Innovative powertrain technologies, electric mobility and alternative fuels for our mobility of tomorrow

Potential – challenges – perspectives

Position paper

Innovative powertrain technologies, electric mobility and alternative fuels for our mobility of tomorrow Potential – challenges – perspectives

Individual mobility and modern freight transport mean well-being, quality of life, freedom, social and cultural inclusion. But our mobility of tomorrow will be more efficient: environment-friendly, resource-lean, quieter, safer, geared to individual mobility needs and seamless logistics. That calls for a holistic mobility concept with a cross-modal approach. Highly efficient, innovative powertrain technologies and alternative fuels will play a central role in this respect.

As Germany's central industry federation, BDI has a responsibility to identify the potential of innovative powertrains and alternative fuels for our mobility of tomorrow – and to help to shape developments. German industry has already achieved great successes for more efficient mobility with its skills at finding solutions. Whether it be cars, utility vehicles, rail, air or modern ships: thanks to research and development, mobility today is essentially more climate and environment-friendly than even just a few years ago. With this technological know-how, German industry can continue to secure its leading position worldwide in developing and shaping innovative powertrain technologies and alternative fuels into the future: for environmentally responsible mobility and for sustainable success on global markets.

In this paper, BDI outlines opportunities and challenges of these technologies for road transport. At the same time, BDI formulates action recommendations for policy-makers in the 17th legislative period of the German parliament. Electric mobility plays a pivotal role in the current debate. For that reason, this paper places a particular focus on electric vehicles, both battery-powered as well as fuel cell-powered vehicles. Electric mobility is an important complement to other innovative powertrain technologies such as highly efficient combustion engines. The introduction of alternative powertrains and fuels will take place progressively. Policy-makers and industry share a responsibility for strengthening Germany's role as the leading supplier of technological innovations in global competition.

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Principles

I. **Our mobility of tomorrow will be marked by a diversification of technological solutions**. For more efficiency, all solutions are important: efficient combustion engines, electric mobility (fuel cells and batteries), hybrid solutions, alternative fuels.

II. **It is a national challenge to be a leader in these technologies of the future**. The aim must be to strengthen cutting-edge technology and production in Germany. The benchmark is international competition, which demands rapid action.

III. **German industry wants to be and can be a leading supplier of electric mobility around the world**. A great strength in Germany is the networking of concerned sectors such as automotive, mechanical engineering, energy supply, chemicals and gases, electrical engineering, information and communication technology and non-ferrous metals.

IV. **Industry and policy-makers must work closely together for research and implementation, applying the principle of technology neutrality**.
Germany needs:

- **strong, technology-neutral promotion of R&D** (continue the "500 Million Euro" programme, include pooled industrial research, link up with European programmes, introduce tax incentives for research, promote the next generation of scientists),
- **rapid implementation** (infrastructure, pilot regions, standardisation, good incentives and framework conditions, strategic raw materials policy, ambitious and realistic expectation management).

V. **German industry offers the German government its support and concrete collaboration**. German industry would like to contribute responsibly to the "National Platform Electric mobility", to help define milestones and measures, to identify research needs also in cooperation with the "Joint Agency Electric mobility", and to work on concrete themes.

Summary

Individual mobility and modern freight transport mean well-being, quality of life, freedom, social and cultural inclusion. But our mobility of tomorrow will be more efficient: environment-friendly, resource-lean, quieter, safer, geared to individual mobility needs and seamless logistics. That calls for a holistic mobility concept with a cross-modal approach. Highly efficient, innovative powertrain technologies and alternative fuels will play a central role in this respect.

Efficiency increases in road transport are possible via a range of technologies. In the short term, the most effective levers for CO_2 and

other greenhouse gas savings are optimisation of existing powertrain technologies and the use of alternative fuels such as natural gas or energy- and CO_2-efficient biofuels. Petroleum-based fuels will continue to be the cornerstone also in the years ahead. Gas-based fuels will increase further, albeit from a low base. Further into the future, renewables will play a more important role in the transport sector. Against the background of competition for use between energy generation and food production, biofuels which make efficient use of arable land will be in demand.

New powertrain technologies will not take the place of efficient combustion engines with proven battery systems in the foreseeable future, but will offer important additional solutions. In the medium to long term, the different variants of electric powertrain (batteries and fuel cells) will constitute a particularly promising option. They make it possible to powertrain locally without emissions. Electric mobility can help to achieve energy and climate policy objectives. To this end, low-emission electricity generation for use in electric vehicles and – if the technological conditions are met – intelligent integration in power grids is decisive. The use of electric vehicles encompasses hybrids, fuel cell cars and exclusively battery-powered vehicles. Other technologies such as vehicles powertrainn directly with hydrogen also represent important options.

With the “National Development Plan Electric mobility”, the “National Organisation Hydrogen and Fuel Cells” and the “500 Million Euro” promotion programme in the framework of the second economic recovery package, the German government has presented important initiatives. BDI supports the German government’s goal of developing Germany into the global market leader for electric mobility. That calls for maximum shared efforts by policy-makers and industry. German companies are leaders in many of the concerned industrial sectors including automotive, mechanical engineering, energy supply, chemicals and gases, electrical engineering, information and communication technology and non-ferrous metals. Industrial cooperation along the entire value creation chain from raw material through to finished vehicle in cross-sectoral, technology-oriented networks is the key to success.

The tasks of industry and policy-makers are clearly defined. Industry delivers innovative technology, concepts and solutions for our efficient mobility of tomorrow. These solutions can only come from industry. Nobody else can provide them. Policy-makers must set the framework conditions in such a way that new ideas can be deployed successfully. This can only be done with a holistic political approach.

What needs to be done? – Strategies and recommendations for the 17th legislative period of the German parliament

Technology-neutral promotion

- Ensure continuation and intensification of support for innovative powertrains, batteries and alternative fuels,
- Apply the principle of technology-neutrality,
- Pursue strong coordination in the German government,
- Encourage pooled industrial research along the value creation chain,
- Rapidly introduce tax incentives for research and development for companies of all sizes also for project promotion and taking appropriate account of sector-specific particularities,
- Give a stronger impetus to promotion of education, research and teaching in the specialist areas of electric mobility,
- At international level, support programmes must be open to international companies for fair competition and against new protectionism.

No new taxes

- In the market introduction phase, electricity and hydrogen for use in vehicles should not be subject to new taxes.

Create incentives and press ahead with infrastructure

- Create the right incentives and framework conditions along the entire value creation chain,
- Renew the five-year vehicle tax exemption for electric vehicles,
- Explore new incentives,
- Long-term subsidies must be ruled out,
- Press ahead with charging, fuelling and communication infrastructures,
- Strengthen realistic expectation management.

Strengthen cooperation

- Establish and bring into operation rapidly the “National Platform Electric mobility” with involvement of all concerned industrial sectors, jointly define milestones and measures,
- Support standardisation, in particular for charging interface and electricity storage units, at national, European and international level,
- Move forward with standardisation and safety certification of batteries,
- Move forward with standardisation, in particular for the charging interface and electricity storage units as a lighthouse project in TEC,

- Generate planning certainty.

Define a conclusive mobility concept

- Sustainable, consistent transport policy for economic growth and efficient environmental protection,
- Invest in excellent transport routes based on need,
- Promote intelligent traffic systems (in particular real-time traffic information, dynamic parking space management, fleet management systems and powertrainr assistance systems, ICT in logistics).

Develop energy and raw materials strategy

- Present a consistent energy concept with a balanced energy mix,
- Pay equal attention to environment-friendliness, security of supply and economic efficiency,
- Overarching vision taking account of all consumers, not only mobility,
- Develop a holistic raw materials concept and ensure functioning raw materials markets,
- Optimisation of existing recycling systems and development of recycling technologies for new battery systems,
- Move forward with research to widen the raw materials base in order to secure the supply of key substances such as lead, lithium, cobalt or nickel and to avoid overdependence.

I. Innovative powertrain technologies, electric mobility and alternative fuels
Many routes – one destination: sustainable mobility

Not one road but many lead to more efficiency. In the short term, the most effective levers for CO_2 and other greenhouse gas savings are optimisation of existing powertrain technologies and technology-neutral use of energy- and CO_2-efficient biofuels. In the case of the combustion engine, Otto and diesel alike, further efficiency improvements of more than 20 % are very ambitious but feasible goals. To improve the efficiency and reduce the CO_2 emissions of combustion engines, further alternative fuels such as natural gas and bio natural gas as well as optimisation of gas combustion engines offer considerable potential. The use of modern lead batteries already makes start-stop operation and recovery of brake energy possible. That means less fuel consumption. While new powertrain technologies will not take the place of efficient, innovative combustion engines in the foreseeable future, they nevertheless constitute important additional solutions. Germany has a special advantage as an industrial nation in that it produces a large proportion of premium vehicles. The introduction of new and complex technologies often starts in premium vehicles. The very cost-intensive research and development work is financed in particular from the profits generated by premium vehicles. The premium strategy, on which every second domestic job with car manufacturers depends, is an important guarantee of success on global markets.

The new dynamic for alternative powertrain technologies and fuels for road transport can be traced to the challenge of climate protection, rapid population growth in many regions of the earth, finite availability of resources and geopolitical imponderables. The tempo of technological developments and their implementation depends on very different factors.

Petroleum-based fuels will continue to be the foundation of mobility in the coming years. The main reasons lie in the extremely high energy density of diesel and petrol, whereby large distances can be covered using a relatively small volume of fuel, and in efficient combustion engine technology. Thanks to progress with clean diesel and the resulting increased market share of diesel, petrol consumption in Germany has decreased by around 30 % over the last ten years whereas diesel consumption has remained stable despite a growing market share. A further advantage lies in the very extensive service station infrastructure and rapid filling possibilities.

Since Otto and diesel engines will continue to be the main powertrain types for the foreseeable future, efficiency increases are right at the top of developers' agendas. In the case of the Otto engine, companies aim at downsizing with supercharging as well as at direct injection. The objective is to run the engine always at the optimal operating point so that consumption by the Otto engine moves closer to the more economical diesel. Clean diesel is being improved not only at the injection phase but also in treatment of exhaust gases. As a result, modern diesel is even cleaner and can at the same time further build up its efficiency advantages.

The role of renewable raw materials for the transport sector is increasing markedly. Biofuels constitute a central pillar of sustainable mobility. They have the advantage of not requiring essentially new engines or a new infrastructure, since they can be added to fossil fuels in a controlled form. Thanks to the fuel mix decree, liquid biofuels are currently already used in around 50 million vehicles in Germany. Addition of biofuels faces some limits imposed by vehicle technology. For instance, biodiesel can only be added to a maximum 7% of the fossil fuel. The product prices of biodiesel are considerable in the case of biodiesel, only slightly above those of fossil fuels in the case of bioethanol (before taxes).

In order to address the issue of competition for use between energy generation and food production in the world regions in question, efforts must focus on the most efficient use of arable land where renewable raw materials are used. This criterion and strict sustainability guidelines should be applied for all biofuels. Irrespective of whether fuels are produced from parts of the plant on the basis of starch, sugar or oil (known as first-generation biofuels) or from energy plants on the basis of cellulose or from plant wastes (known as second-generation biofuels). While bio natural gas and liquid biofuels are already available today with a high level of yield efficiency, second-generation liquid biofuels will only become relevant in volume terms in the second half of the coming decade – probably not least due to high costs.

Gas fuels are growing in importance thanks to their sometimes good combustion characteristics without emissions of fine particles and with low emissions of nitrogen oxides, low carbon content as well as favourable tax treatment and thanks to new combustion engines optimised for these fuels. These fuels will probably further increase their market shares, albeit from a low base (current fleet share < 1 %). Gas fuels include not only natural gas (methane; also referred to as compressed natural gas – CNG) but also what is known as autogas (butane or propane; also referred to as liquefied petroleum gas – LPG). At around 85,000 cars, the fleet of natural gas vehicles is notably smaller than that of LPG vehicles with 306,000 cars, but the number of new registrations is higher than for LPG. Petroleum-based LPG does not contain any renewable components. By contrast, bio natural gas can also be classified as a second-generation biofuel, because the highest efficiency of use is ensured on the arable land where the raw materials are grown, as with first-generation fuels produced in Europe. The quality of the fuel is identical to that of fossil fuel. For that reason, bio natural gas can be added to natural gas in unlimited quantities or even replace it. Given the high octane content of 130, there are additional good possibilities for downsizing engines without losing performance. Natural gas vehicles can already usually more than match the low CO_2 emissions of comparable diesel and petrol models. The third generation of natural gas vehicles now being placed on the market overcomes existing disadvantages in terms of driving dynamics, range and capacity. German manufacturers are technology leaders in the area of CNG. There is considerable potential for vehicles powered with natural gas and bio natural gas in fleets, especially for light and heavy utility vehicles.

In the medium and long term, electric powertrain constitutes a particularly promising option for resource-lean, climate-conscious mobility. Electric powertrain can combine two central objectives of sustainable transport and climate policy: electric vehicles drive locally without emissions. At the same time, the efficiency of electricity networks as well as the use of renewable energies can be improved, in particular if the share of low-carbon electricity generation technologies in the power mix increases. Market introduction of electric vehicles will encompass: hybrids (micro, mild, full and plug-in hybrid electric vehicle – PHEV), range extender electric vehicle (REEV), battery electric vehicle (BEV) and fuel cell vehicles (FCV). Other powertrain technologies such as hydrogen-powered vehicles will in future also be able to make a contribution to climate protection. Similarly, power from low-carbon energy sources should be used for the production of hydrogen.

It is of decisive importance to use the strengths of all innovative powertrain technologies. Only then can market introduction of new technologies succeed. In this regard, customer expectations play a decisive role. For wider ranges of 150 km and more, the strengths of different highly efficient powertrain technologies can be combined. The market potential of battery electric vehicles can be considerably increased through hybrid solutions. Existing battery systems can also be combined with innovative powertrain technologies. For instance, it is possible to place systems using modified components with an intelligent control mechanism on the market relatively quickly. A very promising option for range extension is constituted by electric vehicles with range extender, in which a small combustion engine recharges the battery via a generator. Biofuels could in future also play an important role in this area. For longer ranges, the fuel cell as the supplier of electrical energy offers great potential. What this means is: unlike it is often discussed, there is not a question of selecting a solution and to exclude other technologies (either-or-solutions), but about intelligent solutions that are complementary (as-well-as-solutions). The German government has taken account of this situation by setting up the “National Development Plan Electric mobility” following the “National Innovation Programme Hydrogen and Fuel Cell Technology”.

II. Electric mobility – a powertrain for tomorrow

Mobility on the basis of electricity has long been a reality in rail transport and for trolley buses. And electric powertrain was present also in the early days of the car. In 1901 half of the automobiles in New York had such a powertrain, and only the invention of the spark plug launched the triumphal progress of combustion engines. Enormous progress in battery technology is an important factor for a revival of electric mobility. The prospect of a possible integration of vehicle batteries via intelligent control mechanisms in the power grid also contributes to this debate. Virtually all car manufacturers have developed their own electric vehicle concepts, many with field tests in urban traffic, for instance in Berlin and London. At the same time, fuel cell-powered electric vehicles are moving closer to market maturity for sustainable individual mobility. Electric mobility in road transport is gathering speed. What we need to do now is make a realistic assessment of the potential, promote it – and use it.

1. Potential

Reduce local emissions to zero

At local level, electric vehicles are zero-emission vehicles. There are no transport-generated CO_2 or NO_x emissions locally. Traffic noise can also be perceptibly reduced. For this reason, electric mobility can make a considerable contribution for sustainable mobility, especially in urban areas and cities. By contrast, the global climate performance of electric vehicles depends crucially on the type of electricity and/or hydrogen generation.

A reduction of traffic noise is an important objective. Nevertheless, road surface and tyre noise dominate from speeds of as low as 40 or 50 km/h. An absence of noise emissions can also pose a danger for other road users at low speeds and especially in urban surroundings, in particular for children, older people, cyclists and visually impaired people. Industry is aware of these issues and is working on solutions.

Move energy efficiency and climate protection forward, make better use of renewable energies

Electric vehicles are usually more energy-efficient than vehicles with combustion engines. In this way, they help to consume less primary energy. And they make an important contribution to improving climate protection. In parallel, the aim is to have a low-carbon electricity mix. If it proves possible to coordinate charging with the grid load, electric vehicles can help to make better use of the supply from fluctuating energy sources. At a later stage, batteries can also be used to feed electricity back into the grid when the price of base load or equalising load is particularly high – and if it proves possible to configure the next generation of lithium-ion batteries that this form of operation does not have any significant impact on the service life. In this regard, there is still great development potential also for the lead battery which has been used in electric vehicles for decades. In addition, stationary storage systems can have an important function.

Meet customer expectations

Electric mobility encompasses a wide range of technical solutions which are relevant for the expectations of both passenger transport and freight transport. Battery-powertrainn electric vehicles will be available for the foreseeable future above all as small cars up to the compact class. The focus for use of battery-only electric vehicles is short and medium-distance trips, e.g. in urban areas and for commuting or for distribution. 70% of all car trips in Germany are less than 17 km. For long-distance travel and for particular comfort demands in large vehicles, PHEV, REEV or FCV offer the appropriate concept. Customer comfort expectations such as air conditioning and heating also call for special efforts.

Alongside the technical challenges, in the case of batteries it is important to take account of customer expectations regarding battery charging time and availability convenience. Charging a battery-only electric vehicle takes markedly longer than filling a diesel, petrol or gas vehicle – generally still several hours. At the present time, two minutes of charging an electric vehicle will power a one-kilometre trip, by contrast several minutes filling a modern diesel car is good for around 1,000 km. In the case of FCVs, ranges of around 400 km can already be achieved against a filling tile of three minutes. The future will be marked by a stronger differentiation of vehicle concepts into different use patterns.

The current practical use of electric vehicles attracts high customer interest. At the same time, many customers have euphoric expectations concerning market penetration and costs. Many press releases give the impression that serial production by the million could start as early as tomorrow. It is important to provide information on the strengths of this technology – and at the same time point out that its widespread application is conditional on a large measure of further research and trials, e.g. on the powertrain, secondary aggregates and comfort functions. For that reason, it will probably take about ten years before electric vehicles achieve a significantly large market share.

Secure the market of the future

Consultancy McKinsey estimates the global market volume for energy-efficient cars in 2020 at up to 500 billion euro. The goal of German industry must be to win a large share of the global market based on a leading technological performance. Hence, it is also essential to secure value creation in Germany and in Europe. Many technologies for electric powertrains, energy storage systems, network infrastructure and filling technologies have been developed on paper. Hybrid and electric vehicles with adequate ranges for urban travel or distribution traffic could reach market maturity in a few years. For instance, vehicle fleet operators in the fields of public transport, public and private waste management but also postal, courier, express and parcels service providers and even airports generally have large fleets and/or depots, and have sufficient knowledge of the usage profiles of their fleets. This could facilitate the optimal charging of batteries. And it could provide further knowledge about possibilities for network integration and future bidirectional charging processes. The vehicle fleets of municipal, provincial and federal ministries and authorities as well as car-sharing operators could also serve as pioneers. Experiences could also be used to configure the hydrogen infrastructure for FCV optimally and at an early stage.

German companies are among the most innovative suppliers of these technologies of the future. New patents are registered every day. For the export-oriented German automotive industry, ambitious climate protection targets are simultaneously a challenge and an opportunity. A functioning domestic market for electric mobility is very important as a proof of competence. At the same time, the German market with around three million new car registrations a year is too small for pivotal decisions on direction – global developments are determinant in this regard.

There are also major opportunities for Germany in the area of battery production. In order to be able to seize these opportunities, great efforts are necessary. According to forecasts, the market for lithium-ion battery materials will increase from around 1.4 billion euro now to 4 billion euro by 2015. The market for batteries in the current decade could increase to more than 10 million euro. The value creation share of the battery is currently up to 40% of the electric vehicle. Above all China, Japan and Korea are presently leading production centres for lithium-ion batteries. Yet batteries for electric vehicles will have to meet other requirements than in the consumer electronics area – that is why the race for best solutions is completely open. German companies have already established new alliances. Available home-made battery systems are a key issue for Germany and Europe. Germany is a leader in the further development of the lead battery, which for decades has been playing a central role for safe, affordable mobility with environment-friendly, highly effective recycling and resource efficiency. The manufacture of fuel cells also offers industry new opportunities for high market shares and automotive value creation in Germany. Leading vehicle manufacturers have declared that they will be able to produce FCVs in hundreds of thousands from 2015.

2. Challenges and solutions

Optimise energy storage systems

The mobile performance of battery-powered vehicles depends decisively on their energy storage systems. As things currently stand, battery systems based on lithium ions are suitable for energy storage. They are relatively light and do not take up too much room. But the energy content of a modern battery as a function of volume and weight is still smaller by a factor of fifty than that of modern fuels. Efficient, safe and affordable battery systems are therefore necessary. Lithium-ion or nickel-metal hybrid (NiMH) batteries are available as drive batteries for hybrid and electric road vehicles. However, they cannot act as a substitute for lead batteries (on-board supply batteries) for technical reasons. Similarly, fuel cells in combination with electric engines will not take the place of the lead battery and its functions for safety and control.

The issue of safety in hybrid and fully electric vehicles will require considerable attention in the near future. The safety of battery cells plays a particularly important role in this respect. In this area it is important to define certification procedures which will have to be implemented before serial introduction.

The range of battery-powered electric vehicles is defined by physical and economic framework conditions. For instance, the range of a small car under everyday conditions will probably be around 150 km in 2015 (around 200 in 2020). For use in the vehicle, lithium-ion cells have to be switched into complex battery systems, monitored and temperature-stabilised. Also with regard to the development cycles of batteries, the progress that will be made with the most important component magnitudes by 2020 cannot be predicted today. The additional cost of an electric vehicle is linked essentially to the costs of the battery system and its integration in the vehicle. Hence, battery costs of around 15,000 euro can be expected in 2015 for an electric vehicle in the compact class. These costs must be drastically reduced by 2020, so that competitive electric vehicles can be placed on the market. For a clear cost reduction, highly automated mechanical engineering procedures for long production runs are of decisive importance. The basis for this is early standardisation, including of preliminary products and semi-finished products.

The questions of where batteries are made, whether German and European manufacturers have access to suppliers' data and where batteries are recycled will play an important role for strengthening the secondary raw materials base. Also in the case of fuel cell vehicles, the performance of energy storage systems has a high relevance. The current pre-series vehicles are run with 350bar or 700bar compressed hydrogen storage units, which means that distance ranges of at least 400 km can already be achieved. It seems as if distance ranges between 40 and 500 km will be sufficient for the first commercialisation of FCVs.

Building a charging and service station infrastructure

The focus of the electricity sector's work is on defining the standardisation needs as rapidly as possible. Examples of this include the charging and service station infrastructure but also communication, control and payment procedures in the framework of the liberalised electricity market. Network-related aspects should also be taken into account in this work, e.g. potential overloads on running parts, local needs control (smart grid), network feedback caused by the converter, behaviour in the event of errors.

Example of charging stations: depending on the charging point (private or at charging stations in the commercial or public arena), different charging tempos will be possible. Charging stations in the public arena must also allow the payment procedure alongside information about the charging status of the battery. In addition to these functions, the charging stations must offer simple and secure authentication. By analogy with roaming in mobile phone networks, consumers must be given access to charging stations of operators with which they have no contractual relationship. Electricity distributors, test point operators, network operators or further private investors will be eligible to be operators of charging stations.

For the establishment of a tank-filling infrastructure for FCVs, a consortium comprising seven industrial enterprises (Daimler, EnBW, Linde, OMV, Shell, Total and Vattenfall) booked an important success in September 2009. With the “H2 Mobility” initiative, the partners have stated their intent of working for a first comprehensive hydrogen infrastructure by 2015. This construction is supported by the German government through the “National Organisation Hydrogen and Fuel Cell Technology” (NOW GmbH). For comprehensive provisioning in Germany, it is calculated that around 1,000 hydrogen tank-filling points will be sufficient. Appropriate provisioning in other EU countries is also important for the everyday viability of FCVs.

Improve vehicle and production techniques

In the short term, existing vehicle concepts for electric powertrain will be modified. In the medium to long term, new concepts for vehicles, powertrains, components and construction materials are necessary. Energy storage systems, electric powertrain and electronic control systems as well as the necessary lightweight construction, secondary aggregates and comfort functions, optimisation of engines, integration of powertrain in the system, gears, performance electronics and cooling – all of this calls for a high effort in research and development also in the long term. An example: without weight savings in the frame and in further components, the efficiency gains of electric engines would be neutralised by the high battery weight. Requirements on new materials and their development must therefore be taken into account from the outset and anchored in the promotion and development programmes. The production technology for large series production of components which are not typical for cars today poses major challenges for industry. Successful solutions can only be realised on a cross-sectoral basis along the entire value creation chain.

All in all, a constantly optimised mix of different powertrain and battery technologies is to be expected, which will lead to a considerable CO_2 reduction. The juxtaposition of electric engine and diesel or Otto engine, of battery-, fuel cell- or hydrogen-powered vehicles, of lead battery and lithium or NiMH battery will allow best solutions for a long period.

Shape mobility in a climate-friendly way and enable network integration

An essential advantage of an electric powertrain lies in high energy efficiency and the associated small consumption of primary energy. Even if the entire preliminary chain of power generation and the current energy mix in Germany are taken into account, the CO_2 emissions of an electric vehicle as compared with a vehicle with combustion engine and the same performance is often lower. With an increasing share of low-carbon energy sources also including renewable energies in power generation, electric mobility can clearly improve the global CO_2 performance of transport in the longer term.

From the angle of the energy sector, the introduction of electric mobility will gain acceptance first and foremost if vehicle models and the network connection is economic, electricity prices per kilometre remain attractive in comparison with fuel prices and the additional electricity demand is secured.

At the same time, a new sales segment is created for the electricity supplier, a segment that increases sales of electricity in the transport sector in addition to transport powered by overhead electricity lines, in particular in situations with low load (night charging). Hence, electric mobility can also help to improve the economic performance of existing and newly planned power stations by increasing capacity use.

In order to calculate costs per kilometre from the many aspects such as power consumption, battery costs, additional costs for vehicle investment, infrastructure costs, power costs as a function of the load situation, etc., detailed model calculations would have to be carried out with sometimes still unknown cost components. Authoritative studies are not yet available. However, the construction of such a cost model seems essential for a quantification of the future costs of an electric car pathway. These questions should therefore be answered in the framework of the model regions that were established in the wake of the German government’s second recovery package. Studies for the area of hydrogen infrastructure are being and already have been drawn up at national and international level (“HyWays”, “GermanHy”, “H2 mobility”).

The vehicle battery should if at all possible be charged in a controlled way from the network (intelligent charging management), in order to avoid peak loads for electricity networks. To this end, intensive preparations for the necessary communication, control and payment are already under way, so as to minimise a need for extending the distribution network (in particular in low voltage) and the generation equipment. Nevertheless, electricity installations in buildings need to be modified to take account of the expected new energy volumes needed for electric vehicles. Depending on the capacity or the electrical work which has to be made available, especially in the case of a rapid charging procedure, this energy transport has considerable effects on the mains electricity supply system in existing buildings.

At a later point in time, the battery can also be used for feedback into the network, when the price of base load or equalising load is particularly high and the next generation of lithium-ion batteries has a high level of cycle stability, i.e. is configured in such a way that this form of operation will have only a small impact on the service life. The service life of a battery should be oriented on the service life of a car. Ultimately, the charging process must take place under the control of and in line with the needs of the car driver. Until that is the case, many technical questions must be answered. Neither the battery nor the power network may be compromised. Once these problems have been solved – preliminary work on this has already started – this will improve the integration of renewable energies in the electricity supply system. In the long term, vehicle batteries could possibly be available as bidirectional energy storage systems, for instance to smooth fluctuations in wind energy. By plugging vehicles into electricity networks, the base load capacity of renewable energies can be strengthened. Electric mobility can offer the energy sector important advantages which should also be to the financial benefit of the customer.

With the growing share of renewable electricity generation, the need for long-term energy storage is increasing. In addition to the classical pump storage works, hydrogen production through electrolysis will in future become an option. Whereas vehicle batteries could be plugged directly into the electricity network, hydrogen production via electrolysis should allow a growing demand for base load electricity and hence a link between energy storage and fuel production in the medium term.

ICT for electric mobility

Intelligent linking of electric vehicles and electricity networks calls for highly modern information and communication technologies (ICT). The German government therefore supports the establishment of cross-sectoral ICT solutions in the framework of the “ICT for Electric mobility” promotion programme. It ties in directly with German Ministry of Economy and Technology’s “E-Energy” model regions of technology competition. The focus here is constituted above all by ICT-based charging, control and payment infrastructures, universal data transmission systems, efficient processes as well as intelligent control systems. Extensive services have to be developed to enable a flexible, situation-related choice of electricity supplier and of the desired energy mix. These services are becoming more complex if public parking areas and service stations are used for the charging procedure alongside electricity connections at home. Furthermore, the charging behaviour of users must be further examined. It is conceivable that in addition to reducing peak loads by using vehicle batteries for storage, higher loads can also occur locally as a result of a greater concentration of vehicles (e.g. in shopping centres on Saturdays). This could make a capacity adjustment of electricity distribution networks necessary.

In addition, a large number of intelligent added value services should be used to push the dissemination of electric vehicles. When a charging infrastructure is being established, broadband connection techniques (e.g. Powerline, WLAN and/or VDSL) should therefore be built up to allow simple data exchange with the vehicles during the battery charging procedure. Via this Internet connection, environmental information and map data can be updated or "bonus miles" can be credited or spent. Alongside up-to-date, local traffic data and advice for link-up possibilities with public transport, information about available parking spaces with battery charging stations and payment information, these added value services can however also go far beyond a direct link with electric mobility. For instance, the loaded content can comprise digital radio programmes, news or videos for rear-seat monitors. At the same time, there could be an opportunity to make greater use of intelligent ICT solutions for transport, in particular car-to-x vehicle communication. By way of example, users of FCVs could also benefit from this, to which information about the nearest hydrogen filling possibility could be made available.

Electric mobility, especially battery-powered electric mobility, calls for the flexible exchange of customer data via a communication network which has to meet the highest data protection requirements. Building a separate and comprehensive charging infrastructure for electric mobility therefore offers a great opportunity to put in place a low-cost, publicly accessible broadband communication network at the same time. In addition to providing the necessary services as well as attractive add-on services for users of electric vehicles, this network should also be available for all other traffic participants. After all, this will extract the maximum added value from the investment – and achieve the most rapid cost amortisation.

Diversify import risks

The goal is to reduce dependence on oil-producing countries in politically unstable regions through electric mobility. As long as vehicles with an Otto engine are substituted as typical short-distance and urban vehicles, the contribution of electric mobility to import independence would still be limited. For technical reasons, the refining process produces particular volumes of petrol and diesel. Whereas the fall in demand for petrol leads to surpluses, the growing demand for diesel exceeds European production capacity. As a consequence, the demand for diesel determines capacity utilisation in refineries and hence the volume of oil imports. Import independence would be reduced only if there was a marked substitution of diesel. Typical diesel profiles, long-distance and HGV freight transport, are not a field for application of electric mobility for the time being.

Simultaneously, the demand for raw materials will increase. An essential driver will be the growing demand for lithium-ion batteries, which are used in both hybrid vehicles and fuel cell vehicles as well as in electric-only vehicles. Lithium-ion batteries contain various raw materials, in particular metals. For instance, they use: as anode material, a mixed oxide and phosphate of lithium with nickel, manganese, iron and cobalt; as cathode material, mainly graphite but also silicon, as well as oxide of lithium, titanium and tin; as electrode substrate, also copper and aluminium. In combination with the increasing demand for lithium-ion batteries, a particularly sharp increase in demand for cobalt is expected. Many experts assume that cobalt will prevail over phosphate and manganese in for electrodes in lithium systems. The global demand for the raw material cobalt could increase by a factor of 3.4 by 2030 as compared with 2006 due to demand for lithium-ion batteries. The resulting bottlenecks in the availability of cobalt can only be avoided if global mining capacities are expanded in good time and to a sufficient extent.

As also with other primary materials, Germany is 100% dependent on cobalt imports from abroad. Nevertheless, German industry already covers around 20% of its cobalt needs by recycling cobalt scrap. The recycling rate can be further increased in close cooperation between battery manufacturers and the non-ferrous metal industry. In the case of lead, for example, dependence on imports is lower thanks to almost 100% return of used batteries in efficient recycling systems. Associated developments to systems, processes and installations offer considerable potential for German mechanical engineering. At the same time, however, strategic dependence on mining countries such as Australia, Canada and the United States but also the Democratic Republic of Congo and Zambia could increase. Due to the high concentration of cobalt reserves in unstable countries such as DR Congo and Zambia, further research into manganese and iron phosphate electrodes and also into nickel electrodes which contain no cobalt or only small amounts of cobalt is highly advisable.

Irrespective of the raw material for the electrodes of lithium-ion batteries, the demand for lithium will also increase strongly. Unlike for cobalt, no deterioration of availability is expected for lithium. Yet global lithium reserves are even more strongly concentrated in certain regions. Hence, there is a danger here, too, of strategic dependences. The countries in question are the less unstable countries of South America – namely Argentina, Bolivia and Chile. Even so, the concentration of businesses in mining is already classified as “moderately critical”. A very long procedure is needed to expand production. There is a danger that the supplier companies already in the market will achieve a position of market dominance. Economic recycling processes could work against a possible price increase for lithium.

In addition to lithium and cobalt, the demand for further metals will also increase as a result of growing demand for and production of hybrid and fuel-cell vehicles, in particular for aluminium, copper and the rare-earth metal neodymium. For the electric engines of vehicles, essentially more copper is needed, between 15 and 30 kg per unit. Neodymium is used in particular for magnets in electric engines of hybrid and electric vehicles.

For neodymium, a particularly sharp increase in demand is expected, because the metal is also used in other technologies of the future. Experts calculate that demand will increase more than threefold. This is particularly critical due to the high concentration of mining for the metal – as also for other rare-earth metals – with over 95% coming from the People’s Republic of China. Raw materials exports from the People’s Republic are considerably restricted, especially for exports of metals.

Given high dependence on metal imports as well as existing tariff and non-tariff barriers to trade in raw materials, German and European policy-makers must urgently work for better functioning of raw materials markets. A strengthening of domestic recycling competences must also receive close attention. This should be complemented by support for technology-neutral research into alternative substance systems. In this regard, chemicals research and nanotechnology offer promising possibilities.

3. Political situation

Germany

In the December 2007 "Integrated Energy and Climate Programme", the then German government enshrined the issue of electric mobility. In the national strategy conference organised on 25-26 November 2008 by the Federal Ministries for Transport, Construction and Urban Development (BMVBS), for Economy and Technology (BMWi), for Environment, Nature Conservation and Nuclear Safety (BMU) and for Education and Research (BMBF), the German government set out priorities for a "National Development Plan Electric mobility".

On 19 August 2009, the federal cabinet adopted the "National Development Plan Electric mobility". With the development plan, close cooperation between policy-makers, industry and the scientific community is outlined, and enhanced support through promotion projects, market incentive systems and appropriate regulatory framework conditions in the years ahead and beyond is described. The sectors concerned are expected to move ahead with market preparation and introduction of battery-powered vehicles. The "National Development Plan" identifies the following objectives:

- Germany should become "lead market for electric mobility".
- Electric mobility should make a considerable contribution to achieving climate protection goals ("away from oil" strategy).
- The energy needs of electric cars should be linked to the use of renewable energies and hence strengthen the German government's energy policy objectives.
- By 2020, at least one million electric vehicles (as defined in the "National Development Plan") should be on Germany's roads.
- By 2030, this figure should be five million vehicles. In the long term, transport in towns should happen overwhelmingly without fossil fuels.

The "National Development Plan Electric mobility" incorporates existing research programmes for alternative powertrains and fuels, including:

- 5th energy research programme "Innovation and New Energy Technologies", BMWi, around 2.2 billion euro for promotion of research and development of modern energy technologies in the framework of energy research in the years 2008 to 2011, inter alia for R&D on transport.
- Electricity storage promotion concept, BMWi, 2009 to 2012, 35 million euro.
- 3rd transport research programme "Mobility and Transport Technologies", BMWi, 2008 to 2011, around 300 million euro, until 2010 around 35 million euro for research in the area of powertrain technologies.
- "National Innovation Programme Hydrogen and Fuel Cell Technology" (NIP), BMVBS, in the framework of NIP, an

additional 500 million euro from the federal level and at least 500 million euro from industry, 2007 to 2016; altogether, as a continuation of current federal R&D promotion for fuel cells and – taking account of complementary resources from industry and users – up to 1.4 billion euro is available in the period 2007 to 2016.

- Innovation alliance "Lithium-Ion Battery – LIB 2015", BMBF, 2008 to 2015, 60 million euro from the federal level, 360 million euro from industry, and further BMBF alliance projects (LISA: 1.7 million euro, REALIBATT: 2.1 million euro, LIHEBE: 2.2 million euro).
- "E-Energy": ICT-based energy system of the future, BMWi and BMU, 2008 to 2012, 60 million euro from the federal level and 80 million euro from industry.

Furthermore, as part of the second recovery package, 500 million euro is available until 2011 for applications-oriented research in the area of mobility. The resources are shared among the in-house programmes of BMVBS, BMWi, BMU and BMBF. A small share of the resources also flows into promotion projects under the aegis of the Federal Ministry for Food, Agriculture and Consumer Protection (BMELV). The projects place the research priorities on components (in particular batteries), vehicles, electricity and infrastructures as well as on the interaction between these factors in practice in the framework of the eight model regions. In this way, they partly complement existing promotion priorities of the various ministries or explore new approaches in greater depth.

At the cabinet gathering on 17-18 November 2009 in Schloss Meseberg, the German government confirmed the objective of developing Germany into a lead market for electric mobility and its wish to flank a rapid market introduction of high-performance electric vehicles. What is needed is coordinated and targeted action by all interested parties. For that reason, the different economic sectors should be more strongly engaged. Policy-makers and industry should work together closely. In early May 2010 the most important players should be invited to a summit with the German chancellor. That should give the starting signal for the "National Platform Electric mobility". In this way, exchanges between policy-makers and all relevant industries as well as scientists, municipalities and consumers should be ensured.

Policy-makers recently put in place new framework conditions with decisions on the composition of the fuel pool. On the fuel side, the current mix, measured as a function of total fuel sales, will be replaced from 2015 by a CO_2 reduction target as compared with fossil fuels from 3% rising to 7% in 2020. In this exercise, bio natural gas was included in considerations on meeting quotas for the first time. As a result, framework conditions have been shaped in a technology-neutral way and the conditions for competition in manufacturing processes are created with the lowest possible CO_2 avoidance costs. Sustainability, technology-neutrality and cost-efficiency must continue to be the cornerstones of a responsible biofuel policy also in the future.

International comparison

Numerous leading industrial nations have strengthened their efforts to accelerate research and development as well as market development through promotion programmes and purchase incentives. France offers purchase grants of up to 5.000 euro on the basis of a points system if the vehicle emits less than 60g CO_2/km. In addition, in autumn 2009 France established a strategy for development of the infrastructures for hybrid and electric vehicles and in this way wants to support the purchase of a probable 100.000 electric vehicles by 2015. The French state is financially involved in the construction of production capacities. Great Britain wants to promote research and development of subcomponents for electric and hybrid vehicles as well as offer purchase grants (from 2011, between 2.000 and 5.000 pounds sterling, a total of 230 million pounds sterling) and adopt a car tax. Further European countries offer purchase grants (Spain 2.000 to 6.000 euro, Italy 3.500 euro, Portugal 5.000 for the first 5.000 vehicles and tax concessions) and/or tax incentives (Denmark adoption of a purchase tax at the level of 105 to 180%, Ireland purchase tax reduction of 2.500 euro until the end of 2010, Greece adoption of purchase and car tax).

As part of the November 2008 recovery package, the European Union has started the “Green Cars” initiative. Around 5 billion euro has been earmarked for promotion of various research fields, of which some 4 billion euro of European Investment Bank credits as well as R&D funds in the framework of the European Commission’s 7th research framework programme at the level of 500 million euro flanked by 500 million euro from industry or from Member States.

Japan has presented a five-year programme for traction batteries for an amount of 200 million US dollars, is promoting “environment-friendly vehicles” for a year until March 2010 via a scrappage grant of up to around 2.000 euro, and offers further tax incentives (weight and purchase tax) for the purchase of hybrid and electric cars at varying levels. The USA offers a tax credit of 2.500 to 7.500 US dollars (depending on battery capacity) on purchase of an electric car. The US recovery package ARRA (American Recovery and Reinvestment Act) provides subsidies of 2.4 billion US dollars for the production and development of US batteries and electric vehicles. A large part of the funds (1.5 billion US dollars) will go to companies based in the USA in order to subsidise the production of batteries as well as their components, and to expand recycling capacities. US R&D promotion for energy technologies (including electric mobility) is expected to be a total of 150 billion US dollars over the next ten years. China is promoting technological innovations for more efficient powertrain technologies with around 1 billion euro, and the practical use of around 10.000 vehicles in 13 pilot regions with around 2 billion euro between 2009 and 2011. In this framework, public service organisations and local public transport undertakings receive purchase grants for cars and light utility vehicles of up to around 6.700 euro as a function of the share of electric powertrain and petrol saving quotient.

These far-reaching promotion programmes of other nations pose major challenges for German industry. This is all the more reason for policy-makers to champion fair competition conditions at the European and international level. Promotion mechanisms for a technology or sector should not be limited to national undertakings, but must equally be open to international companies. Otherwise new market barriers and competition distortions will be created, which will intensify the crisis and place a massive brake on technology development and dissemination. There must be no new protectionism on the pretext of environmental protection, technology promotion and combating the crisis.

III. Strategies and recommendations for the 17th legislative period

Technology-neutral promotion

Competition between locations today means competition for innovation. For that reason, promotion of research and development is decisive for the future of our country. Electric vehicles can make an important contribution to our future sustainable mobility. Yet nobody can see today in what direction research and development for new vehicle concepts will move. German industry therefore calls for policy-makers to adopt a technology-neutral approach which leaves room for competition and diversification of technological solutions. Policy-makers must set legal framework conditions in such a way that no option is automatically ruled out. State support must concentrate on the promotion of broad research approaches. Moving forward with a diversity of technological solutions means a new challenge for R&D in companies.

For instance, there is a considerable need for research into battery technology and network integration for electric vehicles. Mass production of battery cells must meet very high quality standards in relation to function and stability. There is also a large need for research for mass production of fuel-cell systems as well as sustainably produced and competitive hydrogen, storage technology for pressurised gases and the establishment of distribution infrastructures for gas fuels (hydrogen, methane), production of energy- and CO_2 efficient biofuels as well as the areas of work materials and lightweight construction materials. In order to secure value creation and jobs in Germany, the efficiency of the entire production system is decisive. Production research must therefore be intensified over the entire value creation chain and also including recycling technologies. This should also encompass requirements for new construction materials.

The German government should ensure strong coordination in the “500 Million Euro” promotion programme (in the framework of the second recovery package “Application-oriented Research in the Mobility Area”).

Strong international competition in particular means that an ongoing continuation and intensification of promotion over the entire value creation chain in close cooperation with industry is decisive.

The involvement of innovative medium-sized industrial enterprises ideally takes place via the established networks of industry and research. Good beacons for this are the globally leading innovation networks of pooled industrial research, as found for instance in the research associations “Powertrain Technology” and “Combustion Power Equipment”. These networks bring together experts from industry and mechanical engineering know-how, the automotive industry and the relevant supplier sectors such as electrical engineering and process control systems.

Almost all large industrial countries promote research and development via tax provisions. For that reason, the German government should rapidly introduce tax support for research and development for companies of all sizes in addition to project promotion and taking appropriate account of sectors-specific particularities. This is decisive, in order to strengthen Germany's position as an innovative location for business. Furthermore, national activities should be closely interlinked with programmes of the European Commission and member states (e.g. EU "Green Cars" initiative).

Also important is a stronger impetus for promotion of education, research and teaching, in particular in the specialist areas of electric mobility. Here, too, the innovation networks of pooled industrial research offer ideal link-ups. The next generation of scientists benefits strongly from such broadly based, organisationally clear innovation promotion since it gives the possibility for industrial and practical research. With an average of one doctoral thesis and four study or diploma papers per project, pooled research achieves education excellence for engineers. The research associations already mentioned on their own account for around 200 ongoing projects at Germany's best universities. The fascination of STEM disciplines in particular should be better communicated starting at school.

At international level, policy-makers should work for fair competition. Promotion measures should not be limited to national undertakings. New protectionism places a brake on new technologies.

No new taxes

In the market introduction phase, electricity and hydrogen for use in vehicles should not suffer additional taxation. Policy goals such as increased use of renewable energies should not be pursued to the detriment of vehicle manufacturers and customers. There are already high taxes and levies on electricity.

Time-controlled charging as a whole is well covered by the "Electricity Network Fees" decree. Something similar should be implemented for the natural gas network. In the medium term, it is important to ensure that the use of equalising energy from vehicle batteries does not suffer network utilisation fees.

Create incentives and press ahead with infrastructures

Policy-makers should concentrate on pre-competitive support of research and development as well as on the infrastructure. Market introduction of alternative powertrains and fuels can be supported by policy-makers through the correct framework conditions and sensible incentives. In particular, regulatory adjustments which benefit users can offer effective incentives for market introduction. With electric mobility, new utilisation and business models will probably be developed. It should therefore be verified at regular intervals whether measures such as the introduction of interchangeable number plates for first and second vehicles on the Swiss model can strengthen new forms of mobility. Continuation of the five-year car tax exemption for electric vehicles can be an important incentive in the early phase of a market introduction. Further possible incentives should be examined when the time is ripe and also against the background of an international comparison, possible distortions of competition and the objective of technology-neutral promotion. There should be no permanent subsidies.

The German government should support the construction of a charging infrastructure for battery-powered electric vehicles and establishment of a provisioning infrastructure for hydrogen through appropriate framework conditions. With the construction of a charging infrastructure, a communication network should be created at the same time via which the necessary payment data can be exchanged across borders and added value services can be accessed. Successful market introduction involves successful expectation management: ambitious and realistic. Policy-makers also have a responsibility here.

Strengthen cooperation

Targeted promotion of innovative powertrains and fuels requires a closely coordinated approach by policy-makers at European, national, provincial and municipal level, and cooperation with the relevant sectors of German industry and their federations (car manufacturers, suppliers, mechanical engineering, battery producers, energy providers, ICT service providers, chemicals and gas industry, system providers, electrical engineering, non-ferrous metal producers). A successful example of this is that “H_2 Mobility” memorandum of understanding signed by industry, policy-makers and federations and which sets out to enable the construction of a hydrogen infrastructure for the wide commercialisation of FCVs in 2015.

The German government would like to give further concrete form to the “National Development Plan Electric mobility” through objectives and measures, with involvement of all players from industry, academia and politics. German industry welcome the summit that the German government plans for May 2010, and will actively flank and support the “National Platform Electric mobility” as well as the planned close cooperation at expert level. A coordinated approach by policy-makers and industry is important to create the overall system of electric mobility. In this regard, unnecessary red tape and reporting obligations should be avoided. With the clear support for electric mobility of two ministries (BMVBS, BMWi) and the establishment of the German government’s “Joint Agency Electric mobility” (GGEMO) on 1 February 2010, the German government has already responded to industry’s concern for pooled competences.

At national, European and international level, cooperation for standardisation is decisive. Of particular importance for the development of battery-powered electric cars is coordinating and flanking support of the necessary standardisation exercises at interfaces, e.g. in charging infrastructures, information-related process descriptions and data formats for battery charging procedures in the liberalised electricity market. Practical, affordable and where necessary also innovative payment procedures should be the aim. Alternative charging technologies such as inductive transmission or alternating battery systems still require a considerable degree of coordination and standardisation. Electrical engineering federations are well placed for standardisation of plugs. A considerable need for standardisation can still be observed in the area of storage technology. The organisation of large series production at optimal cost will only be possible once the diversity of variants among preliminary products and semi-finished products has been limited. Attention should be paid to compatibility with existing systems.

For the use of battery-powered vehicles, a safety certificate covering the cells and batteries used is a precondition for safe operation. The safety of the battery is indispensable for market success.

German industry campaigns for joint standardisation for electric mobility to be defined as a beacon project for transatlantic economic integration in the TEC (Transatlantic Economic Council).

The German government should develop a long-term perspective for sustainable mobility in order to create planning certainty for industry. With a view to battery-powered electric mobility, the “National Development Plan” offers a good basis for this. Offensive political deployment is necessary, coordinated between the sectors and various authorities, for solutions that are compatible with the German electricity market: in the EU, with the regulatory authorities of EU countries, and providing support in international standardisation.

Define conclusive concepts for mobility, energy and raw materials supply

Strengthen mobility, protect the environment, secure growth – this can only succeed with a coherent concept for our mobility of tomorrow. The German government should develop such a concept – and implement it in dialogue with all relevant partners. The best product innovation is of little use if cars are stuck in congestion. Preventing this is the task of policy-makers. The priority must therefore be given to all growth- and environment-relevant measures. That also includes investments in excellent transport routes and in intelligent traffic systems as well as multimodal solutions.

An energy and raw materials strategy is essential. This also means further development of existing and new recycling processes, and widening and securing the raw materials base for electric mobility. German industry offers policy-makers its cooperation.

The following scenarios mark out important milestones:

Short-term scenario:

- Needs-oriented infrastructure construction with the right framework conditions for private investments;
- Comprehensive deployment of transport telematics and traffic management systems (in particular real-time traffic information, dynamic parking space management, fleet management and driver assistance systems, ICT in logistics);
- Technical optimisation and efficiency improvements in (existing) vehicle concepts and powertrain technologies;
- Improvement of hybrid technologies;
- Optimisation of conventional liquid fuels and gas fuels;
- Use of energy- and CO_2-efficient liquid biofuels on the basis of starch and sugar (bioethanol) or plant oils (biodiesel, hydrated plant oils) as well as gas biofuels with extension of the raw materials base to cellulose and bio wastes (bio natural gas);
- Enhanced technology-neutral research and development for innovative powertrain technologies, alternative fuels and storage technologies (for electricity and pressurised gases) as well as agreements on common standards;
- Concentration of field tests (hybrid technology, hydrogen for fuel cells or combustion engine, electric cars), first work on building charging, tank-filling and communication infrastructures for alternative powertrain concepts;
- Stronger European and international coordination, in particular on standardisation issues;
- Improvement of fibre composites and sealing materials / composite materials.

Medium-term scenario:

- Market-relevant introduction of alternative powertrains (e.g. electric mobility);
- Energy- and CO_2-efficient liquid biofuels with extension of raw materials base to cellulose (bioethanol) and bio wastes (bioethanol, BtL);
- Further development of charging, tank-filling and communication infrastructures for alternative powertrain concepts;
- Use of hydrogen and bioethanol for fuel cells and combustion engines;
- Improvement of fibre composites and sealing materials / composite materials.

Long-term scenario:

- Energy- and CO_2-efficient biofuels with “novel” fuels / fuel components;
- Electric car fleets, also as a storage medium for renewable energies;
- Greater us of Car2X communication and cooperative driver assistance systems which meet data protection criteria.

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