG has a clear disadvantage against natural gas, because it is a by-product of the oil production, which may perhaps be an indication for the reason of the wide dissemination as well. [77] However, this means in consequence, that the end of the oil age will also herald the end of the LPG era .

In comparison of the two alternatives, the following list is to illustrate the key differences: [78]

- The LPG drive is usually used for the conversion of vehicles, whereas natural gas installation is almost only found with a range of line-production cars with optimized engines. This is why an NGV is usually more expensive.
- Natural gas is measured and sold in kilograms, has twice the calorific value of LPG per kg and is (currently) about 0.30 € more expensive than LPG.
- Natural gas is advantageous with respect to CO_2 emissions. While LPG saves approx 11% $C0_2$ emissions compared to petrol, the number is 25% for natural gas.

[71] gas 24.de: News, based on information from the natural gas mobil GmbH, 11.09.2013
[72] Fuel Monitor DE: LPG & Gas - give cheaper gas
[73] ADAC ADAC cost comparison - converted to LPG? , As of 07.08.2013, p 3
[74] ADAC: natural gas costs compared to petrol and diesel vehicles, as 02.2005, p.1
[75] BDK Special: alternative drive technologies, 09.2004, p 3
[76] Petrol price currently: Germany Current petrol prices: Petrol, Diesel, LPG, 09.2013
[77] Focus online: Alternative Kraftstoffe - Guides gas vs. LPG, 2012.
[78] Harz Energie GmbH & Co KG: Natural gas and LPG - a juxtaposition, 2010

- Both alternatives produce almost no other pollutants during combustion.
- Natural gas has the advantage of substitutability. Natural gas engines can usually be powered by biomethane from renewable resources partially or completely, without engine modifications. LPG is missing this fall back opportunity of using regional renewable energy resources. It is however, often found as add-on, so the initial engine has a "bi-fuel" capacity as it can still use ordinary petrol.

In terms of sustainability, natural gas is thus to be regarded as the much better alternative, because on the one hand it is the most environmentally friendly fossil fuel, and on the other hand (which is even more important) can be substituted by renewable resources. Therefore, the conclusion will focus on the CNG technology, as also car manufacturers prefer this technical solution.

Growth rates regarding the natural gas are recorded to be highest for emerging countries with their own gas reserves, as their fuel costs for drivers are of significant importance. In Thailand and Argentina, for example, more than ¾ of the costs for propulsion can be saved using a natural gas drive. Whether and to what intensity the natural gas engine can grow dominating, is however decided on the US domestic market. The chances of the technology there are controversial. Although the shale gas is a good prerequisite for growth, experts point to the history of the diesel engine, which also is still waiting for its breakthrough. In Germany, the market share in 2011 was still a matter of parts per thousand (5,200 vehicles out of 3.1 million newly registered vehicles). was. According to the ADAC still more gas stations, vehicles and advertising is required. Finally also subjective reservations are associated with natural gas. For a long time, Natural Gas has been looked at as a poor man's technology. To achieve a change in this respect, according to experts, requires persuasion. [79]

All in all, the natural gas is also facing similar problems as all the previously discussed driving means. Firstly, regional factors foster the spread. In this case, it is natural gas deposits in connection with the enormous importance of fuel costs as in Asia and around the (mainly Southern) Pacific. Furthermore, much depends on the infrastructure spread out. For example, while LPG is listed in current price reports for all fuels, natural gas finds little or no attention in the overviews. A "thin" supply network as in Germany therefore has a breaking effect on the dissemination of the technology.

Finally, the US market provides another interesting aspect the question of substitution in the overall fleet context scenario. An increase of alternative drives. would be sustainable in the ecological sense with a declining share of combustion engines. Little would be gained with a development in which, although increasing the proportion of gas-powered vehicles, the share for combustion engines remained stable, so that growth would be achieved at the expense of another alternative, such as the electric drive. The German federal government has issued the target of one million vehicles in 2020, both for electric vehicles and natural gas vehicles, with both drive technologies still far away from this number. It remains to be seen whether the users generally turn away from the combustion engine and choose between current and future technologies or whether the proportion of the environmentally conscious, while steadily growing, is so low that alternative forms of propulsion remain in direct competition.

[79] Schmidt, N: Affordable and Green - Now come the natural gas cars, Wall Street Journal Online, 2013

2.6 Biofuels

Biofuels are distinguished depending on the technological availability in a first and a second generation. "In the first generation of biofuels, biodiesel and bioethanol were of particular importance. Biodiesel is produced mainly in Europe and primarily from rapeseed and to a lesser extent from sunflowers. In North America, especially soybeans are used primarily and in Southeast Asia palm oil. Among the so-called second-generation are biofuels that until today are not produced on an industrial scale, synthetic biofuels such as bio-methanol, bio-mass-to-liquid (BTL), pyrolysis-diesel, biogas and hydrogen from biomass (see IFEU2004). Unlike the first generation not only the fruit of the corresponding energy plant is utilized in their preparation, but their entire skeleton made of lignocellulose. In addition, any form of plant arising in agriculture or forestry such as including wood, straw, grass and the like can be used for this biomass as input material, which increases the energy yield and mitigates the immediate competition with food production compared to the first generation (see Gattermayer 2006). " [80]

Regarding the development of the biofuel consumption Germany consumed about 53 million tons of fuel in. Next to diesel fuel with 60% and petrol with 34%, the share of biofuels was at 5.7% or 3.8 million tonnes. The biofuel sales in Germany rose rapidly until 2007. By high world agricultural prices and the taxation of the pure fuels, biodiesel and vegetable oil, this changed and sales in 2008 dropped to 3.7 million tonnes. It remained almost constant until today. In 2012, main biofuels in Germany are Biodiesel, with sales of more than 2.5 million tons and bioethanol with 1.3 million tons. of are the. In comparison, the subordinate roles were for vegetable oil fuel with about 25,000 tons and biomethane with almost 22,000 tons. [81] In a global view, world production is displayed as in the following illustration:

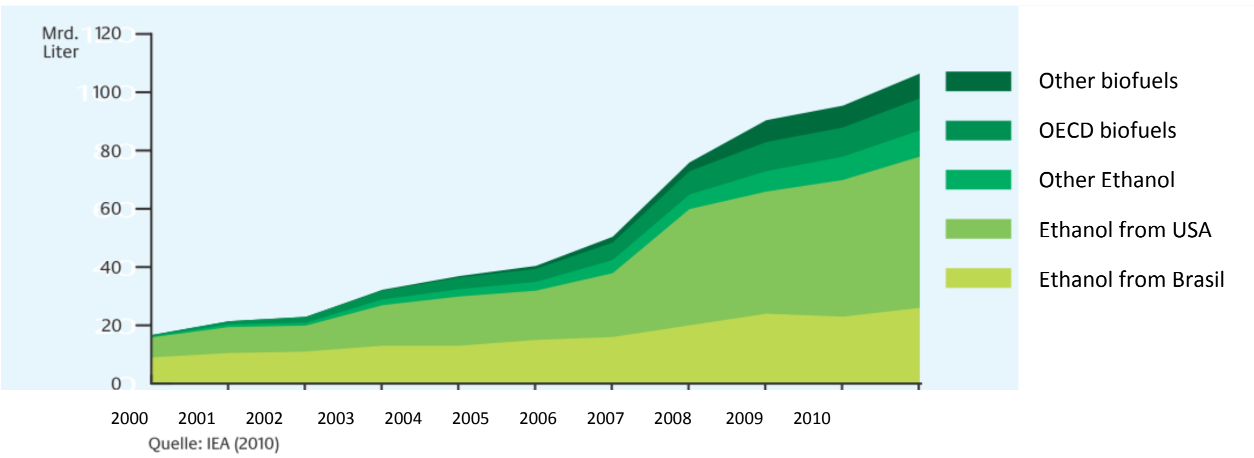

Figure 10: Global biofuel production from 2000 to 2010
Translated from source: Federal Ministry for Economic Cooperation and Development: Biokrafstoffe - opportunities and risks for developing countries, BMZ Strategy Paper 14/2011, p 8

[80] Wackerbauer, J / J Lippelt: Short to Air: Biofuels pick up in Ifo Worldwide Express Service 11/2011 – 64 Year

[81] Agency for Renewable Resources: Development of Biofuels in Germany, 2013

In the years from 2000 to 2010, the worldwide production and consumption have increased steadily and in 2011 represented about 3% of the world production of fuel, nearly tripled between 2006 and 2010. According to forecasts (by the International Energy Agency), the share of biofuels in transport can increase to 27% if the fuel efficiency for the first generation is extended and the market stage for the second generation are achieved. [82]

Biofuels are assessed sometimes positively, sometimes critically, depending on the viewing angle and target position. The environmental benefits of biofuels are undeniable. The production from renewable resources poses no further direct strain on the global climate. Also, biodiesel burns non-toxic and does not produce sulphur, thus being about 75% cleaner than traditional diesel. At least for the pure biodiesel this can often be used without a retrofit of the engine (while vegetable oils often require a conversion). So compatibility with a majority of diesel vehicles would lead to a lower re-fuelling price, and biofuel could help to save on costs. [83] In a negative sense it was demonstrated previously that the increased demand for agricultural products has a significant influence on the prices of food in Europe and the United States. Forecasts regarding the future developments need to be dealt with carefully. Pessimistic scenarios lead to a range of negative deltas between demand and supply, s insufficient offer creating shortages, while positive scenarios argue in favour of enough agricultural production to meet the requirements. [84] Regardless of the scenarios, in this context there is another economic factor. In 2009, the self-supply with biodiesel and bioethanol in Europe was at 98.7%. It is evident that a further increase in demand leads this autonomy to decreases and thus the dependence on imports and price volatility to increase. In the long term it can be assumed that for import-dependent countries, the prices of agricultural products tend to rise, which in turn has negative socio-cultural impacts. [85] A complete replacement with biofuels is also hard to imagine. In Germany, diesel consumption alone would require the entire country as a cultivation area. In addition, and similar to maize, rapeseed cannot be grown continuously in order to maintain the soil fertility. [86]

Like with all previously discussed or presented propulsion and fuel models, also biofuels underline some in principal similar patterns. In particular, the market in Germany illustrates the inextricable link of market acceptance and economic advantage. With the reform of the taxation of biofuels in 2007 in conjunction with high world agricultural prices the market plummeted by almost 50%. Although stabilization came next, the market level has not yet recovered the former volume, let alone grown. This leads to the hypothesis that the present other technical innovations for sustainable mobility, depending on the development of actual prices, can cannibalise market share in the field of biofuels. Also, a certain scepticism from German consumers towards biofuels was briefly explained in the introductory chapter. Here the thesis is that this scepticism also includes the fear (or lack of certainty) regarding food shortages and corresponding inflation. Finally, with a growing demand dependence on imports may increase, which in turn is inhibitive. All in all, again, total price factors, supply and application security, image and regional advantages and situations play crucial roles.

[82] Federal Ministry for Economic Cooperation and Development: Biokrafstoffe - opportunities and risks for developing countries, BMZ Strategy Paper 14/2011, p 8

[83] Fuel Monitor DE: Biodiesel - real alternative or niche market

[84] Federal Ministry for Economic Cooperation and Development: Biokrafstoffe - opportunities and risks for developing countries, BMZ Strategy Paper 14/2011, pp. 8-10

[85] Wackerbauer, J / J Lippelt: Short to Air: Biofuels pick up in Ifo Worldwide Express Service 11/2011 - Volume 64, p 39

[86] Fuel Monitor DE: Biodiesel - real alternative or niche market

2.7 Hydrogen power

Surprisingly, masterminds of the past were already very aware about the potential of hydrogen, as can be seen from the following quotation:

"Water is the coal of the future. Tomorrow's energy is water that has been decomposed by electricity. Disassembled so the elements of water, hydrogen and oxygen are secure for the foreseeable future, the energy of the earth." [87]

Accordingly, the hydrogen power has been attributed for a long time and as almost no other alternative with an outstanding future potential. [88] Basically a number of car makers have invested in research for quite some time in this area, again with some alternative approaches to propulsion and similarly different concepts. There are two main technical alternatives for the use of hydrogen. For example, while BMW focused his research on the development of a hydrogen internal combustion engine working in principle much like a conventional 4-stroke petrol engine, other manufacturers (such as Hyundai) preferred to go for the development of a fuel cell drive. [89]

A direct comparison between hydrogen and conventional mineral oil is illustrated here:

Hydrogen as fuel	Mineral oils (petrol/diesel)
Almost complete avoidance of emissions	Easy handling of petrol and diesel
Reaction to water when ignited; source could be ordinary (purified) water	High volumic energy, economically favourable
No dependency on finite, fossile resources	Well-known and established technology
Creating new jobs	Comprehensive supply grid

Figure 11: Specific fuels compared
Translated from source: H_2 YDOGEIT: Knowledge / hydrogen, 2013, np work according to a study by Sven Geitman, 1998

Unlike some other alternative forms of propulsion, hydrogen power is best characterised to have developed a clear trend towards one dominant fuel cell technology. The hydrogen-powered internal combustion engine is similar in operation to the conventional petrol engine with the only difference that instead of petrol, hydrogen is burned. But combustion engines have only a typical efficiency of 25%, with a peak around 40% (Carnot efficiency). However, with the hydrogen combustion engine, there is a possibility of a bivalent configuration (similar to the hybrid). For the transition period until the establishment of a comprehensive hydrogen infrastructure, the hydrogen combustion engine would have rather good prospects as a clean alternative drive. Subject to the lower overall efficiency however, in the long run the combustion engine would lose out against the fuel cell drive. [90]

[87] Quote taken from Jules Verne in 1874 www.hycar.de hydrogen, 2013, np
[88] LTB Special: alternative drive technologies, 09.2004, p 6
[89] BMW Homepage: BMW Hydrogen, 2013, np See and Gomoll, W.: Hydrogen propulsion ventures into everyday life, into time-online, June 11, 2013, np
[90] www.hycar.de hydrogen, 2013, p o and H_2 YDOGEIT: Knowledge / hydrogen, 2013, after a oS Study work by Sven Geitman, 1998

The principle of the fuel cell has been known for longer than one might expect due to the current intensive research under operation. Sir William Robert Grove (1811-1896) when researching on batteries in 1839, developed the first fuel cell in the world. With this technology, it was possible to convert the energy of a chemical reaction directly into electrical energy without detours for the first time. The basic reaction is identical in all types of fuel cells, the reaction of hydrogen and oxygen to water, in other words the reverse of the water electrolysis reaction. Fuel cells have a much higher efficiency than internal combustion engines and other power converters. This is mainly because the chemical energy of the fuel is converted into electrical power directly. [91] The efficiency of the fuel cell is theoretically 75-80%, the overall system including the reformation of hydrogen is estimated with an efficiency of 40%, which is still well above that of a combustion engine. Whatever source is used, the fuel cell is considered technically as extremely favourable. It also has already managed to demonstrate the potential in many demanding applications, such as aerospace. [92]

The extraordinary potential attributed to hydrogen powered drives, can be established by the creation of the Clean Energy Partnership. The co-operation of twelve leading companies (such as BMW, Daimler, Shell, Statoil, TOTAL, Volkswagen, Vattenfall Europe) will jointly follow the establishment of hydrogen as a fuel of the future. With the help of hydrogen, a sustainable mobility for the future shall be enabled without emissions of greenhouse gases. [93] In the German national investment program (nip) for hydrogen and fuel cell technology the following milestones are determined for hydrogen and the year 2023: [94]

- Fuel cells for electric vehicle propulsion systems and hydrogen infrastructure for a comprehensive, zero-emission mobility, with
  - nationwide, more than 500 public hydrogen filling stations,
  - more than half a million fuel cell cars on the road and
  - 2,000 fuel cell buses in regular service in the use of public transport

- Hydrogen production from renewable energy sources and integration into the energy grid and system as a link between sustainable mobility and energy supply
  - 1,500 MW capacity electrolysers for hydrogen production from renewable sources
  - Definition and implementation of successful business models for power to gas
  - Exploration of hydrogen storage for buffering renewable electricity

- Fuel cells for stationary energy supply by decentralized combined heat and power plants housing and building supply, in the industry and a resilient power supply for public radio transmissions, telecommunications, etc.
  - more than half a million fuel cell heaters in operation
  - more than 1,000 MW of fuel cell CHP plants in operation
  - more than 25,000 secure power supply systems installed

[91] www.hycar.de hydrogen, 2013
[92] H_2 YDOGEIT: Knowledge / hydrogen, 2013, and work according to a study by Sven Geitman, 1998 Mobile Power.Info: Fuel Cells, 2013
[93] CEP Press Release: BMW is more of hydrogen, OJ, p.2
[94] NOW: Hydrogen and Fuel Cell Technology - Key elements of the energy revolution 2.0, 2013, p 5

Like other alternative forms of propulsion however, the hydrogen fuel or hydrogen as the energy and power source poses problems that do not yet allow an ad hoc mass distribution as of today. The main obstacle is the sustainable production of hydrogen. Regenerative methods are being investigated and researched on, but industrial mass production has not yet been established. For the time being, there will remain a focus on hydrogen gas, which is a by-product of e.g. oil production, which leads to an analogy with natural gas. [95] There is thus a dependence on fossil fuels, contradicting a sustainable development. Furthermore, the fuel cell currently is still too expensive. The costs for a respective Hyundai are e.g. estimated at more than € 100,000, which is considered a hindering factor even to very environmental friendly consumers. Studies of the US technology consultancy LUX Research indicate that the assumptions on decreasing prices with increasing production volumes will not impact substantially at least until 2030 (see figure). As the hydrogen production and the costs of the energy losses only contribute with 1/3 of the total system costs, the fuel cell has to become less costly in the long run. And again, there is a parallel to an alternative form of propulsion, the electric drive. [96]

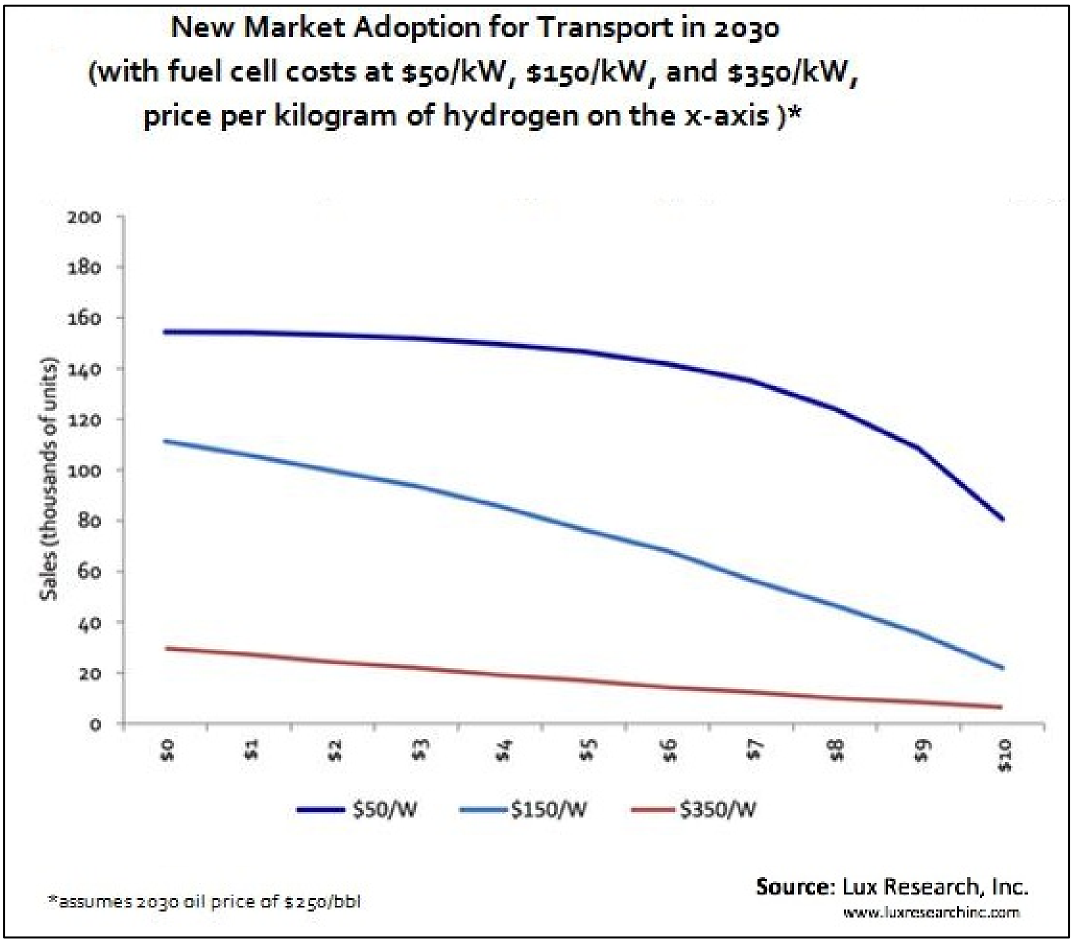

Figure 12: Interaction of sales and cost of the fuel cell
Source: The Time online: study nourishes doubts about the success of the fuel cell, 09.01.2013, p.1

95 greenmotorsblog.de: Hybrid and Fuel Cell Cars - The Future Outlook, 19.07.2013
96 The time online: study nourishes doubts about the success of the fuel cell, 09.01.2013, p.1

Another problem arises with the existing infrastructure. As with the electric and gas-power plans, also hydrogen lacks a systematic refuelling infrastructure. In 2012, in Germany there were only 14 (worldwide 2011: 212) publicly accessible filling stations [97] . This number is to be increased to 50, with the help of a federal initiative (€ 20 million in funding). The factor of uninhibited mobility as critical element towards technology dissemination has been discussed in the first part of this paper. The long existent security question regarding the highly reactionary hydrogen seems addressed after years of research with the delivery of the standard vehicle by Hyundai. Among security aspects, solutions still remain to be rolled-out on respective scale regarding safe storage of hydrogen and hydrogen re-fuelling stations. [98]

But in contrast to other discussed alternative fuels, hydrogen has a number of advantages that according to experts make it the most promising energy source in the area of mobility. The key benefits are listed below:

1. Hydrogen as gaseous fuel can be produced with every conceivable source of energy. Hydrogen from renewable electricity is according to many experts (e.g. Jeremy Rifkin) is a way to an oil-independent future. In other words, a successful industrial-scale use of renewable energy as a hydrogen supplier could help to substitute oil and coal. A technical background for this idea is the ability to store hydrogen in large quantities, e.g. in an existent natural gas grid. As a side effect, the production of hydrogen creates a theoretical basic load capacity set-up for solar power plants and wind farms. In this model unused electric energy produced during the day is in parts converted by means of electrolysis to hydrogen, and converted back to electricity at night or when there are insufficient weather conditions. Although losses in this process may be 50-70% of the original yield, the conversion to hydrogen is an option, at least to utilize excess electricity profitably in parts. [99]

2. Hydrogen (fuel cell) power drives are clearly independent from fossil fuels in any case. For example, unlike with the hybrid drives supporting combustion engines are obsolete, regardless of the current technical solution. Both hydrogen-based combustion engines and fuel cell technology are possible completely free from any fossil help and with almost zero emissions. In addition, while hydrogen is often produced as a by-product in the industry, it can be produced from renewable energy sources only, so that the entire life cycle approach assesses it extremely positive. [100]

3. By the existing technical means to use hydrogen directly, or via a fuel cell for propulsion, hydrogen bears a certain flexibility. If e.g. it remains impossible to cut costs per fuel cell, in the long term, the direct combustion could be an alternative even at a disadvantageous efficiency, bridging to substitute the use of mineral oil.

4. Fuel-based hydrogen power makes electric drive fir for everyday use. Battery-powered electric cars have the disadvantage of technically storing volts. These are too expensive, too heavy and too weak for a longer range. In addition, the battery technology of today's generation has a weakening performance over time.

[97] auto motor sport online: opportunity for future, 2011
[98] Doll, N.: Government plans network of hydrogen filling stations, 2012 online in The World, p 1
[99] The time online: study nourishes doubts about the success of the fuel cell, 09.01.2013, p.1
[100] H_2 YDOGEIT: Knowledge / hydrogen, 2013, np and work according to a study by Sven Geitman, 1998, Mobile Power.Info: Fuel Cells, 2013

Hardly an expert sees the possibility that all these disadvantages could be fundamentally overcome in the foreseeable future. [101] All these disadvantages are (at least ideally) eliminated by the fuel cell. Theoretically the typical cell components neither wear nor age from use, and the actual energy can be re-supplied near endlessly. In a way, the fuel cell corresponds to switchable battery that can be recharged indefinitely. [102]

The charm of the technology is in the long range (300-400 km in the practice test Mercedes B-Class F-Cell) with at the same time little refilling time (about 2 min, comparable to natural gas-powered vehicles). The identity of the automobile - maximum flexibility - could therefore (and with an appropriate infrastructure) be implemented with a fuel cell as with no other electric mobility concept. [103]

5. Directly related to this is the question of the mobility of the future. The electric car is much advertised as optimal urban transport, but is and will probably remain limited to this rather small radius. The hydrogen propulsion, however, has the advantage that an electric drive becomes possible from Amsterdam to Brussels, Aberdeen to Newcastle or Copenhagen to Hamburg. It is questionable, to what extent citizens of the future will adapt their behaviour, whether they will completely switch to small electric cars (e.g. Renault Twizy), public transport and bicycle and a car is only used to cover long distances. But also in this case, there is no more pragmatic solution than the hydrogen drive. [104] An insight into the possible development of the urban mobility can be seen in the following illustration:

Strategic commandments for urban mobility sytems		
Create a sustainable kernel	**Rethink the system**	**Integrate the system**
Invest in a sustainable infrastructure for urban mobility	Gear the political agenda towards a turn to public and sustainable transport systems	Interconnect stakeholders and fabrics of the systems and the citizens

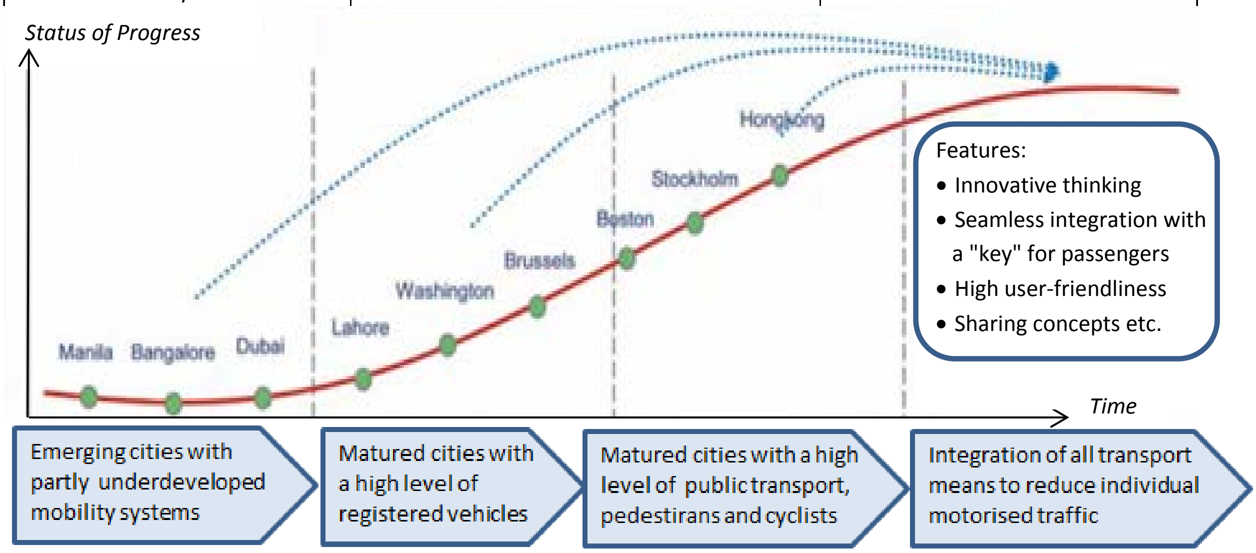

Figure 13: Mobility in Cities
Source: W / Audenhove Van, FJ:., The future of urban mobility PTI March / April 2012, p 15

[101] Doll, N.: Government plans network of hydrogen filling stations, 2012 online in The World, p 1
[102] Mobile Power.Info: Fuel Cells, 2013
[103] Black, M. Ch: Now, the fuel cell must only count online in time, 2012, p 1
[104] Black, M. Ch: Now, the fuel cell must only count online in time, 2012, pp. 1
and Lerner, W / Audenhove Van, FJ:., the future of urban mobility PTI in March / April 2012, p 15

6. If costs are calculated as pure the pure operating costs, then hydrogen fuel is economically viable already today. The Hyundai ix 35 for example refuels for a tank of gas just under 50 €, at a specified range of 594 km, which corresponds to about 8 € per 100 km. The comparable petrol needed at the current price would amount to just under 10 € per 100 km. In this respect the private user could realise an advantage from transition. [105]

Overall, the hydrogen fuel is widely seen as the most sustainable concept. In addition, there are also critical voices, but especially the innovation hurdles stand in the way of the drive concept. As of today, the hydrogen fuel is being slightly left behind and has to be careful not to suffer the fate of some good technical innovation before, namely that a far less favourable solution attained a market position barring the market access. Thus the existing challenges and constraints, such as cost reduction for fuel cells, appropriate infrastructures, use of renewable energy for hydrogen production and supply and a smooth and trouble-free handling of hydrogen as soon as possible is to be addressed by a holistic approach. As the previous elaborations demonstrate, this is only a necessary prerequisite for the diffusion of hydrogen. Following quotation is thus to finalise this chapter:

"In the end, not only the economy is decisive, but also the human will: How do we want to live how do we want to be mobile" [106] Undisputedly hydrogen is one if not the best solution for a flexible mobility while preserving the environment.

[105] Gomoll, W.: Hydrogen propulsion ventures into everyday life, into time-online, June 11, 2013
[106] Black, M. Ch: Now, the fuel cell must only count online in time, 2012, p 2

3. Summary

The above elaborations on the different types of drives and power sources provide certain similarities that can be useful for the design of further sustainable mobility research in the field, and in the field of hydrogen-powered mobility in specific. In principle, the detailing of the chapter allow for two conclusions on factors that have positive as well as negative impact on the regional and global distribution of innovative solutions.

Germany as a region has a broad political will to reduce CO_2 emissions and to influence sustainable mobility, combined with ambitious goals regarding the dissemination of sustainable propulsion. In addition, the car industry recognizes the need for alternative or at least more efficient solutions in mobility, also driving in certain sectors, as the diffusion of some sustainable innovations are especially suited to help securing their own position. From the point of view of a consumer, the steady increase in prices of petroleum-based materials as well as at least on a regional level, increasing environmental awareness are driving forces behind interest in alternative technologies, and partly support growth in individual sectors such as the hybrid one.

Despite favouring factors the proliferation of alternative forms of propulsion in general is still a marginal phenomenon and all the different technologies put together represent only a small part of the total vehicles in use worldwide. This gives rise to the following theses:

- With regard to the theory of diffusion of innovations and the total sum of all vehicles alternative drives are still on the verge of overcoming initial barriers to innovation. Depending on the drive form, these are indeed differing stages, but none of the alternatives has succeeded in a global market penetration just yet.
- The specific developments, cultural conditions and distribution of resources in each region within the global marketplace typically lead to different preferences in the user's choice of a drive. In this context, the question is whether it will be a future alternative drive dominating globally (such as the combustion engine) or whether a technology can only achieve a regional dominance (e.g. USA: hybrid / electric while Europe diesel / biodiesel a.s.o.)
- Almost no alternative form of propulsion is free of technical challenges for the future, thus the need for research is substantial. At the same time, no alternative or future mobility can be reduced only to the technical solution, but rather builds on achieving a holistic concept consisting of a technical solution, security of supply and further factors. An impression of this can be obtained from the following illustration, promoting a strategy for Germany as a driver for sustainable mobility:

Goal 3: Lead supplier Germany, Roadmap AL VII CO2-optimised mobility

Impacting on economy and society	Training and qualification in Hightech jobs Keeping and creating job opportunities Cross-sectoral networking	Valueyield and securing welfare in Germany
Development of products and services	Implementation of the NPE activities programme Materials / technologies for emission treatment Development of alternative fuels	Germany: lead supplier for premium products
Enabling Technologies	Developing new materials, production methods and components Involvement of renewables as energy carriers for mobility Support for the technology transfer	Innovator for climate-friendly mobility
Socio-economic preconditions	Dedicated marketing "Made in Germany" Political and legal framework to foster innovation	Acceptance of technology/products
Today	2015	2020

Figure 14: Mission CO_2-free mobility of the future
Translated from Source: Report of the promoter group mobility: Recommendation for future project - moving sustainability, energy-efficient mobile ", 2012, p.30

The developments above clearly show that the success needs a concept of a holistic process including the interactions that arise from socio-cultural and economic motives. In other words, not the most innovative solution by itself is inevitable, but rather the one that best meets the needs of a specific group of people involved in a specific environment. From this context, theses can be derived, regarding specific barriers to the dissemination of innovative technologies, some of which find themselves below:

- The particular technology must result in a benefit for the user. Often this is an economic benefit or a benefit (like e.g. environmental awareness), that the customer rates higher than a purely economic one. Whenever this advantage loses its effect (e.g. biofuels in Germany) and negative aspects overshadow the perception of the customer (e.g. diesel causes cancer) this results in a negative impact on the spread of technology.
- Obviously there is a correlation between the spread of a technology and the availability of a power substance. Hence the thesis that sustainable mobility is a concept from a technical innovation for the means of locomotion and the corresponding supply concept (sufficient grid). The example of diesel in the USA shows that without ubiquity of supply, there is a slowing effect on dissemination, if not worse. Therefore, unrestricted mobility as the core character and integrated feature of the car is a key supportive or inhibiting factor for the spread of an alternative fuel/power technology.
- In addition to the relatively simple and tangible obstacles partly irrational reasons emerge for rejection or approval of a technology. Issues such as image, security, trust in technology, personal conviction, but also driving fun have an influence on the personal decision of the individual.

In line with the formulated hypotheses and in the context of the currently leading alternative technologies, hydrogen power is at the beginning, and has in certain ways not yet achieved to overcome the technological innovation barrier. Like with other alternative drive concepts different technical solutions are under examination at the moment, and the future knows, which will be the best technical approach respectively will prevail.

General consensus is achieved for the fact that hydrogen has a enormous potential for becoming the future fuel. However, the technology faces a number of challenges that are yet to be addressed. The first production vehicle from Hyundai is to be seen as an important step in the direction of the hydrogen-powered future. Challenges are to reduce costs, to increase the security and to establish a distribution network for hydrogen. Naturally, the technology will then enter into the competition with other drive concepts and it will be crucial to what extent the user a can benefit more from this than from other approaches, be it economically or under other aspects. With regard to research, in parallel to the technological details, according to the described limitations a obstacles, a more holistic research approach would be advantageous. In other words, for the spread of a drive technology of any kind, the technical solution, a concept for supply and a "marketing concept" need to jointly convince the end-user. Ultimately, this user decides whether and to what extent an individual mobility technology can penetrate the market.