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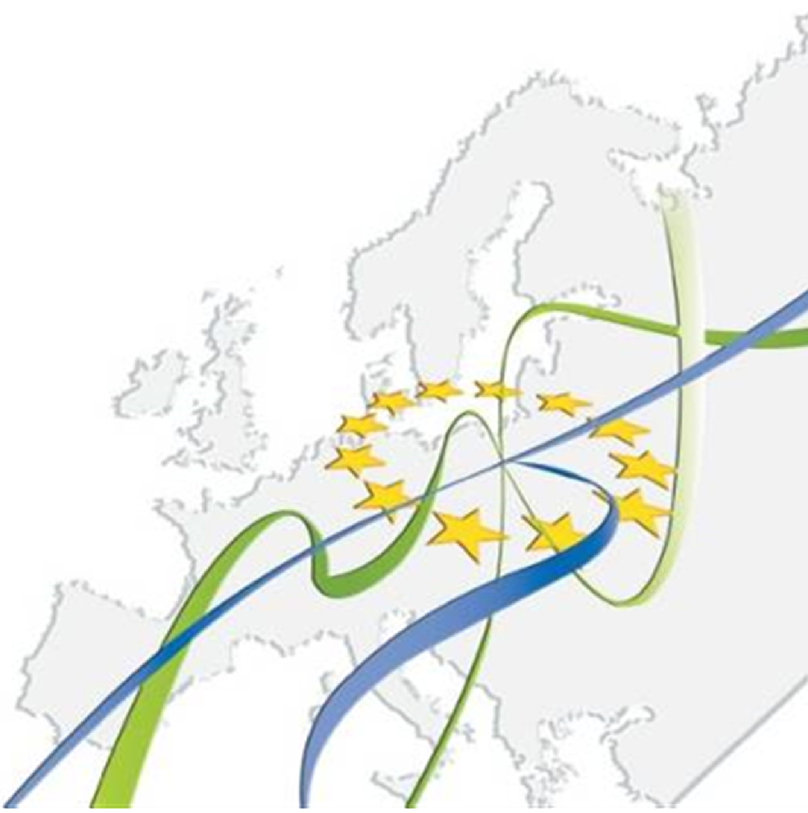
European Roadmap

Infrastructure for Green Vehicles



October 2012

Content:

1. Introduction

In its new Strategic Research Agenda, ERTRAC has addressed major societal challenges such as **decarbonisation in road transport**, reliability of the road transport system and the need for safety and security in road transports. The table below shows the societal challenges to be tackled in the future:

	Indicator	Guiding objective
Decarbonization	Energy efficiency: urban passenger transport	+80% (pkm/kWh) *
	Energy efficiency: long-distance freight transport	+40% (tkm/kWh) *
	Renewables in the energy pool	Biofuels: 25% Electricity: 5%
Reliability	Reliability of transport schedules	+50% *
	Urban accessibility	Preserve Improve where possible
Safety	Fatalities and severe injuries	-60% *
	Cargo lost to theft and damage	-70% *

* Versus 2010 baseline

Table 1: Guiding objectives for 2030

It will be mandatory **to overcome the future challenges of road transport to secure sustainable person mobility** (individual mobility with the choice of your own means of transportation as well as to use all the possibilities of public transport) **and goods transport for the future, a basic requirement that humans will presuppose as self-evident also in the future.**

In urban areas, where travel and transport distances are normally short, battery-electric propulsion will be a feasible option for motorised transport. Longer distances will require the use of other powertrains. From todays point of view the Internal Combustion Engines (ICE) will play an important role here. In the context of the European road transport system over the next decades, the development of complementary solutions will be key to meet mobility demands.

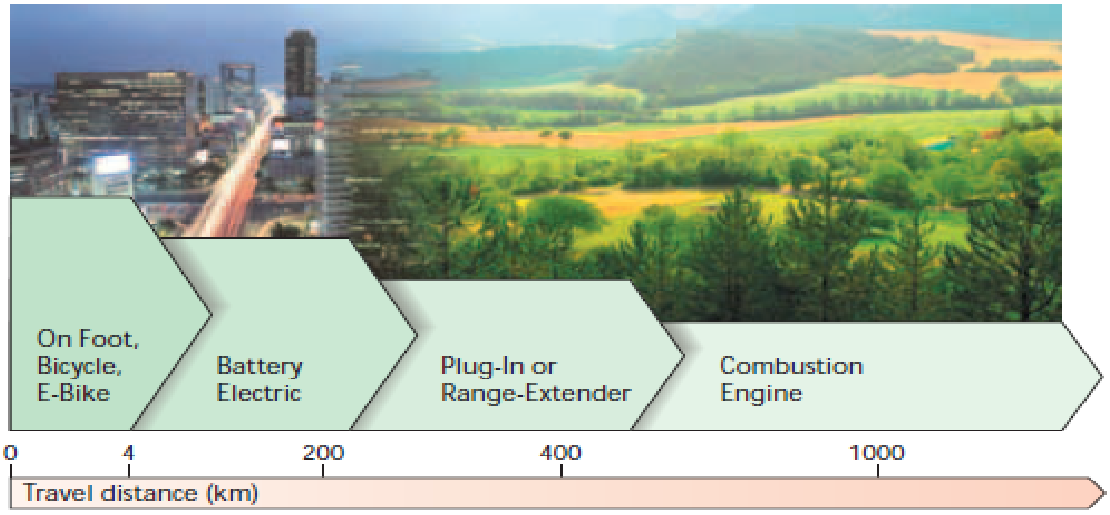


Figure 1: Dominating mobility solutions for both urban and long-distance travel

The future will request a Sustainable or 'Green Mobility' with, among others, 'Green Vehicles' and for those the necessary infrastructure to secure an individual and environmentally friendly mobility freedom and 'green' goods transport. Especially, to secure mobility and goods supply in cities and conurbation will be a great challenge to be solved in the future.

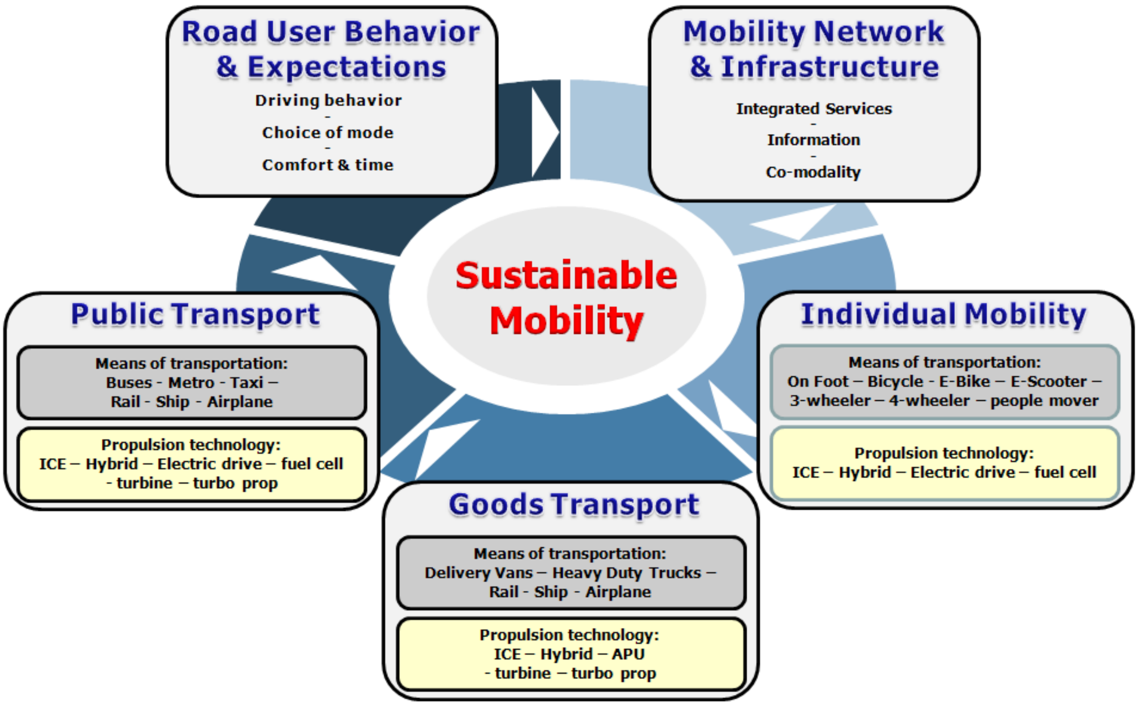


Figure 2: The context of Sustainable 'Green' Mobility

A sustainable transportation system, or to say sustainable mobility, is one that:

- Allows the basic access and development needs of individuals, companies and society to be met safely and in a manner consistent with human and ecosystem health, and promotes equity within and between successive generations.
- Is affordable, operates fairly and efficiently, offers a choice of transport mode, and supports a competitive economy, as well as balanced regional development.
- Limits emissions and waste within the planet's ability to absorb them, uses renewable resources at or below their rates of generation, and uses non-renewable resources at or below the rates of development of renewable substitutes, while minimising the impact of the use of land and the generation of noise.

In the context of sustainable mobility, with its individual mobility, public and goods transport, the pertinent infrastructure technology carry an important role to overcome the problems of environmental impact, air quality and sustainable mobility.
'Green Vehicles' and the corresponding infrastructure have to go ahead hand in hand to overcome future challenges. The green vehicle market is not yet well developed, as well as the infrastructure to serve such a market is not yet in a proper shape.
Within this roadmap we define 'Green Vehicles' as vehicles with 'new' technologies, seen as 'green'. Technologies as fuel cell electric vehicles (FCEV) or hydrogen driven vehicles, hybrid electric vehicles (HEV) or full electric vehicles (EV) with or without plug-in devices, vehicles powered by gas, bio-fuels or dedicated new Internal Combustion Engines (ICE) with a strong reduction on environmentally impact.
For those 'Green Vehicles' an adapted infrastructure is needed. The claim of this European Roadmap is to analyse which new infrastructure for those 'sustainable mobility' is needed, which existing infrastructure should be extended and which research is needed. This includes the infrastructure for traffic and transport in urban and conurbation areas (the cities with travel distances of normally less than 100 km), for the middle distance of intercity/regions (with travel distances up to 300 km) and for the long distances with the Trans European Core Network (with distances of more than 300 km). Not to forget logistic needs and a smart city planning to avoid unnecessary trips.
The bow of this roadmap encompasses goods road transport and person road traffic, individual and public concepts, 2- to 4-wheelers and new mobility solutions, delivery cars, trucks and buses. A brief journey will touch the co-modality solutions.
A lot of infrastructure technologies and processes are already known, some already developed, interesting and promising ideas appear and research initiatives have been undertaken. The smart electricity grid, charging devices in multi-storey car parks, filling stations for hydrogen, gas and renewable fuels, logistics and services, information systems for users, traffic management are only some infrastructure needs for new research, development and implementation.
The development and market introduction of the 'green' vehicles and the provision of the complementary infrastructure must take place at the same time. **The sooner coordinated actions of road transport stakeholders and legislation will be undertaken the better it will be to secure a future 'Green Mobility'.**

One has to take in mind that the introduction of new car concepts like electrical cars is a delicate process. There are huge investments involved. There obviously is a relation between political targets, social needs, and investments made by automotive industry. The market acceptance can be difficult caused by costs and the needed service infrastructure to support these new concepts. The implementation is neither a market push nor a market pull. It is a combination of both. Evolving technologies create a demand as a (social) demand creates technologies. To make green vehicles a success some cooperation between parties are needed. Clear visions can stimulate market acceptance. Examples can be the closing of city centres or city zones for “dirty” vehicles. But also investing in charging places, stimulating green vehicles by taxes or other means (e.g. parking facilities) can help market introduction. Greening mobility therefore needs a positive climate. The aim of this road map is to make clear that infrastructure is needed for green cars. It is not the aim to commit policy, nevertheless policymakers can use the suggestions to improve and stimulate the market introduction of green vehicles.

The aim of this roadmap on ‘Infrastructure for Green Vehicles’ is to give a consistent overview, to show the different fields of application, to explain the challenges and benefits for environment and customer, to point out the most promising concepts and to define the Research and Development (R&D) needs on a time-line; this for the different infrastructure applications. We describe the needed infrastructure with its requirements to reach the goal of a connected, customer-oriented and integrated ‘Infrastructure for Green Vehicles’, to secure the success of a ‘green vehicle market’ and to overcome the transition to a ‘green’, sustainable mobility. The consideration is focused in the green road mobility which of course is a part of a multimodal green mobility where all modes interact in a sustainable manner. The ‘multimodal’ part could not cover the infrastructure for all the modes of transport, but indicating how a green multimodal information structure will be built to provide holistic cooperative information to the traveler (on all the existing opportunities within each mode of transport either conventional or green).

Links to other roadmaps and strategic papers

The infrastructure and mobility network, hand in hand with green vehicles, will be a dominant research and development challenge for road transport for long time. A lot of research and implementation effort is needed to improve the way to green sustainable mobility.
The experience, strategic papers and the input from the involved partners built the basis of the European Roadmap ‘Infrastructure for Green Vehicles’. Furthermore the **European Green Car Initiative** (EGCI) is to mention with a lot of influencing input for future sustainable mobility and goods transport. Particularly to mention we would like the EGCI project CAPIRE with the input on the electrification parts. For the energy part, results from the **European Expert Group on Future Transport Fuels** gave an important input. Obviously the **European Commission** has a great influence on the future vehicle development; papers important for road transport are among others surely:

- The Transport White Paper setting the EU transport policy: COM(2011) 144, White Paper 2011 ‘Roadmap to a Single Transport Area – Towards a competitive and resource efficient transport system’
- The strategy for clean vehicles: COM(2010) 186, ‘A European strategy on clean and energy efficient vehicles’.

2. Benefits and challenges

The value of an ‘Infrastructure for Green Vehicles’ is to see in customer and environmental benefits. ‘Green Vehicles’ with the adapted infrastructure will offer sustainable solutions for personal individual and public mobility as well as for environmental friendly goods transport.

Good and secure roads and a flexible traffic management will ensure a comfortable, safe journey and sustainable goods transport.
The 'Infrastructure for Green Vehicles' will support the societal need for decarbonisation and sustainable, 'green' mobility and transport in the road transport system - adapted technologies, processes and systems are absolutely necessary. Infrastructure is a key enabler to reach the CO_2 targets, to reduce the Green House Gas (GHG) emission. Not to forget that infrastructure is helpful to enable good air quality in urban areas due to the smart electric grid with zero emission driving possibility, traffic management with regulated traffic flow, e.g. special lanes for green vehicles. It could also play a role concerning the conventional fossil fuel dependence and energy supply safety. The aim to achieve clean air in conurbation, reduce sound pollution caused by transportation, to improve air quality and to reduce the green house gases makes it necessary to find 'Green Infrastructure' solutions. All this will lead to a better liveability in cities and regions.
A better infrastructure for Energy, Information and Communication Technology (ICT) and Services (Logistics & Physical infrastructure) solutions, in parallel with green vehicles, will be more in line with the consumer's needs and the driving and transport pattern of today and those for the future.
To point it out, an 'Infrastructure for Green Vehicles' will contribute to secure a sustainable mobility for persons and for goods transport for the future.
Innovation in technology is not enough to reach the sectors targets, but also a holistic approach with elements such as organisational planning and city planning is needed.

The **challenges** to establish a really customer related and integrated sustainable infrastructure could be summarised as:

- The coordinated implementation of the 'Infrastructure for Green Vehicles' and the 'Green Vehicles' itself is needed. Some infrastructure technologies as well as some green vehicles are already there or on the way. All road transport stakeholders, e.g. states/government, automotive industry, infrastructure builders/operators have to undertake coordinated actions.
- The system integration with the interaction between the different technologies, ICT systems, players and business models will be a huge challenge.
- The high investment in road infrastructure and the long time for return on invest
- The lack of standards between the different cities, regions and the cultural differences
- The different cycle times for the different industries (e.g. cars – ICT – roads)

Not to forget, a problem of today and probably some next years is the unstable economic situation that impedes needed development and advancement.

Considering the large predicted growth and request in 'Green Mobility' solutions, a leading position of Europe in infrastructure technologies is critical for the global competitiveness of the European automotive and infrastructure industry, for the manufacturers, the Research and Technology Development (RTD) providers and the entire supply chain. With a European Leadership in adapted infrastructure technologies, processes and systems we will see benefits on economics and jobs.
The necessary investment in infrastructure devices has to be provided by cities, regions, governments, by private public partnership or private investors.
One circumstance should be considered, even if cost remains an important challenge. The question will be which additional service and information costs will be accepted by the customer, which benefits can be achieved using the new infrastructure offers. This in fact is a social and therefore a political issue. It request balancing direct costs (infrastructure, petrol et cetera) against other costs like health, environment, climate change and comfort.

The energy costs will continue to rise and concomitantly the fuel costs, which allow a higher effort for sustainable mobility technologies. In addition, which sum will be equalised by impeded mobility, traffic jams, missed dates, wrong traffic information, empty driving trucks, etc.

A brief overview on benefits and challenges for an 'Infrastructure for Green Vehicles' is given in the following table.

2.1 Brief overview on benefits and challenges

'Infrastructure for Green vehicles' together with 'Green Vehicles' will offer sustainable mobility.
Benefits of an Infrastructure for Green Vehicles
- Is a key enabler for sustainable, 'green' mobility and transport - Enables the electrification of vehicles, absolutely necessary for it - Supports the reduction in CO_2, GHG and other hazardous emission - Enables better liveability in cities and regions - With the support for the market success of green vehicles helps to secure energy supply by the consumption of less conventional crude oil based fuels - Delivers all information for best travel, individual or public, not only for green vehicles - Provides an efficient, sustainable goods transport system - Increases European competitive ability for both automotive industry as well as for other industries involved in road technologies
Main challenges for an Infrastructure for Green Vehicles
- The coordinated implementation of 'Green Vehicles' and the pertinent infrastructure. All involved stakeholders have to undertake coordinated actions - The system integration and interaction - The high investment for road infrastructure - The need for standardisation within Europe and the difficulty to come to one European approach - The different cycle times of the different industries (e.g. car – ICT – roads)

Table 2: Overview on benefits and challenges of Infrastructure for Green Vehicles

3. A short look into the future of 'Green' Vehicles'

For the vehicle development of the future, one clear statement can be set up:
There will be a larger diversification in propulsion systems, vehicle design and application in the future.
The traffic in cities and conurbation will be more and more electrified, long distance travel and transport need fuels for a long time.

The following picture from the International Energy Agency shows the diversification of the technology, a rapid light-duty vehicle technology evolution over time assumed (Blue map scenario).

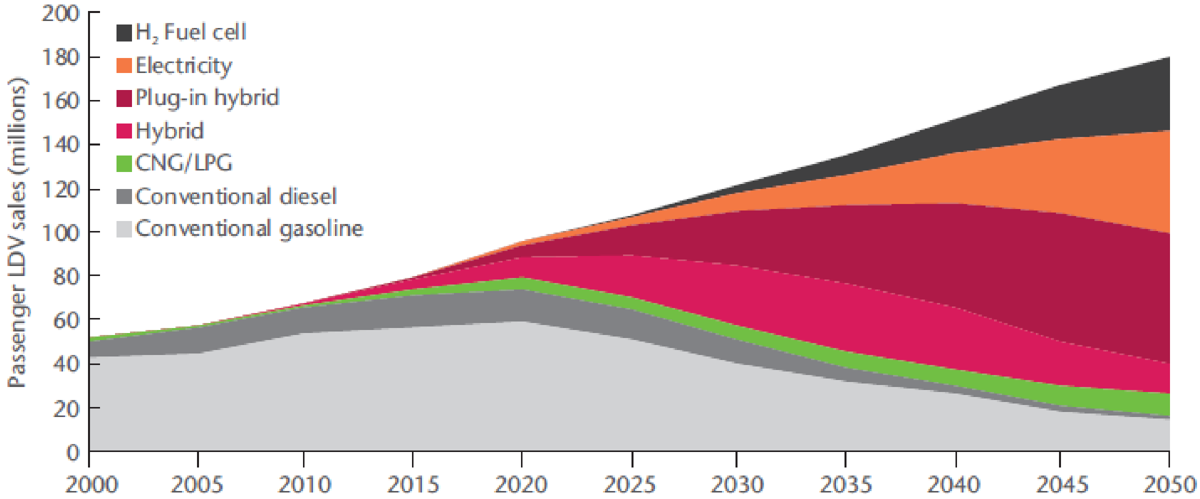


Figure 3: Annual light-duty vehicle sales by technology type, Source: IEA, Technology Roadmap, electric and plug-in hybrid electric vehicles, updated June 2011

Passenger Cars and Light Commercial Vehicles

Regarding **cities and conurbation**, often emission burdened, we expect to see for personal travel small and comfortable cars, some with conventional design, some with new design and structure. New types of 'people movers', 1- to 4-wheeler concepts will be seen. The typical Electric City Car (ECC) will be designed such that it can be operated for most of the day by a single charge. The average mileage in European cities is almost always below 100 km per day at low speed. Range and speed are not a strong limiting factor for urban traffic. Furthermore, since an average vehicle is parked for 20-22 hours of the day, the possibility of low power charging is obvious. If the battery is not sufficient to complete a full day's driving, due to the limitations imposed by affordable costs and by the timing of recharge, the use of a fuel based Range Extender will remain necessary until the next generation of much more advanced battery technology becomes available. Environmentally friendly vehicles for the delivery of goods and for craftsperson, with new design, e.g. modular structure, settle the daytime work. Changing purchase habit causes new types of delivery chains. The propulsion systems will be mainly electrified ones: Hybrids and Plug-In Hybrids (PHEV) with diesel or gasoline ICE, Full Electric Vehicles (EV) with plug-in devices and in the far future as well fuel-cell driven electric vehicles (FCEV). Also vehicles with Liquid Petroleum Gas (LPG) or Compressed Natural Gas (CNG) will be in use to take care of daily work. All traffic in cities and conurbation will be on a silent and environmental friendly zero emission level.
On the edge or outside the cities, distribution hubs will manage the transhipment of goods. The transhipment from long distance heavy duty trucks on smaller distribution vehicles. Most of the passenger cars, without the possibility to drive as Zero Emission Vehicle (ZEV) for at least some kilometres, will park outside the city centres.

Heavy Duty Trucks and Passenger cars for long distance travel

For the **medium to long distance** travel we will still see passenger cars powered by optimised diesel and gasoline fuels (with a lot of technological features to reduce consumption and emission), Plug-In Hybrids and Range Extenders, LPG or CNG driven vehicles and probably

hydrogen driven vehicles. In the longer term, charge while driving as a solution may remove the need for vehicles powered by ICE as range extender and create full freedom of mobility in a long term perspective.
The Heavy Duty Trucks (HDT) will for a long time still require diesel (or other) liquid fuels due to their high energy density. Hybridisation will develop gradually and solutions for electric road systems in major transports corridors (e.g. in dedicated lanes) shows a significant energy reduction potential more long term. HDT will stepwise develop from tailored trucks, self-operating trucks, sustainable trucks, transport integrated trucks to traffic integrated trucks.

In principal, all Original Equipment Manufacturers (OEM) followed the same path for the development of future vehicles, with boundaries coming from technological possibilities, customer expectations, market success and legislation, and even from the development of the environment.
The following shown fuel and passenger car propulsion strategy illustrates a possible path to sustainable mobility for individual road travel. The figure shows on the left side the most important primary energy source from crude oil and natural gas to renewable. Out of those the energy carriers, shown in the middle, are produced. On the right side of the figure the used propulsion systems are listed.

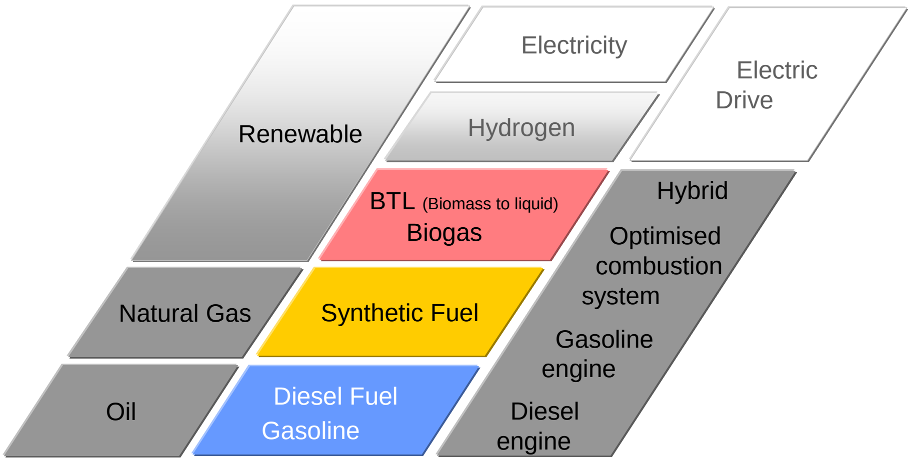


Figure 4: Fuel and passenger car propulsion strategy; Source: Volkswagen AG

It is considered that electric drive technology has the greatest amount of potential for sustainable mobility over the long term. A clear statement is that there will be no sufficient solution in the short term range. Albeit that there is no telling right now whether the electricity used will be generated in a fuel cell using renewably generated hydrogen or classically stored using a battery. That is why such propulsion strategy vigorously has to pursue both technologies.
The basis of the strategy is continuously to increase the efficiency of all conventional powertrains by means of rigorous, consistent implementation of the downsizing concept, direct injection, charging and engine displacement reduction and the utilisation of new efficient combustion systems like HCCI (Homogeneous Charge Compression Ignition) or low temperature combustion for all diesel and petrol engines. Hybrid technology is another efficiency improvement measure to further reduce fuel consumption of combustion engine based powertrains.

It seems that the challenges associated with electric drive technology need to be tackled today and that several years of research will still be required. Indeed, it will probably take at least another ten years until these new technologies have secured a big enough share of the market to actually produce a significant degree of change. It is vital, therefore, that the distant goal of electric drive is supplemented with a strategy for the near future – i.e. a strategy which involves effective and realistic phased evolutionary development aimed at achieving the revolutionary objective of sustainable mobility.

One of the crucial steps in this development is the electrification of powertrains. The share of drive performance produced by electric powertrain technology will gradually increase in future, eventually ending in a fully-electric-powered vehicle. This evolutionary path is very much dependent on the further development of battery storage capacity, or charge by driving concepts which would eliminate the need for large batteries for many vehicles.

Within this European Roadmap ‘Infrastructure for Green Vehicles’ a ‘Green Vehicle’ is defined as one that is significantly less harmful to the environment than comparable current ICE conventional vehicles. Vehicles that contribute to sustainable ‘green’ mobility fuel efficient, eco-friendly with a small carbon-footprint. A sustainable life cycle approach including exhausting of rare elements and raw materials is another aspect of ‘green vehicles’. These green vehicles are fuel cells or direct hydrogen driven vehicles (with the H2 derived from non-fossil sources), hybrids and full electric vehicles with or without Plug-In device, vehicles powered by gas, bio-fuels or dedicated fuels/energy from renewables, as e.g. 2nd generation bio-fuels with high CO_2 saving potential, not in competition with food.

Even if we assume, that autonomous driving ‘green’ vehicles are ready for roads everyday life in 2020 (Larry Burns, former General Motors development chief; VDI Nachrichten, 20. April 2012), we can speculate only how mobility will look like in 2050. One can determine that vehicle concepts and structure will spare resources regarding material, energy consumption and production, and they will change to more convenient ‘moving concepts’.

Figure 5: Heathrow PRT (Personal Rapid Transit); EU project CityMobil – towards advanced road transport for the urban environment. www.citymobil-project.eu

Figure 6: ‘Skyrider’ - mini airplane PAV (Personal Aerial Vehicle) for individual traffic; EU project mycOpter – Enabling Technologies for Personal Aerial Vehicles; www.mycopter.eu

The main question is not if, but when (near) zero emission vehicles with new vehicle concepts will penetrate the market, at least in urban mobility.

For those ‘Green Vehicles’ an adapted infrastructure is needed.

4. Infrastructure solutions in European Road Transport

The claim of this European Roadmap is to analyse which new infrastructure is needed, which existing infrastructure should be extended and which research is needed. Policies, laws and regulatory requirements are only mentioned if necessary.

The picture below shows as one example the future vehicle solutions for sustainable mobility with their vehicle market maturity and the affiliated energy infrastructure availability.

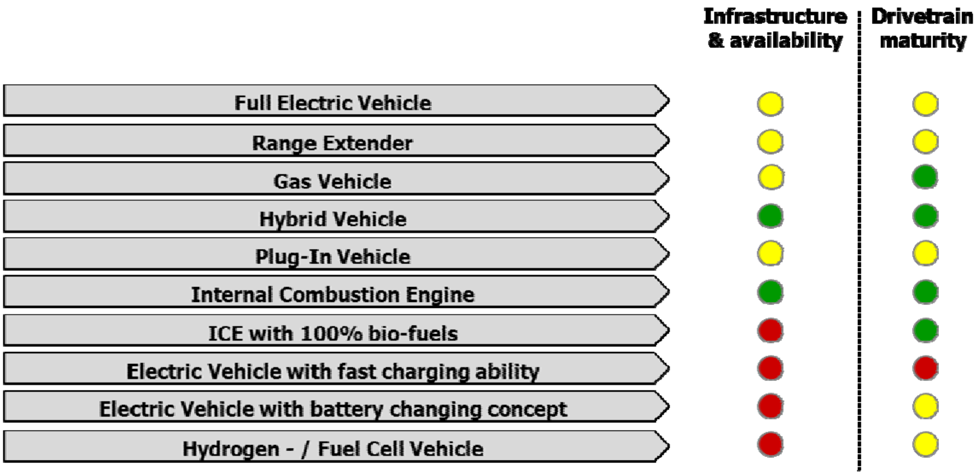


Figure 7: Solutions for passenger 'green' cars with market maturity and infrastructure availability

Generally green vehicles development and market penetration, and the infrastructure belonging to it, have to go ahead hand in hand to overcome future challenges. The green vehicle market is not yet well developed, as well as the infrastructure to serve such a market is not yet in a proper shape. In most cases the vehicle development will be the leading part, sometimes the infrastructure has to go ahead (e.g. hydrogen and gas infrastructure). This roadmap will not be the roadmap for vehicle development; its aim is to give an overview on the pertinent infrastructure for green vehicles, the requirements and necessary actions, milestones and research steps.

The infrastructure industry is a cross industry with multi stakeholders, OEM and suppliers, cities, regions and state governments, private and public organisations, from vehicle manufacturers over Information and Communication Technology (ICT) and logistics providers to road builders. This consortium has to manage the mobility system integration and has to fulfil environmental aspects as well as customer expectations.
To achieve a connected, integrated and customer-oriented infrastructure, it requires activities and research in areas identified in the infrastructure for green vehicles:

- Transport flow from an infrastructure system perspective
- Transport and logistics in a corresponding infrastructure
- Distribution-net of fuels/energy carriers
- The driver in the system, in the infrastructure belonging to it
- Service and maintenance of 'green' infrastructure
- Service and maintenance needs on vehicles within a 'green' infrastructure
- Requirement of vehicles operating in a 'green' infrastructure
- Infrastructure Software and Hardware (hubs, road surface, etc.)

- The intelligent transport system interaction with ‘green’ infrastructure
- Business models with an infrastructure perspective
- Integrated city and long distance planning
- Smart city planning
- Congestion management

4.1 The Energy Infrastructure

If we are looking to find solutions for a ‘green mobility’ and the affiliated infrastructure, we have to regard the whole system with its dependencies:

- The energy infrastructure itself
- The availability of green vehicles and mobility solutions
- The security of energy supply and the availability of energy

Regarding the infrastructure itself, the problems of today, the problems to solve, are that the energy, especially the electric energy, is not where it is used and often not available when it is used (solar, wind). This causes the development/investment in:

- New electric wires
- Increased grid stability
- New storage capacities
- Solution to use the surplus electricity for the production and storage as fuels
- The integration of new gas power plants
- A coordinated system/net between solar, wind, and gas electricity

The so called ‘Smart Grid’ is to establish.

In the decades leading to 2050, there will be the need for vehicles to develop simultaneously a wide range of complementary propulsion systems and fuel/energy types, this will be the challenge. It is expected that ‘Green Vehicles’ will have their highlight after 2030.

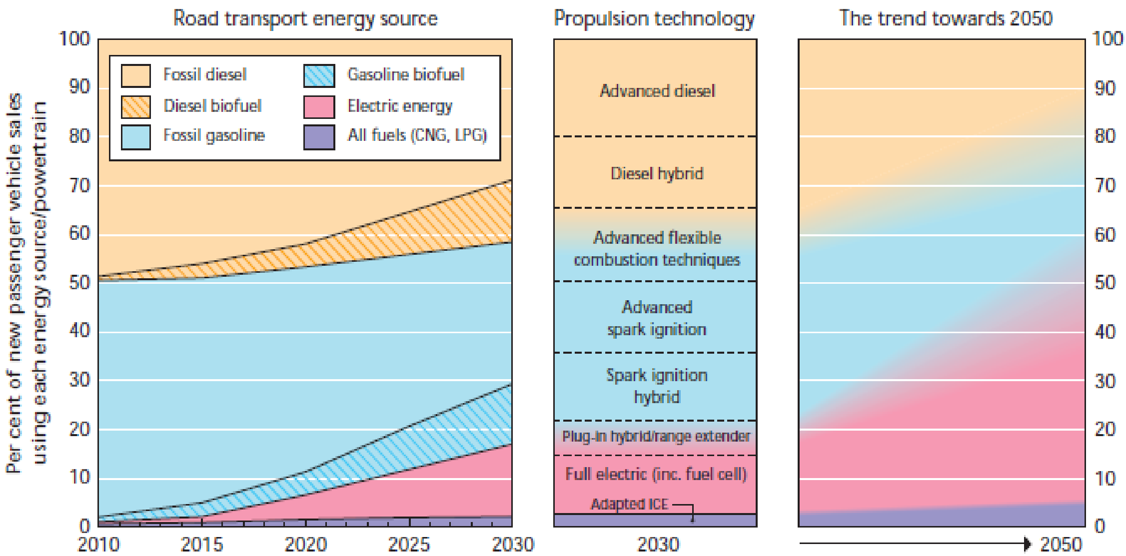


Figure 8: The evolution of passenger road transport energy source and propulsion technology, towards 2050

Although the electrification of road transport will be a strong and inevitable trend the fact is that, by 2030, the ICE will remain the dominant propulsion technology.

- The question how and if we can secure the supply of energy, the knowledge that we have limited fossil energy resources, especially on crude oil in the future, the expected 'oil production peak', the uncertainty how alternative and especially renewable energy can substitute fossil energies, makes it necessary to think about new and alternative 'energy pathways' for the future.

4.1.1 The energy pathway for road transport [1]

Due to the further increase of road transport and road travel, the task to secure mobility in the future, increasing environmental problems, limited fossil oil and gas resources or at least increasing costs for it, the necessity for road transport to use fossil fuels for a long time, especially for heavy duty trucks and long distance travel, we will pay special attention on the energy pathway. We describe the whole energy pathway, not only from a vehicle view. To secure future sustainable mobility and transport, to define an accepted way towards it and to build up the pertinent infrastructure for it, an agreed energy strategy for all energy users is necessary.

Today liquid fuels are the main energy carrier for transport, a substitution of fossil oil therefore needs to start as soon as possible, if we aim to built up a nearly CO_2-free and largely oil-free energy supply for transport.
But, the absolute decarbonisation target of the European Commission to have a Conventional-CO_2-Fuel-Free-Scenario in 2050 in Europe is very aspiring and needs a totally new European Fuel Strategy for all energy producers and users.
An extensive decarbonisation of transport will contain two main steps: 'increase of energy efficiency' and 'decarbonisation of energy supply' in all transport modes. So optimising the whole chain from the sustainable production of energy, the energy carriers and the energy distribution and use will be one of the most challenging goals for the next decades.
Decarbonisation of energy in this context is a cross sectorial topic, aiming all kinds of energy users, not just transport. Available energy sources, esp. renewable, have to be shared in an optimised manner by an energy strategy over all those users.

Renewable electric energy, stored in a battery system and transferred into mechanical power by an electric motor, is today the most promising and sustainable pathway in transport and therefore the Priority 1 long term target for the short distance mobility sector. Beside this option the renewable electrical energy could also be used to generate Hydrogen, used directly in an ICE or in a fuel cell vehicle. Also other chemical energy carriers might come up, e.g. power to CH_4.
Nevertheless, due to technical, financial and infrastructural restrictions at least within the next two decades the use of Hydrocarbons in combustions engines will stay one of the necessary pathways.

In the face of limited availability of affordable renewable and sustainable energy, the special demand on energy carriers in the different road transport sectors and in some cases the lack of alternatives, means that we must think about dedicated energy sources for dedicated sectors.

[1]: Out of the ERTRAC contribution to the European Commission Expert group on Future Transport Fuels; Future Transport Fuels, The Energy Pathway for Road Transport

Europe has to provide the necessary, suitable and sustainable energy strategy 2050 to secure mobility in the future.

The energy needs for transport

Today oil is the main energy source for transport, liquid fuels will stay the main energy carrier. More than half of the crude oil is consumed by road transport. Without a dramatic change, oil will stay the main energy source for transport, even if there are strong efforts to substitute oil, to develop new renewable energy sources and to use sources independent from fossil oil import.
A substitution of fossil oil needs to start as soon as possible, if we will built up a nearly CO_2-free and largely oil-free energy supply for transport in 2050.
Unconventional and renewable fuels and electricity will increase but they can not substitute all transport modes due to technical reasons. In example based on today's knowledge Aviation can not switch to electricity as propulsion energy, as well as H_2 is not suitable / possible for ships and Heavy Duty Trucks; the energy storage would consume their cargo.
The new International Maritime Organisation (IMO) regulation for the marine sector forces that the ships are required to purchase expensive after treatment solutions or low sulphur fossil fuel to reach the new NO_X and sulphur emission levels. The latter solution will lead to a disturbance on the middle distillate (e.g. diesel) production causing higher prices for other sectors.

The energy pathway to secure mobility in 2050

Diversification of primary energy sources, with the aim of gaining independence from fossil reserves, decarbonising energy sources, and maximising the use of electricity from renewable sources for mobility, are therefore the resulting focal issues of a fuel and propulsion strategy.
The chain of primary energy – energy carrier – energy user have to be newly defined in a way to secure the energy for future mobility as well as the energy for e.g. households, plastic and chemistry industry. As the availability of renewable electricity seems to be ensured due to the strong increase in wind and solar power installations, the Hydrocarbon pathway is much more uncertain and needs further attention.

The energy pathways for liquid and gaseous energy:

A look on the picture of the main energy pathways for liquid and gaseous energy shows the necessary energy pathway to secure first the necessary energy for future transport needs and secondly to secure a largely oil-free and a renewable energy supply for transport.

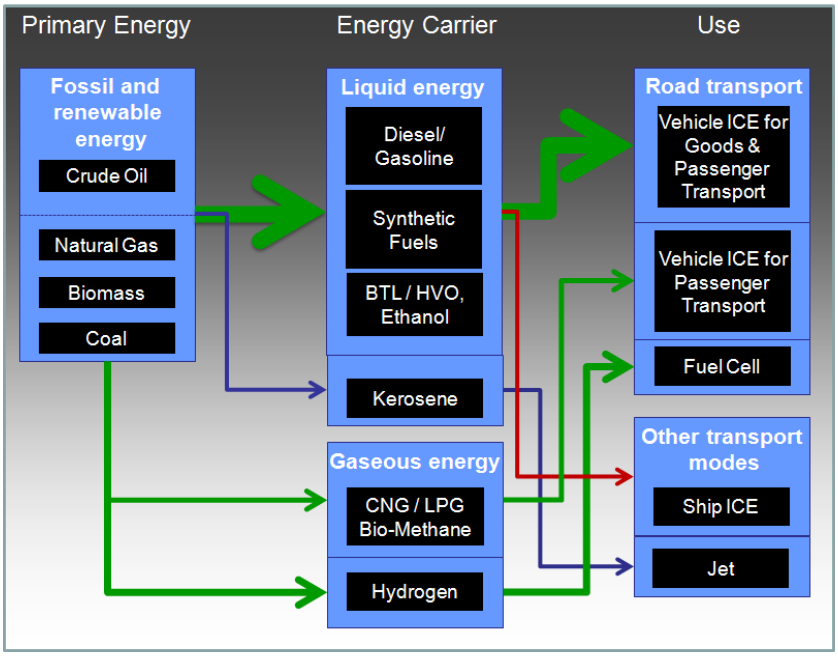


Figure 9: Main energy pathways for liquid and gaseous energy

For transport the biggest part of crude oil should be used to produce liquid energy mainly for road transport / mobility. Even if the long term future of short-distance mobility will be the electric drive, liquid fuels will continue to be the backbone of transport and mobility for a long time, especially for long-distance transport.

> Heavy Duty Trucks will need diesel like fuels for the next decades. Some replacement may come from Natural Gas, bio-fuels and in the far future with charge by driving solutions.
> For passenger cars the goal is renewable and electric (electric not next 15 years); for the time being mainly gasoline and diesel is needed for long distance. In addition conventional diesel is needed because of the legislation background on CO_2 fleet targets (90 gCO_2 / km + 120 gCO_2 / km).

The development of future liquid bio-fuels made from renewable resources (Biomass to liquid, BTL, and bio-technologic fuels) as well as the significant further optimisation of currently existing bio-fuels (e.g. Fatty Acid Methyl Ester (FAME), Hydro treated Vegetable Oil (HVO)) are also crucial steps on the road to sustainable mobility.
We are talking about a 2nd generation bio fuels not in competition with food and a next generation of bio-technologic fuels, not in competition with food and the use of agricultural land!
Biomass to liquid fuels can be produced using numerous different types of renewable biomass and residual biomass material. One of the major benefits of such fuels is that they are sustainable – a quality determined by the fact that they satisfy the sustainability criteria defined by the EU. In addition they are characterised by a compatibility with the existing infrastructure of filling stations and the vehicles on the market today. They imply a CO_2 reduction of more than 70%, reduce competition with food production and have a clear technical potential for mineral oil substitution of around 20%. The advantage of existing bio-fuels such as bio-diesel (e.g. FAME, HVO) and ethanol made from food crops (e.g. wheat) is that these resources are widely available today. There is significant EU potential of bio-diesel

feedstock and land availability for oilseed crops production. Potential for indirect land use change induced by bio-fuels should be mitigated. The production methods do, however, need to be improved if these fuels are to make any significant contribution towards easing the CO_2 burden.
Biomass to liquid fuels need to be included into a broader strategy to achieve the goal of sustainable mobility. It is important, therefore, that we pave the way today for the use of biomass based fuels in future.

The other main future bio-fuel which meets the stringent demands is ethanol made using straw, or potentially ethanol or other alcohols/hydro carbons from e.g. alga. This bio-ethanol is particularly suitable as a component in petrol fuels. The status of vehicle technology today means all cars are already able to use up to five per cent by volume of ethanol in petrol.

Nowadays one fears that there can be bottlenecks with the supply of diesel fuels from fossil oil sources. Two measures are necessary to take. The production in the refineries should change to more diesel production. Secondly, biomass to liquid based diesel is an ideal supplement to the petroleum-based fuels currently in use, because it can be mixed in any desired blend. But, the availability of biomass based fuels is limited and road transport stands in competition with other transport modes regarding the use of biomass based fuels.

The market and the policy have to take corresponding measures to secure the availability of bio-diesel for road transport. And furthermore it is easier at this stage to define the specific chemical and physical attributes of synthetic fuels than it is to define those of conventional fuels. That is why there are so many links to biomass based diesel fuels as designer fuel which can be used as a constructive element in engine development. They allow us to work simultaneously on developing a fuel and an engine towards an optimised combustion system.
One prime example of this is the HCCI (or so called low temperature) combustion process which combines the low emissions of a petrol engine and the efficient level of fuel consumption associated with diesel engines. This technology illustrates how a fuel strategy can become a fuel and powertrain strategy.

The shown fuel and propulsion strategy endorses the use of different sources of energy rather than a wide range of energy mediums (i.e. fuels). Diversification of energy sources means a variety of raw material is used to produce alternative fuels. Synthetic diesel fuels offer particularly interesting prospects. The focus should be the use of CO_2-neutral biomass, e.g. wood, straw, energy plants and all usable waste, for the production of biomass based fuels, a non-sulphuric diesel fuel devoid of any aromatic compounds and which, when combusted, generates a much lower amount of pollutants and only emits as much CO_2 into the atmosphere as was previously absorbed by the plants during photosynthesis.

Recently microalgae, yeasts and other microorganisms have shown a promising potential for production of liquid biofuels. Intense research on the production of hydrocarbons by genetically engineered organisms yield promising results. Such bio-technologic fuels are not in competition with food, do not use agricultural land and perform a direct production of hydrocarbons. Yields/ha can be 100 times higher than 1st and 2nd generation biofuels.

The fuel production from coal (Coal to Liquid, CTL) is not included in this strategy, caused by the high CO_2 emissions during production.
Another important point is that the quality of synthetic fuels is largely independent of the actual raw material used! The technology used to manufacture synthetic fuels constitutes a

key element in the pursuit, at once, of a fuel that is independent from fossil fuels and better fuel quality (and thus reduced local emissions).

Besides the fuel driven vehicles, we think that there will be also an increasing part of passenger cars using Natural-gas and Bio-gas.

The electric energy pathways:

The picture of the electricity pathway and for the non-transport users is given below.

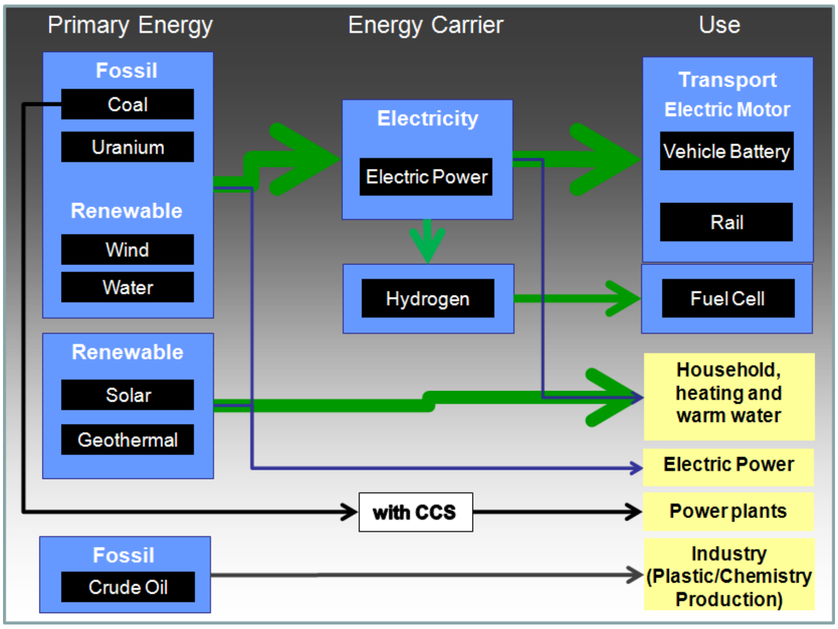


Figure 10: Main energy pathways for electricity, households, power plants and industry (CCS = Carbon Capture and Storage)

Electricity as a transport 'fuel' in a larger scale will require modification and improvement efforts and investments. Requirements will differ from country to country. However, this shouldn't be a show stopper since large scale transport electrification levels will not be achieved within the next decade, that means time for grid adaptation is available but efforts needs to be planned and initiated today.

A further challenge represents the European (worldwide) standardisation needs. Efforts are on its way but need to succeed soon since otherwise electrification of road transport will be faced with additional cost burdens and insufficient consumer acceptance.

Future electricity-storage technology will play a vital role when it comes to a further considerable lining up of fluctuating renewable energy production from wind and solar. Above a certain percentage of renewable in the electricity grid there is the need to store the surplus renewable electricity for example by batteries or pumping water up and down. Hydrogen produced by electrolysis is still an excellent option to store surplus electricity, even if you lose today around 40% of the electric energy when using electrolysis process. For the future these are options like the high temperature electrolysis to achieve higher efficiencies. With fuel-cell technology in cars and busses, the hydrogen can be used in this way.
The fact that fuel-cell vehicles have a longer fuel range than electric-powered vehicles and can easily be refilled could still open a strong role for them for the future in long distance

passenger travel and universal car use. Today, cost reduction targets for fuel cells and hydrogen distribution technology must still prove their cost reduction potential; however the desirable benefits justify a further role in research, transport and energy policy.

The only thing we can be sure about right now is that it is not a matter of primary importance whether or not sustainable mobility is hydrogen and fuel-cell based or electricity and battery based, since what is important is that both forms of energy be generated from renewable energy sources in the long term.

Main statements of this pathway are:

- To use the full spread of electricity a lot of research, development and investment has to be done in batteries, smart grids and infrastructure.
- It is expected for the future that electricity will mainly come from renewable and low-carbon technologies.
- Energy needs for electric vehicles can be assumed by the electricity system without major problems, with about 0.1 % of additional EU electricity demand per 1 million of electric vehicles.
- Beside direct electric use, electricity could also be used to generate other carbon-hydrogen (CH).

Furthermore

- Fossil fuel powered railroad transport has to change to electricity powered wherever feasible.

Additionally non-transport energy pathways:

Heating with biomass i.e. is one of the most efficient usages of that energy, but low temperature heat can also be produced by solar thermal panels. On the other hand hydrocarbons are not able to be produced directly out of solar power. Even heating oil is still used in households, where as in the same time there is a lag on Diesel fuel in the market.

- Household should use mainly renewable energy from solar (electricity and heating) and geothermal sources. For households there is a substitute for liquid energy.
  That is forbidding biomass usage for heating, replaced by solar thermal, geothermal energy or heat pumps, could nearly double the availability of Bio-fuels.

- To use crude oil just for heating will not only endanger the mobility and transport future; it will also burn the future for the plastic and chemistry industry.

4.1.2 The Infrastructure for electric, liquid and gaseous energy carriers

As an introduction to this chapter on the infrastructure for electric, liquid and gaseous energy carriers, some statements for the application and use of energy for passenger cars and goods transport could be helpful. The following table will give a brief overview.

<table>
<tr><th colspan="3">Type of transport</th><th>Short term</th><th>Medium term</th><th>Long term</th></tr>
<tr><td rowspan="3">City / Urban</td><td rowspan="2">Personal mobility</td><td>Private cars – City cars & 'city movers'</td><td>ICE as main powertrain. Increasing share of bio-fuels</td><td colspan="2">Will change to electric power (PHEV, EV). Wireless charging for electric vehicles in main cities and dedicated regions</td></tr>
<tr><td>Public transport – city buses, urban buses</td><td>ICE as main powertrain. In some cities electric 'trolley' buses and pilots with fuel-cell buses</td><td colspan="2">Plug-in and wireless charging electric buses in main cities and dedicated regions. Fuel-cell powered buses in dedicated cities</td></tr>
<tr><td>Goods transport</td><td>City transport for goods – 'city transporters'</td><td>ICE as main powertrain. Increasing share of bio-fuels and hybridisation</td><td colspan="2">Will change to electric power (PHEV, EV). Frequent (e.g. wireless) charging available for electrified vehicles in main cities and dedicated regions</td></tr>
<tr><td rowspan="9">Intercity / region</td><td rowspan="6">Personal mobility</td><td rowspan="3">Private cars – intermediate / regional distances cars</td><td colspan="2">ICE as main powertrain outside cities. Increasing share of bio-fuels</td><td></td></tr>
<tr><td></td><td colspan="2">Plug-in hybrid electric vehicles, Range Extender</td></tr>
<tr><td></td><td rowspan="2">Gaseous hydrocarbons (e.g. natural gas, biogas) will be an appropriate solution in medium-term. As replacement for diesel-fuel, natural- and bio-gas it is fast applicable</td><td></td></tr>
<tr><td rowspan="3">Public transport – regional distance buses, intercity buses</td><td></td><td></td></tr>
<tr><td colspan="2">ICE as main powertrain outside cities. Increasing share of bio-fuels and hybridisation</td><td></td></tr>
<tr><td></td><td colspan="2">Will gradually change to electric power (PHEV, EV). Frequent (e.g. wireless) charging available for electrified vehicles in main cities and dedicated regions. Range extender outside cities</td></tr>
<tr><td rowspan="3">Goods transport</td><td rowspan="3">Regional goods transport</td><td colspan="2">ICE as main powertrain outside cities. Increasing share of bio-fuels and hybridisation</td><td></td></tr>
<tr><td></td><td colspan="2">Gaseous hydrocarbons (e.g. natural gas, biogas) will be an appropriate solution in medium-term. As replacement for diesel-fuel, natural- and bio-gas it is fast applicable</td></tr>
<tr><td></td><td colspan="2">Will gradually change to electric power (PHEV, EV). Frequent (e.g. wireless) charging available for electrified vehicles in main cities and dedicated regions. Range extender outside cities</td></tr>
<tr><td rowspan="9">Long distance</td><td rowspan="6">Personal mobility</td><td rowspan="3">Private cars – long distance passenger cars</td><td colspan="3">ICE will be mandatory. Increasing share of bio-fuels</td></tr>
<tr><td></td><td colspan="2">Plug-in HEV, Range Extender</td></tr>
<tr><td></td><td></td><td>PHEV, Fuel-Cell, Hydrogen. Wireless charging on main European axis, possibly shared with HDTs</td></tr>
<tr><td rowspan="3">Public transport – long distance buses, coaches</td><td colspan="3">ICE will be mandatory. Increasing share of bio-fuels</td></tr>
<tr><td></td><td colspan="2">Plug-in HEV, Range Extender</td></tr>
<tr><td></td><td></td><td>PHEV, Fuel-Cell, Hydrogen. En-route charging on main European axis</td></tr>
<tr><td rowspan="3">Goods transport</td><td rowspan="3">Long distance goods transport – 'High Capacity transport Trucks'</td><td colspan="3">ICE will be mandatory. Increasing share of bio-fuels. Biomass based fuels is important for long distance and intermediate transport in long term</td></tr>
<tr><td></td><td colspan="2">Some hybrid components, Fuel-Cell auxiliary power unit (APU)</td></tr>
<tr><td></td><td></td><td>Continuous grid connection on 'green corridors' and highways for HDT hybrid systems</td></tr>
</table>

Table 3: Some aspects on propulsion & energy application

4.1.2.1 The Infrastructure for Electric Energy

The move from a part of conventional combustion based mobility to more electric or full electric mobility poses many questions with answers depending on a multitude of interdependent parameters. The matter is quite complex and because of that, when treated only in qualitative terms, gives rise to controversy that may slow down the decisional processes. The aim is to help quantifying the importance of the charging infrastructure and grid integration in the global electric energy system and its business models.

Reliable electricity supply must be available for EV/PHEV recharging, with convenient access to recharging stations.

We don't estimate that the impact of EVs and PHEVs in use will have a significant impact in the electric grid. One million electrified vehicles, something not very easy to achieve, represent approximately 1% of the Spanish electric demand only. We can realise that the current distribution network is ready to absorb this load at this early stage without any specific investment plan; there is room for further load increments. The electricity sector has endured much higher increases in demand than the expected one due to the electrified vehicles. Obviously, it is possible that in certain areas the concentration of EVs and PHEVs requires reinforce the local grid but this case is not different than others like, for example, the creation of a new business in a neighbourhood.

Because their electricity demand is not constant during the course of a 24-hour period, EVs and PHEVs have the valuable characteristic of being a deferrable load. Daily recharging can be scheduled for periods of non-peak demand-a principle called valley filling. Assuming electrified vehicles can be recharged at any time of day is probably unrealistic, as most recharging will occur at home in the evenings and overnight.

The role of day/night recharging is a key issue but demand control (forcing the charging process in the most convenient hours for the electrical system) reduces availability to the owner of the vehicle by reducing the added value of this mobility. The role of electricity pricing (e.g., differential day/night, real time pricing) to meet both consumer and producer needs must be fully explored. For PHEVs, overnight recharging appears to be the main initial requirement, whereas for EVs, recharging opportunities away from home are a more critical concern to achieve widespread demand for and use of vehicles.

EV and PHEV expansion will be primarily driven by infrastructure investment. No expensive infrastructure like what would be needed for hydrogen powered vehicles is required. National governments can help coordinate early adoption sites, targeting large cities and urban areas that have ample recharging access. By 2012, it should be determined which local and regional units of government are welcoming electric-drive vehicles through such efforts, and they should be coordinated to ensure a transition toward a national system.

For the short term governments should also ensure local electrical capacity and systems to accommodate whole areas plugging in their electrified vehicles at night; the development of local grid/distribution plans will help.

For the mid to long term, the vehicle and infrastructure technology for cable-free charging in cities, e.g. for buses at traffic light stops, at special places for passenger cars, is to examine and to develop. Another key issue is determining how and when to join up cities for electrified vehicles by developing recharging opportunities on intra-city travel routes. Ultimately, to enable long distance passenger travel by EVs, PHEVs and with access to all parts of a country, easily accessible, fast charging facilities or as a long term vision inductive charging will be needed on motorways. For long distance goods transport on green corridors charging without cable is a vision for the long term future.

Also it's important to be aware that most of the demo pilots in Europe, include roadside slow charging infrastructure, is an infrastructure that probably will become obsolete in a short period depending on the proliferation of fast chargers.
When as many powers should be used as for today with liquid fuels, there are major changes to be made.

Today the electric grid has the burden of an unevenly load shape. The electricity demand is distributed unevenly over the day. This causes unnecessarily high costs to secure the electric energy supply. The total installed capacity depends on the peak demand.
With the implementation of renewable wind and solar electric energy this challenge will enlarge. More energy storage systems to stabilise the grid will become necessary.
The challenge is to find a way for 'valley-filling', to store the surplus electricity in times this electricity is not used. The aim is to smooth the daily load shape.

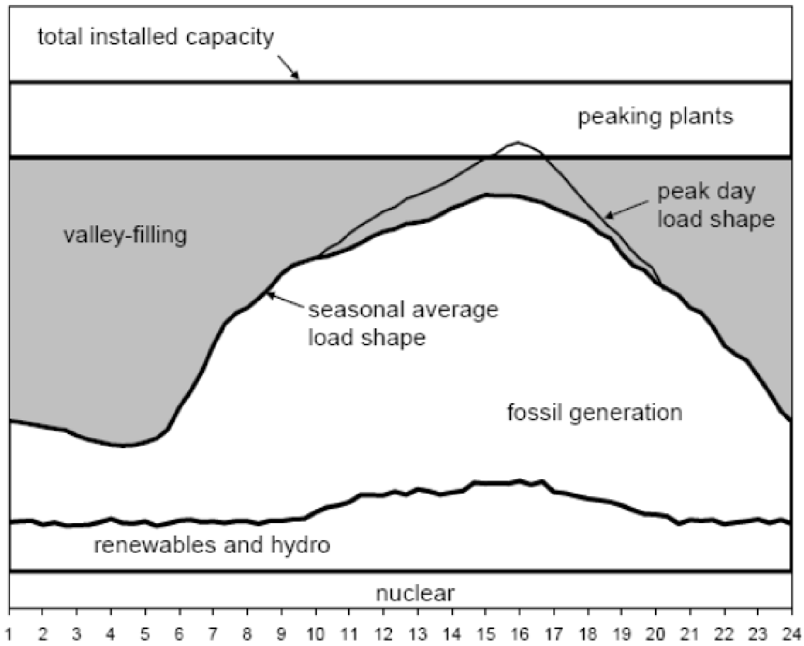


Figure 11: Typical load shape and generation sources; Source: Le Francais en Ecosse (LFEE), 2007

The electricity grid and the electricity supply will change step by step to a **Smart Grid**. In this established smart grid, in a mid- to long term perspective, it is expected that electrified vehicles with 'Vehicle-to-Grid' (V2G) technology and renewable energies can help to smooth the load shape and tear down the frontiers of valley-filling.

The charging infrastructure

The charging infrastructure, as well as the grid infrastructure, has to accompany the market penetration of electrified vehicles from the very beginning.
Infrastructure cost for charging are depending on place and type of charging. If the charging point is in a garage or an inside place investment is low, if the charging point is on the roadside the costs increases. In the case of a fast charge charging point costs will increase strongly. The impact of a fast charge point on the grid is greater (harmonics, load) than the

slow charge but there is no need to create a specific dedicated network but reinforce the existing one to ensure security of supply.
Implementing the V2G technology to stabilise the grid by using the car as energy storage device, costs for the bi-directional charging/discharging infrastructure will increase.

The charging of a battery depends, besides of the battery characteristic on the:
- Charging power (i.e. the voltage/amperage) and charging time
- Charging technology

The following table will show the context between charging time and charging power:

Charging time	**Power in kW**	**Power in Amps**
Slow charging	3-6 kW	10-16 amps
Fast charging	around 25 kW	16-32 amps
Ultra-fast charging	45 kW and more	> 32 amps

Table 4: context between charging time and charging power

Also the estimated use of the vehicles will determine the kind of charging infrastructure more appropriate to optimise the infrastructure costs. In houses and office buildings, the more appropriate charging infrastructure would be slow charge because the car stays a big amount of time parked in the garage. On the street, the more appropriate would be fast charge because the use of public space is an increasingly scarce resource. Recent results show us that the presence of fast charger on the street increment the use (km) of the electric vehicles but not the use of quick charge charging points in the same proportion. This fact would compromise the payback of the investment. However, governments and industry need to determine who will pay these costs, at what point during electric vehicle expansion should different investments be made, and how investments will be recovered.

Regarding the charging technology, today the following steps are feasible:

> Charge while stationary
  > Slow plug-in charging
  > Fast plug-in charging
  > Ultra fast plug-in charging

  For the mid and long term, the possibilities for wireless (e.g. inductive) or contact charging have to be examined.

  > Inductive charging: charging over inductive loops or inductive wire in the road, e.g. at bus stops, in front of traffic lights, parking spaces
  > Contact charging: charging by direct contact, e.g. over the car numberplate, on the roof of a city bus or through a pick-up connecting to rails in the road.

> Charge while driving
  > Inductive charging: charging over inductive loops or inductive wire in the road, e.g. on ‘green corridors’, special lanes
  > Contact charging: charging by direct contact, e.g. over contact rail in road or by catenary system.

One other 'innovative' electricity recharging systems should be considered. Battery exchange systems can provide very rapid replacement of depleted batteries with those that are fully charged, although many questions remain in regard to cost, extra required battery supply, compatibility of the battery systems used by different OEMs and replacement of new batteries with potentially older batteries.
One big challenge to be solved for the battery exchange system is the standardisation of the batteries and the exchange technology. To consider are among others: the plug-in technology, the cell technology, standardisation at cell level or at small package level, robotic exchange, etc.
Another question is if one should change empty batteries and charge them by fast charging or if one should change charged batteries. Fast charging could be important for battery exchange systems, since it increases the effective supply and lowers the number of batteries that must be kept in reserve to meet peak demand. The burden is the charging time of about 15 minutes. To change fully charged batteries is much faster but introduces challenges in storage space/capacity and safety.
Battery technologies and licensing systems would also need to be compatible.

Charge while stationary

Different possibilities will accompany the introduction of electrified vehicles, plug-in solutions, inductive and contact charging.

Plug-In charging

The plug-in charging technology will be the first to accompany the electrified vehicles during market introduction. Slow charging at home and during work and shopping in some big centres will be the first step. Charging points/columns with about 3.5 kW and a charging time of about 4 hours are needed to have a vehicle capacity for about 50 km. Besides the extension of the infrastructure, the second step will be fast and ultra-fast charging options. Ultra-fast charging points requires about 45 kW (up to 100 kW) to reduce the charging time to acceptable 15 minutes.

Inductive charging

To make electric vehicle easier to use, the developing of a wireless/cable-free charging system is requested. It's the technology to charge a vehicle's battery wireless if transmission system is nearby. For example, charging equipment buried in the road surface will be able to charge while signal stop or brief parking for shopping. Development is on-going for the future to feed electricity from vehicle to home wireless as well. Evolution of charging and feeding will make electric vehicle even more convenient. It will develop even more comfortable car life.
In Geneva and Torino together about 30 buses are running since 2002 with the so called Inductive-Power-Transfer-Technology (IPT). The buses in Torino are running reliable 200 km each day, without long charging stops. Through the business-concept of occasional short charging there is the benefit of lower weight to move, less space is required and there are no trips to battery changing stations necessary. During night the battery will be charged completely, over day during operation, charging will be done depending on demand and possibility. At dedicated bus stops, accordingly equipped, battery charging with 10 to 15 percentages will be done during getting in and out of passengers. The in-between charging

provides enough energy for daily operation, so that the stored energy could be reduced to a minimum.
The end results for daily bus operating, costs and system efficiency are very positive after 10 years.

Figure 12: Wireless charging of busses in Turin, Italy
Source: Conductix-Wampfler AG, seen by M. van Walwijk 2011, Secretary General IA-HEV).

Even if the test results for buses are very positive, there are a lot more points to solve in general and especially for passenger cars.

The challenges of inductive charging while stationary are:
- the today's bad efficiency has to be improved
- the position of the vehicle must be very exact to the transmitter
- the transferred energy quantity depends on the air gap. A standardised distance is necessary. A very expensive possibility is the connection with a plate positioned by a robot

Contact charging

Two possible solutions are feasible:
- direct contact via a vehicle part to a contact plate, e.g. via numberplate of the vehicle to a relevant contact
- a robotic connection, e.g. a plug coming from floor or wall connecting with the vehicle or a pick-up connecting to rails in the road or to a contact surface on top of the vehicle (e.g. for city buses)

Charge while driving

Inductive charging

Inductive charging or wireless power transfer (WPT) could mitigate the limitations and problems of battery-powered electric vehicle by delivering electric power to moving vehicles via time varying magnetic fields. Successful demonstrations of this technology have been carried out throughout the world in outdoor conditions. An efficiency of 80% with reasonable air gaps has been measured. The challenge is to maintain a defined air gap under realistic driving behavior and different additional load. The extra cost (just for the construction) for such a technology is estimated with some M€/km. For long haul trucks, one can imagine solutions on 'green corridors' in the far future. For passenger cars there could be a solution in the far future on some dedicated lanes on highways.

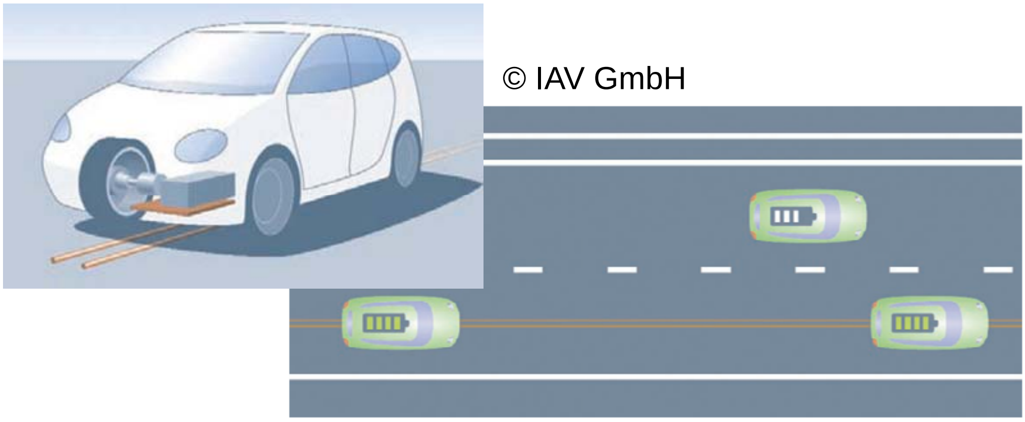


Figure 13: Vision of road integrated charging (Source: Martijn van Walwijk, Secretary General IA-HEV)

However, there are still a lot of deployment considerations to be solved which include estimating the life-cycle costs (e.g. lithium demand vs. ferrites demand) and benefits of roadway electrification as well as determining optimal operational approaches, including synergies with automation technologies.

Among the already identified problems, two issues can be highlighted. First, the sanitary aspects of such a technology must be studied. The magnetic field emitted by many passing cars, i.e. traffic, may be not the same as the magnetic field emitted by a single passing bus or truck, e.g. on a dedicated lane. Second, the construction and durability of the devices must be studied. Indeed, the primary coils are likely to be included in concrete structures which will be embedded in the pavements. If it is embedded in a concrete pavement, the WPT device is likely to both weaken the slabs (the device cuts the slab in two parts) and to prevent their dilatations. If it is embedded in an asphalt pavement, i.e. flexible pavements, the concrete device is likely to move and to weaken the pavement structure as well.

As it is, there are thus strong research needs to develop a basis for defining a sensible deployment stating strategy that is technically, economically and politically supportable. In this aim, demonstrators at different scales are still necessary to identify the implementation and regulation issues.

Contact charging

For the so called contact-running charging, two possibilities are there: the overhead line and a sliding contact in the street surface. For the overhead option, many years experience is available from the so called 'Trolley-Bus'. Sliding contacts have also been used in several tram systems around the worlds for more than 10 years and are currently being adapted to heavy duty trucks.

Siemens is testing today the 'trolley system' for truck application. It might become an option for goods transport on main European axis.

Figure 14: Electric truck on a Siemens test track north of Berlin; ©Siemens-Pressebild

Figure 15: Alstom APS system (here a tram in Bordeaux) which is currently being adapted to heavy trucks (source Alstom).

Nevertheless a sliding contact is always critical. Research is needed to analyse the potential of such technology and to understand the ecological and economic benefit.

Standardisation

It is important to avoid over-regulating in order to allow for innovation. The International Standards Organisation (ISO), the International Electro technical Commissions (IEC), SAE, the Underwriters' Laboratories (UL), and other organisations can play important roles in coordinating and setting standards. Likely areas for standardisation are:

- Plug types
- Inductive and contact charging
- Interoperability of charging systems
- Recharging protocols
- Communications protocols between cars and recharging infrastructure
- The different electricity providers have to standardise the paying systems.
- The allocation of the vehicle to the plug socket must be defined
- Regulations for public recharging that ensure safety with minimal administrative challenges
- Battery recycling standards and regulations
- Standards for battery packs (not for the cells)
- Utility regulations conducted by state/provincial authorities to ensure orderly participation in this market

The grid infrastructure

Vehicle to Home, Vehicle to Grid

The idea of Vehicle to Home (V2H) and as second step Vehicle to Grid (V2G) system is to use the distributed and stored electric energy provided by the batteries of electrified vehicles. Needed is an appropriate interface for the exchange of electricity and data between the vehicle and the grid, this based on a business case involving the car owner, energy providers and grid operators, public authorities and utilities.

Before you can use the possibility of integration vehicle to electricity grid, some basic steps of the charging infrastructure must exist.

A basic step to facilitate the market success of electrified vehicles is the possibility for owners of electrified vehicles to charge the vehicle at home as well as during business hours. Simultaneous or as fast follower to charging at home/business, the establishment of a smart charging infrastructure, the Grid to Vehicle (G2V) possibility to charge everywhere will take place. G2V infrastructure at parking structures, during business hours and shopping, are essentials for the market introduction and success of electrified vehicles.

The fully integration of electrified vehicles to the grid, the V2H and V2G infrastructure needs some more technologies and investment.

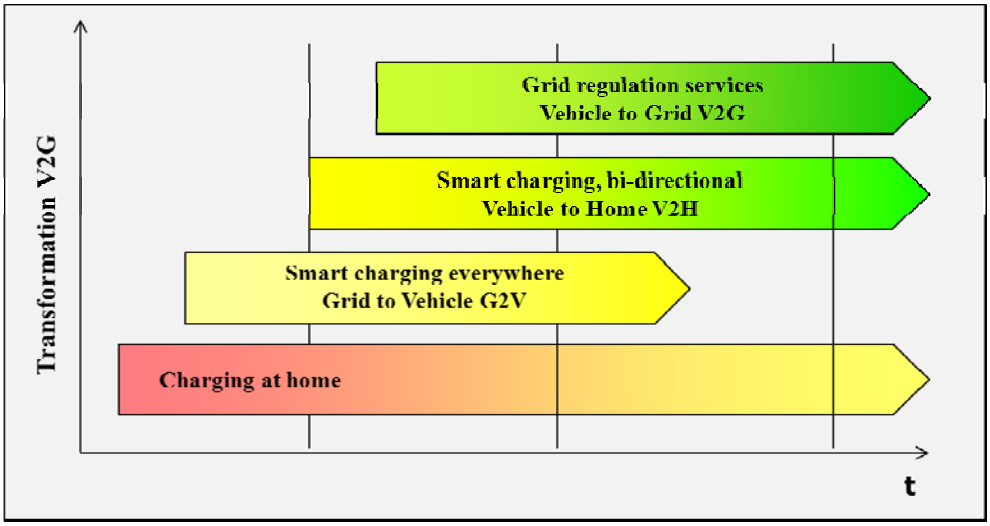


Figure 16: Development steps Vehicle to Grid over time; Source: Basic picture from 'Interessengemeinschaft Vehicle to Grid' (IG V2G); goals for the years 2009 – 2011

The stored electricity of electrified vehicles could be used as back-up capacity to help to tune down unusual demand spikes, at home and in the grid.

The bi-directional V2H system could be extended to a home assisting charging system.

The possibility to be examined is to utilise the electric vehicle with large capacity battery as the electric power source of a home, connecting with energy management system which is to use energy more efficiently at residence. The vehicle integration is not disturbing the usage of the car while feeding electricity to the home steadily. It watches the amount of electricity left in the vehicle's battery constantly and defines the available amount to feed to home.

From charging at low-load times up to the provision of extra control energy, plug-in vehicles could contribute essentially to the 'shaping' of the energy load of the energy supplier. With these benefits they support also the enlargement of renewable energies in the electric grid, not easy to predict.

Grid powering from batteries could be very useful for provision of peak power and load balancing, but needs to be controllable by vehicle owners. There could be important limitations on how much depletion in battery capacity that vehicle users will tolerate (e.g., the driver must be able to leave the car parked at work and be able to get home again). Adverse impacts on battery life must also be understood and minimised.

With dynamic pricing, the EV owner would make a profit because the midday peak price offered for selling power during the afternoon should far exceed the cost of charging the battery at night.

This is the final frontier of valley filling and is an exciting idea, given all of the potential benefits.

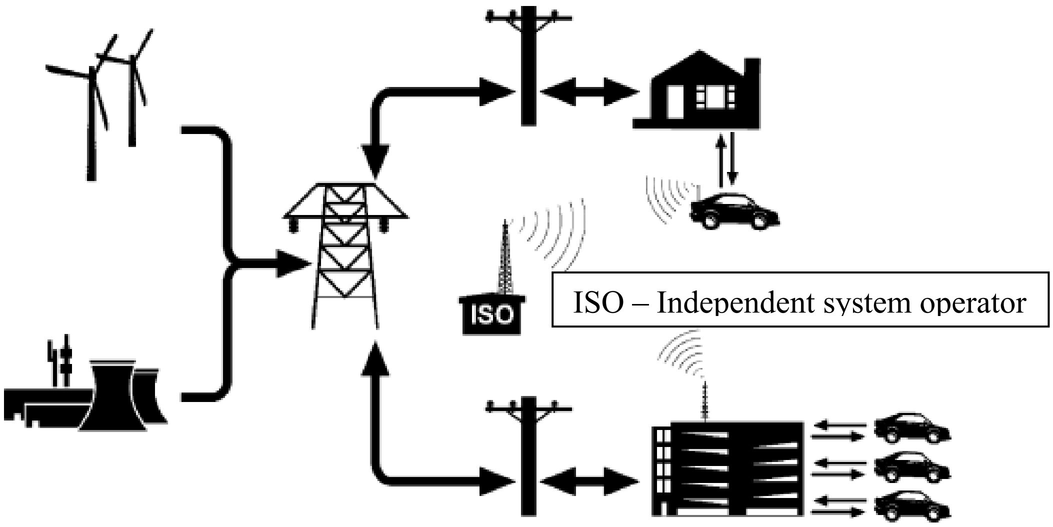


Figure 17: Concept of 'Vehicle to Grid'; Source: Willett Kempton; ScienceDirect, Journal of Power Sources 168 (2007) 459-468

The Vehicle-to-Grid technology will not be ready for the short term application. The relation of utility to expenditure is to examine, a lot of research is to be done to introduce this technology to the market, in a mid to long term perspective.

Main challenges today:

- Willingness of the vehicle owners to provide their battery for load-optimisation and control energy.
- Battery technology: Development of long-life batteries for frequent charging – discharging. Further progress in battery capacity, weight and cost has to be achieved.
- Provision of a Smart Grid technology in dependence of load-speed (slow/fast) and place (city/landscape, at home/on a trip): Smart Grid and Smart Metering are essential components of V2G.
- Development of a communication infrastructure between network-operator, vehicle battery and load-infrastructure. The complexity of knowing the battery-load-condition, charging points, grid-load. When to charge the battery from the grid, when could power given from battery to the grid.
- Fast charging needs a load-performance up to more than 100 kW. This could not be carried out with the existing infrastructure. Fast charging infrastructure in parking buildings, at train stations, airports and shopping centres needs a connecting performance of several MW.
- Thrift of fast-charging infrastructure, vehicle identification and payment systems if in each case only small quantities to be 'refuelled'.
- The complexity of the distribution systems required: Two-way inverters would need to be developed and installed on a wide scale to bring V2G to fruition.
- Billing infrastructure business models.

Smart Grid, the 'Internet of Energy'

Vision: "…A future energy supply may be organised in a decentralised manner with a large amount of renewable energy sources. Due to the fact, that the energy supply of this facilities is partly difficult to plan and foresee, the demand for regulating energy in the grid would rise…." (ENCO, 2007)

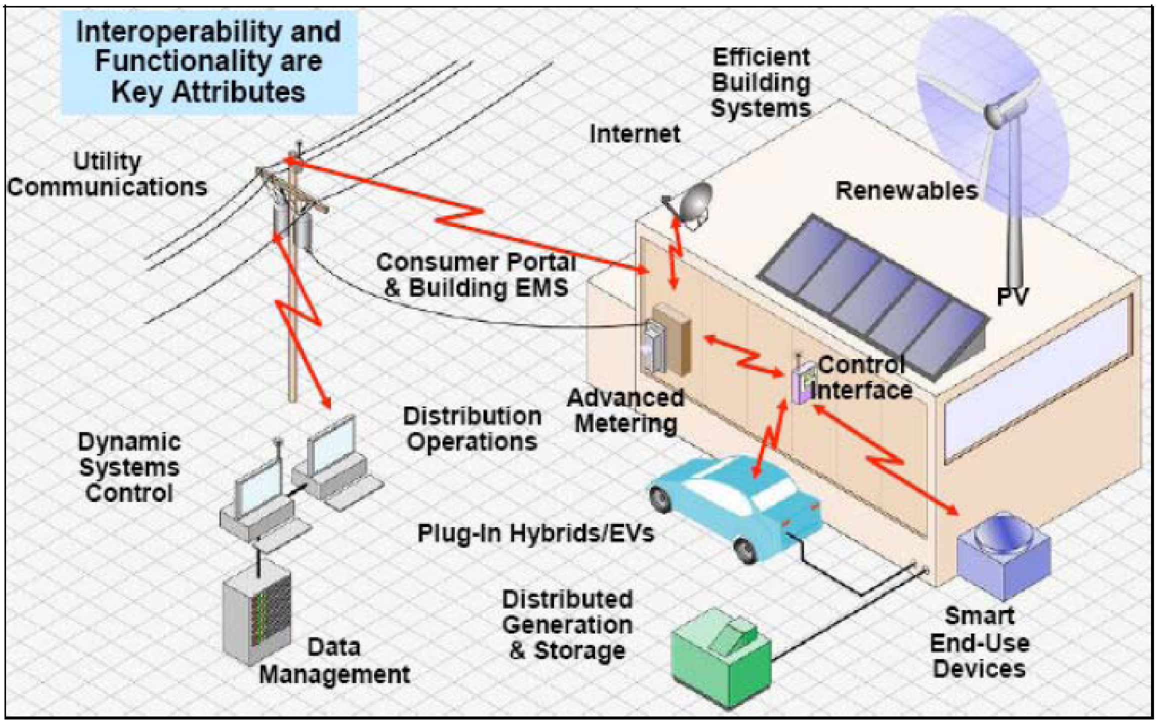


Figure 18: The Smart Grid; Source: Trend Watching Group (2008)

As said, the electricity grid and the electricity supply will change step by step to a **Smart Grid**. The grid is presently strictly one-way, meaning that utilities have no way of measuring electricity usage with any more granularity than a monthly manual meter reading. Information on consumption and return of electricity are needed in a very finer dissolution. The online-control of consumers, decentralised production plants will allow an optimised regulation of the electricity grid.

Big companies from the ICT sector as IBM, Siemens are developing today with international energy suppliers the corresponding hard- and software. Smart Grid is the answer for volatile production and open markets; it is the connection of the ICT industry with the energy supply industry.

There is a great correspondence that the electric mobility will be an essential part of this 'Internet of Energy'. The possibility to use the car batteries as intermediate store makes the plug-in electric vehicles to an indisputable part of the Smart Grid. As part of the Smart Grid the 'Smart Metering' hardware and communication network, the Automatic Metering Infrastructure (AMI), is a key enabler of the electricity valley filling approach. Smart meters will measure electric usage in real-time and communicate this to the utility via radio frequency or broadband over power line technology. The role of smart metering should be fully explored via trials, with good information sharing. All forms of advanced charging systems (e.g., vehicle-to grid power flow, day/night price differentials, restricted charging during peak demands) will require smart metering systems.

Smart meters and the wider smart metering system will offer:

- A common application layer and protocols allowing, through the 'end-to-end' smart metering system, remote communication with compatible charge-points and plug-in vehicles.

- The opportunity for energy suppliers to introduce time-of-use tariffs to incentivise off-peak plug-in vehicle charging.
- The opportunity to meter and transmit plug-in vehicle usage separately, allowing energy suppliers to develop tariffs specially for plug-in vehicles; and
- The ability to support dynamic Demand Side Management (DSM) - actions that influence the quantity or patterns of use of energy consumed by end users – in conjunction with a future smart grid, potentially allowing plug-in vehicle recharging to respond to signals from the grid. DSM must optimise the recharging of vehicles based on the available generation capacity and understanding which customers' vehicles will need to be fully charged at what time of day.

The Integration of Renewable Energies into the Smart Grid

In the same way that electric vehicles enable load shaping to increase utilisation of installed generation capacity, renewable energies also enable greater adoption of intermittent energy sources by scheduling electrical loads to coincide with periods of strong wind or sun. Wind in particular is suitable for providing electric vehicle charging, as it tends to peak around dawn and dusk when vehicle recharging will be most convenient and affordable.
Another possibility is if EV batteries continue to increase storage capacity, excess power generated from utility scale wind power plants during the night could be stored in EVs and then used to provide power to the grid during the day.
A promising solution to use the surplus electricity is the production and storage as fuels.

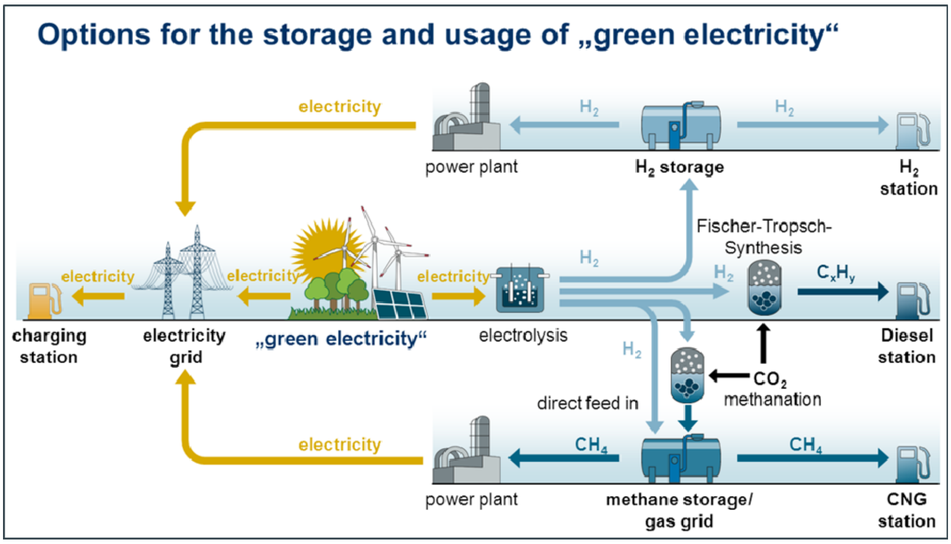


Figure 19: From surplus electricity to fuel; Source: Volkswagen AG

Concerning fuels the transition of the energy system towards high penetrations of renewable energies results in even more possibilities to make use of green electricity. Load shaping through EVs and the subsequent use of the electricity in the car is the most efficient way (well-to-wheel) among those, but the conversion of electricity into chemical energy carriers has important benefits as well. These are namely the possible relief of the electricity distribution grid and the reduction of otherwise necessary new construction of high voltage power lines in the short and medium term as well as the potential to utilise net generating surpluses from renewable energies in the long term (serving as long-term energy storage after 2025).

The chemical storage technology is based on electrolysis as its essential component, converting water and electricity into hydrogen, oxygen and heat. The efficiency of the process reaches 60% to 80%, depending on the utilised technology (Proton Exchange Membrane or Alkaline) and the required product properties (purity, pressure, etc.). The hydrogen produced can be stored and transported and then be used for re-electrification (given a price spread on electricity markets) in adapted power plants or as a fuel in FCEVs. In the long term, utilising substantial net generating surpluses from renewable energies, this pathway may become highly important for sustainable long distance mobility.

In the short term though, with FCEV still being in research/ development status, there are two different potential pathways to utilize the hydrogen produced. They are direct feed in of the hydrogen into the gas grid or further transformation of the hydrogen into hydrocarbons that are consistent with present-day ICE vehicles.
When feeding hydrogen directly into the gas grid, however, certain regulatory limitations and customer demands must be taken into account because of the multitude of requirements on fuel gas of different end user appliances (boilers, turbines, engines, stoves) and the distribution grid (gaskets, joints, compressors, pipelines, etc.). This is due to the fairly different substance properties of hydrogen and methane regarding for example heating value, Wobbe-Index, ignition boundaries, permeability and compressibility.
One potential pathway towards hydrocarbons is the methanation (efficiency from hydrogen to methane is about 60 %) of hydrogen with carbon dioxide, producing a methane rich mixture of gases (containing CO_2 and H_2 as well) that meets the standards for natural gas and can thus be blended to the gas grid without any restrictions. The well-to-tank emissions of the Substitute Natural Gas depend on the source of the CO_2, which can be either fossil (from power plants, cement plants or ironworks) or renewable (from biogas/bio-methane plants, breweries or bioethanol plants).
Another possible fuel from green electricity and CO_2 is synthetic diesel that is produced by Fischer-Tropsch-Synthesis. This process is, however, even more complex than the methanation and has a lower efficiency.

Essential challenges of today, to solve for further progress, are:

- Repercussion on the grid stabilisation caused by a multiplicity of decentralised grid supply. The separation between producers and consumers will be annulled, within the smart grid 'prosumers' will act.
- The development of energy management systems for the consumer with a wider range than only smart metering, able to communicate and steer installation up to the small management of in/out of other energy like solar energy.
- Development of information and communication technologies from the energy utility to the 'prosumer'.
- Optimisation, also of the dimension, of the electricity grid because of the integration of a lot of different producers/consumers up to electrified vehicles.

Smart Grid could be the enabler for new technologies, for e-mobility as well as for renewable energy as solar or wind.

But different levels of technology will involve different costs. Optimisation and standardisation will eventually be necessary.

Business models

For the specific market-potentials and the market-introduction-speed dedicated development steps are crucial (e.g. provision of vehicles), in which activities for the support market development, boundary conditions, technic) are necessary. If the expected technology developments will occur, new business models raise up at the interface of vehicle-mobility and power supply. These new business models will offer new possibilities of cooperation between the branches and will change fundamental the relationship between power plants, vehicle drivers and car manufacturers.

Essential challenges are today:

- The economic justification for utilities and consumer, the relation of expenditures (investment) to the utility, the gain for grid or electricity provider and the consumer.
- Evolution of services, which satisfy the needs of vehicle owners, electricity supply and automotive industry and which will be accepted by the customers (intervention into the car, energy management for the house).
- Pertinent elements, as tariff structures for vehicle owners and –operators (e.g. park & charge), financing models (leasing and management of vehicles and components as batteries).
- Composition of the interface to the consumer and new widen services (offer of ecological electricity, mobility instead of energy, etc.).
- Operating of stand-alone systems, as solar panels on the garage-roof without direct grid connection.

Framework conditions

The described evolution and the broad market introduction of electrified vehicles, of the smart grid and pertinent business models need broad accepted and reliable governmental and political framework conditions.

Essential challenges to develop are today:

- (Quality-) standards and security-guidelines
  Likely areas for standardisation are:
    - Plug types, inductive and conductive charging, boost-charging, recharging protocols, communications protocols between cars and recharging infrastructure, regulations for public recharging that ensure safety with minimal administrative challenges, battery recycling standards and regulations, utility regulations conducted by state/provincial authorities to ensure orderly participation in this market.
- Legislation framework for the relationship between vehicle owner and electricity supplier.
- Framework conditions for the control of the ecological quality of the activity (electricity, infrastructure, communication) and the traffic-emergence (traffic-control, parking-space management, building legislation).
- Tax aspects and incentive measures

Overview on challenges and research needs for the infrastructure for electric energy

Essential challenges today for the market development of a pertinent infrastructure for the green vehicles are:

From vehicle side:

- Production of batteries with high capacity, a big increase in charging-/discharging cycles, short charging times, low weight and costs
- Energy- and driving management within the vehicle
- Specialised design and structure for hybrids and electric vehicles
- The high voltage and high current in electrified vehicles. The generated magnetic alternating fields can disturb the vehicle electric system (board computer) and can have a harmful influence on the human body

From infrastructure side:

- Establishment of the Smart Grid
- Establishment of a service network to allow a reliable operating of the vehicles (hubs, charging points, information on the charging infrastructure)
- Business models for charging and bi-directional charging (prices, billing)
- Potential electromagnetic radiation issues needs to be addressed
- Safety issues to pedestrians/bicycles/etc. needs to be addressed
- Road maintenance

4.1.2.2 The Infrastructure for Liquid and Gaseous Energy [2]

The Report of the European Expert Group on Future Transport Fuels (December 2011) concludes:

The main alternative long-term options for substituting oil as an energy source for propulsion in transport are electricity, liquid biofuels and hydrogen; synthetic fuels as a technology bridge from fossil to biomass-based fuels; methane (natural gas and bio-methane) as a complementary fuel; and LPG as supplement.

Single-fuel solutions covering all transport modes would only be possible with liquid biofuels and synthetic fuels. However, feedstock availability and sustainability constraints limit their supply potential. It is therefore unlikely that there will be a single solution for the fuel for future mobility. The precautionary principle would then already advise to base projections on future mobility on multiple options. Fuel demand and GHG challenges require the use of a great variety of primary energy. Therefore, all environmentally and economically sustainable fuels will be needed to reduce the existing 96% oil dependency of the European transport sector.

Biofuels

Biofuels could technically substitute oil in all transport modes, with existing power train technologies and existing re-fuelling infrastructures. First generation biofuels are based on traditional crops and on animal fats. They include FAME biodiesel, bioethanol, HVO and bio-methane. Second generation biofuels are produced from ligno-cellulosic feedstock and wastes. They include bioethanol, higher alcohols, hydrogen, DME, BTL and bio-methane.

[2]: main source: Report of the European Expert group on Future Transport Fuels January 2011 and December 2011.

In the near future, an increased production of known biofuels as Ethanol and FAME/DME will be still blended with conventional fuels. European wide standards for ethanol are on the priority list. The production of glucose based biofuels and biofuels from residuals (e.g. straw) will ramp up.
Bio-synthetic fuels can – by design – be used neat or be blended at any mixing ratio with conventional mineral oil based fuels. This applies for all main bio-synthetic pathways: HVO, GTL, BTL and new pathways as the biotechnological fuel production originates from the thousands of years old principle of microbial fermentation of sugar-rich raw materials.

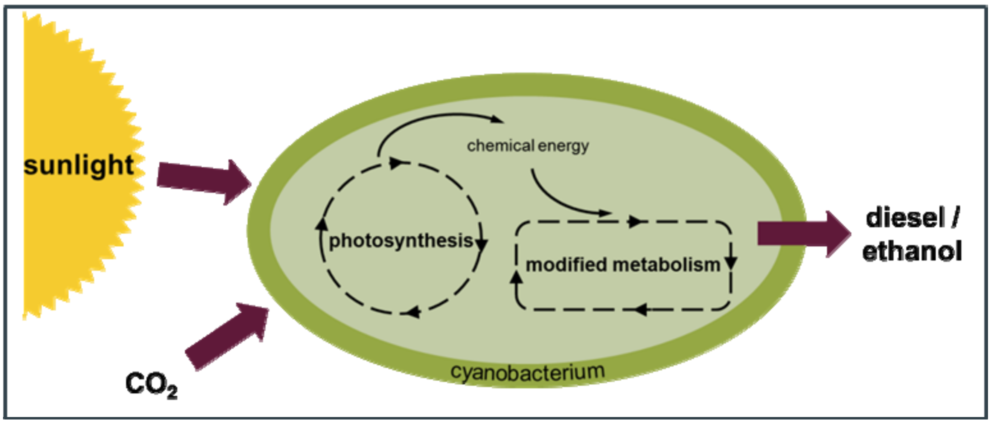


Figure 20: Biotechnological fuel production; source Volkswagen AG

As long as the blend-in concentration is compatible with the blends mandated by the Fuel Quality Directive and existing standard vehicle technologies, biofuels can be distributed through the existing re-fuelling petrol/diesel networks and no specific infrastructure is required.
Modifications to the existing infrastructure and distribution systems could be required by high-blends of ethanol and bio-ether, as E85 with 85% ethanol and 15% petrol.

Methane and Liquefied Natural Gas

Methane can be sourced from fossil reserves of natural gas or from biomass and wastes as bio-methane. Additional refuelling infrastructure has to be built up to ensure area covering supply. Methane in compressed gaseous form (CNG) is an unlikely option for long-distance road freight transport because of low energy density. Liquefied methane gas (LNG) could be a possible option in these cases. Harmonised standards for bio-methane injection into the gas grid and the build-up of EU-wide area covering refuelling infrastructure have highest priority.

Liquefied Petroleum Gas

LPG (Liquefied Petroleum Gas) is a by-product of the hydrocarbon fuel chain, presently from oil and natural gas, in future possibly also from biomass. The core infrastructure is established. Enlargement in several European countries is necessary.

Hydrogen

Hydrogen is a universal energy carrier which can be used as fuel for transport. Hydrogen can be produced from all primary resources and therefore offers diversity of supply of energy.

Hydrogen can be produced on both a small and large scale from centralised and decentralised production. It is currently used to supply energy to a wide variety of industrial applications.

The use of hydrogen in a fuel cell with an electric motor is an alternative and a complementary solution to the storage of electricity in batteries for EV or hybrids. It provides longer range and faster recharging compared to the storage of electricity in batteries for EV. In the long term, it may be also possible to use hydrogen to fuel internal combustion engines, either directly or blended with natural gas (up to 20%).

Hydrogen as an alternative fuel for transport needs building up the necessary refuelling infrastructure, in order to reach a sufficient geographical coverage to accompany vehicles' market entry.

Infrastructure build-up for hydrogen and the needs for battery electric vehicles are complementary. It would not be wise to pick one or the other. Battery cars are more suited for the small size segment and shorter range, whereas fuel cell cars can serve larger cars and longer range.

The investment for the hydrogen infrastructure should be concentrated in areas of high population density (large cities) and should build on existing infrastructure.

Between 2020 and 2030 the first steps are taken and the commercialisation can firm up. The investment risks decrease as the fleet increases and the technology further tested. The learning rate will go down. After 2030, the goal is to achieve 25% market share in 2050.

In terms of geographical coverage, territorial spread is key and a gradual and coordinated build up of infrastructure across Europe would be needed.

A reasonable approach is to start in one or several geographical areas in order to de-risk the technology then develop a roll out plan for Europe.

One should combine national and European longer term interests and allow smaller scale demonstration and deployment projects to de-risk the technology and absorb the learning costs, reducing these for subsequent roll-out projects. In this way private and public stakeholders can together build up a European infrastructure network in a cost efficient way.

In the past, Europe has built a number of times parallel fuel infrastructures, such as the full size area covering distribution systems for several quality grades of gasoline and diesel, and in a smaller scale also for LPG and methane.

4.2 The Service Infrastructure

We can foresee some significant events for future Service Infrastructure solutions.

I. **Increased cooperation**: Smart ITS solutions, applications and services that support users of the system in an enhanced ITS infrastructure is vital. New solutions are being developed at the industry level in close collaboration with infrastructure owners and other stakeholders, such as cargo owners and transport operators. It should be noted that all modes must be addressed to ensure optimum utilisation of the whole transport infrastructure.

II. **Vehicle specialisation**: There are various solutions that enable the effective management of the city's transportation needs; two different systems can emerge in parallel with each other. One system of small, light vehicles, primarily for personal travel, and another system for heavy vehicles used for public travel and for the city's service and transportation needs.

III. **Mode separation:** Even if different modes will interact more with each other and uses the same infrastructure when possible we expect a physical and operational separation between modes, with well planned meeting places or transfer points between different modes that enables an efficient and seamless transport chain.

Information for the road user will not be different for drivers of green vehicles then for traditional cars. The relevant information they additional might need is about fuel and charging abilities. The general idea is that the best way to give this information will be by in car navigation systems or smart phones, rather then by information places besides the road. Those systems are more accurate and much more up-to-date.
A special issue might be the relation to incident management. A changing car fleet and power trains will give additional risks to those people involved in traffic accidents, broken cars et cetera. A risk assessment should be made defining what additional risks might occur and what the possible control measures could be.

The Service Infrastructure for Cities

The service infrastructure for “green vehicles” in the urban environment of future cities needs to include

- Vehicle-related services such as parking, charging, maintenance and mobility services (car sharing/car pooling; short term rental)
- Non transport related services such as delivery services, retail or office/meeting facilities available for short term rental.

Charging points for persons / private mobility

An easy to use possibility for charging the own vehicle will be during work in the parking areas of the companies.
Charging in cities itself will be offered mainly through shopping centres and on bigger parking areas.
Park & Charge with wireless charging systems is the idea of a convenient charging system.

Integrating green mobility services

Service offerings directly related to road transportation and non transport related services need to be integrated. As space in urban areas is both, expensive and scarce, the footprint of the different service infrastructure needs/functions have to be minimised. Those “hubs” will help to tackle the side effects of urban mobility, such as pollution, noise, congestion, land use by offering highly space efficient serve solutions within one piece of infrastructure. Multi-modality is another crucial aspect of the infrastructure as changing from one mode to another should be made as convenient as possible.
The concept of such all-integrating hubs, which are closely linked to the public transport system, is recently emerging as a service-design domain in mobility research.

Figure 21: An integrated urban mobility services hub as an energy self-sufficient building structure; Source: Volkswagen Group.

Infrastructure for city transport

With the expected increase in freight demand and the need for innovative solutions to concentrate transports to dedicated city corridors, we conclude that there is a further need for efficient solutions that contribute to reduced environmental impact from the transport.
In conjunction with that, the infrastructure, management of loading and unloading goods, transport logistics and vehicles continue to evolve and adapt.
This means more opportunities for inter-and co-modal transport solutions and to increase logistics efficiency by using more integrated logistics information in physical transports through the use of ITS solutions. Development of the city's physical road and ITS infrastructure will also be of vital importance and that new solutions are developed at the industry level in close collaboration with infrastructure owners and other stakeholders, such as cargo owners and transport operators.
The fundamental objective of the city's transports and possible infrastructure solutions is how these can be made more "green" in terms of sustainability with other societal goals. It should be noted that all modes must be addressed to ensure the best possible utilisation of the whole transport infrastructure. Of particular interest are the transfer points, which tie together the different modes, thus enabling effective unbroken chain from sender to final destination.

For freight transports, charging facilities will probably initially be located at terminals and hubs, etc. and for buses running in public transport services we foresee that they will be located at the operators garages and at end stations. *When the technology for wireless charging is ready it would be transferred to charging zones in the city.*

A first step, in order to propose and give examples of what measures should be taken in a city transport corridor and the required research in this area, is to clarify the effects we hope to achieve with the action taken. A summary of the effects that are considered relevant to strive for is given below, followed by an overview of actions which have the potential to contribute to the desired effects. The effects that are considered relevant at an overall level are divided into two areas, "Reducing the local environmental impact" and "Efficient transports for cities". These two main areas are explained in more details in this chapter.

Figure 22: Illustrate city corridors for different modes; Source: Volvo

Reducing the local environmental impact

The local environmental impact of transport is a part of the emissions of smog-forming and harmful substances (such as sulphur oxides, nitrogen oxides, carbon monoxide, particulate matter and polycyclic aromatic hydrocarbons). Accidents that result in releases of hazardous substances is also something that can have serious effects on the local environment, and measures to minimize the risk and impact of such emissions is therefore considered appropriate to take. The traffic noise is an example of local environmental effects of humans and nature that should be considered. This is primarily a problem in densely populated areas where traffic intensity is high, but also for areas with sensitive environment.

For heavy vehicles, unlike passenger cars, consist the greenness in a transport not only of direct energy consumption but also "work done". It is the executed transport in relation to the used energy consumption that determines its true greenness.

Efficient transports for cities

The most significant impact factors for the efficiency of a transport is considered to be transport cost, transit time and delivery performance (reliability). The transports cost include the cost of fuel, driver salaries, vehicles, transfer and administration.
The total transport time is, for much of the driving time and unwanted stops due to congestion, but to some extent also the time for loading, unloading and administration. The opportunities to meet the required standards of delivery performance (i.e. in the degree to which the goods arrive within the contract time) are highly dependent on the risk of delays on the route, for example, due to bottlenecks in the system. The transport flexibility for deviations (e.g. traffic accidents) causes that alternative routes are also essential to achieve that successful delivery accuracy can be maintained. The flexibility of the system is affected by other factors such as regulations relating to driving and rest periods.

The infrastructure layout and available support is an important driver for the efficiency, some examples of challenges:

- An increased strategic perspective of society and increased community involvement in the location of terminals, hubs, and "gates" in the city or its surrounding area, in order to minimise unnecessary transport movements.
- Terminals, hubs, and "city gates" with improved availability and easy access, security and service for the vehicle and “driver villages" for drivers.
- Service points that allow "One stop shopping" to reduce unnecessary driving to and from the workshop and between workshops, but also to reduce unnecessary downtime.
- Location of service points to reduce unnecessarily long runs and unnecessary fuel consumption.
- Redundancy and re-routing to keep the transport running and to minimise unnecessary stops that leads to increased costs for goods owners, transporters and other stakeholders.
- The infrastructure for ITS is deployed. Information providers and information brokers receive and deliver relevant and real-time situational information to transport operators

Green Hubs and Green Corridors

There is a relationship between the future mobility paradigm in the cities and the way the charging infrastructure will operate as a part of the global Smart Grid Model and as a part of the Green Hubs and Green Corridors models.
‘Green hub’ means development of efficient interfaces in the transport system. Efficiency in this context is defined as high operational performance, effective use of resources, limited impact on the surroundings and the environment. The approach to develop hubs according to this ambition has two dimensions:

1. The improvement of the hub itself, focusing on operational improvements, reduction of energy use of processes in the hub, and so on, and
2. Relieving the hubs of temporary or geographically concentrated pressures by connecting the hubs with each other.

Figure 23: A hub for rail and road transport; Source: Volvo

Green Hubs and Driver Village

Increased demands and expectations on using the down time during loading and unloading of cargo and the driver's rest time can be used to perform basic inspection and maintenance of vehicles and trailers, may also enable improvements in the working situation for drivers. First, from a social perspective but also from a demographic perspective. Increased difficulty in recruiting drivers in Europe implies that the average age of the drivers may need to be raised and that we at the same time get more female drivers. This implies a greater need for community service linked to terminals and hubs. Driver Villages are established where there is access to accommodation, restaurants, shops, post and bank services, health care, etc.

Green Corridors

Green Corridors will be established when a desired concentration of long distance transportation takes place in certain areas and roads. These need to be supported by a customised or developed service infrastructure.Green corridors refers to High Capacity Transport and integrated transport concept and modality in a well-defined routes.

Figure 24: A Green Corridor for road transport; Source: Volvo

The latter approach is also included in this domain, through the development of 'Green corridors'. This means that the connections between the hubs should adhere to the same standard as the green hubs: high operational performance, effective use of resources and limited impact on the surroundings and the environment.
Green corridors should be conceived as long-distance freight transport corridors between those major hubs both within Europe and between Europe and other parts of the world. Green corridors are not a parallel or competing set of transport corridors but mark rather a holistic approach to European transport policy. It brings together the objectives of reducing emissions, increasing energy efficiency; combining efficiently various transport modes (with the right level of innovation in each of these modes) and supporting the competitiveness of European industry and transport.

A definition of a Green Corridor

Within a Green Corridor we can find:

- sustainable logistics solutions, with a documented reduction in environmental and climate impact, high security, high quality and efficiency
- an integrated logistics approach with the optimal use of transport modes; harmonised rules and transparency for all stakeholders
- a concentration of national and international freight service on the relatively long distances
- efficient and strategically located transshipment points as well as customised and supporting infrastructure
- a platform for development and demonstration of innovative logistics solutions such as information systems, collaborative models and technology

(The Swedish Transport Administration 2008 - SE)

We also stress the importance of business models and information management from a holistic perspective, and that the corridors should be physical and be visible on a map. A prioritisation of physical corridors admits a common priority for eliminating bottlenecks and focusing on best practice for demonstrate the effects. Other prominent features in the corridor are that it includes business models and information, generated from a comprehensive information flow (X2X), e.g. re-routing to alternate routes when traffic jams or accidents. Furthermore, there is a need of transparency for large investments and cooperation between cities, regions, countries.

An additional reference is the EU's TEN-T network of priority transport links within Europe. Again, the concept of green corridors mentioned in connection with a policy review in 2008. Amongst other things, the corridor shall permit substantial freight to hubs 24 hours a day, 7 days a week. Furthermore, they should optimise the utilisation and efficiency of logistics chains, while the external impact on safety, congestion, noise and pollution is minimised (TEN-T Days 2008).

Efficient transport service

In addition to the factors mentioned above are also customer service in the form of, for example, the traceability of goods, which helps to maintain the efficiency of the transport. A freight security with respect to both the damage and crime is affecting factors. To complete the picture of the effectiveness of a transport, it is also appropriate to take into account social aspects such as safety of the driver (in terms of both road safety and crime) and service for the driver (food, accommodation, etc.).

For the above factors, which are considered to directly affect transport efficiency, also some indirect factors can be added. Increased competition as a result of common regulations that provide transparency to many players is considered to push the development of transports in a direction that affects efficiency positively.

An efficient infrastructure needs to be designed so that it supports increased transparency between stakeholders and that it enables greater intermodality. I.e., one needs, in a macro perspective, actively eliminate lock-ins and barriers. Infrastructure planning of neighbourhoods, cities and transportation infrastructure needs to be in more harmony with society's anticipated transportation needs. This is a sensitive area and a show stopper because it speaks for a stronger community involvement and a weakening of market forces.

Energy charging infrastructure

According to this, the future charging infrastructure will be located and operated as a part of those Green Hubs and Green Corridors and for the same reason some of the previous infrastructure will become obsolete. The Smart Grids will manage all the loads of the system, including EVs, taking into account multiple variables but integrated in the concept of 'Smart Cities'.

The Service Infrastructure for Long Distance

The concept of transport corridors is marked by a concentration of freight traffic between major centers and the relatively long distances. Within these corridors industry will be encouraged to rely on co-modality and advanced technology to accommodate rising transport volumes while promoting environmental sustainability and energy efficiency. Green transport corridors will reflect integrated transport concept where short sea shipping, rail, inland waterways and road complement each other to make it possible to choose environmentally friendly transportation. They will be equipped with adequate transshipment facilities at strategic locations (such as seaports, inland ports, rail yards and other terminals and installations) and depots, initially for traditional fuels and later for bio fuels and other forms energy carriers. The Service Infrastructure shall support this.

Road infrastructure

A general observation is that the development of green vehicles and the needed infrastructure for them will not develop by it self.

A technical development is needed. The costs related to green vehicles and the state of the art makes it clear that this at this time is not a serious alternative for the traditional car fleet. At this time it is not possible to predict which technology will prevail and maybe it is possible that several technological solutions for green cars may exist next to each other in the future.

To compete with the traditional car fleet it is necessary that besides an enormous reduction in LCC for those green cars, stimulation by governments is necessary. This can for instance been done by regulation on emissions or a tax policy. This leaves market parties free in the choice of solutions, which is sensible because it can not be predicted yet which technology will develop in relation to costs and social acceptance. For the automotive industry it will be necessary to have a European approach for it is impossible to invest in solutions that are only related to a few countries. Note that green cars by themselves do not offer any additional value compared to the traditional cars and trucks.

For this reason it is too early to invest in large scale project in the infrastructure for long distances.

Looking at the different solutions already on the market, it will be easy to accommodate present infrastructure to new fuels as bio-diesel. There is no need for the road owner to invest in this as nowadays an infrastructure already exists and is being exploited by the private market. Based on offer and demand, the private market will take initiatives to make sure that these kinds of fuels will be available. The task of a road owner is to facilitate this (which already is taking place).

Electric cars need charging facilities. Also this can be left to the market where as demand rises, energy companies or other groups will invest in this. Also here the road owner can facilitate this based on a national and international policy.

Large scale investments in technologies, as for instance inductive charging, need investment in the present road infrastructure are not to be expected for a long term. First it should be known which technologies will prevail before a decision can be made.
It is the classical chicken egg question. Based on a European policy that will stimulate alternative cars and trucks by making them cost attractive, a technical development will take place. Based on that, decisions can be made about investments in the road infrastructure. It should be noted that those investments might be high and interferes with present asset management policies. High investments and related maintenance costs have to be decided on a political level. So again, a policy promoting green cars is needed.
In order to facilitate this demonstration projects are needed. But it seems wise to have these demonstration projects for very dedicated solutions, like public transport and first on a local level (better business cases). Nevertheless, the chicken-egg question is a relevant one. Based on trust in a solution a system approach is needed where road operators and highway research institutes are associated at the beginning of the projects until deployment, so as to solve the arising issues, e.g. the durability of the pavement. This can take a long time.

4.3 A brief look on co-modality solutions

With more than 50% of global population in cities, still increasing urbanisation and suburbanisation in the dynamic European regions, road transportation is a crucial topic for both, cities and their inhabitants as the need for efficient urban transportation is still growing. By 2020 75% of all Europeans will live in city regions.
Co-modality thus serves the purpose for city and inter-city transportation to provide the city and its inhabitants with the most (time- and cost-) efficient modes of transportation for the different distances and purposes.
As co-modality is one of the lead visions and core concepts of EU transport policies, cities will need to develop and implement the infrastructure needed for supporting the most efficient modal choices, esp. with regard to the easy accessibility and diffusion of “green” vehicles and car-sharing services.
The challenge of integrating the needed infrastructure for “green vehicles” has also been acknowledged as one of the most important issues by automotive executives in KPMG’s Global Automotive Executive Survey 2011.
The new infrastructure needed includes

- Hubs for space-efficient, safe and convenient parking & charging of electric vehicles that are closely connected to the public transport services. It also needs strengthened services for the vehicles and the users i.e. drivers and passengers. The extended service services can create an extra value for the society. These strategic interchange-hubs at the core and periphery of urban areas need to serve the dual purpose of personal and goods road transportation, as the consolidation of the increasing traffic from transportation of goods will be integrated in these interchange-hubs.

Those multi-purpose hubs as one important element of the future cities transportation infrastructure need to be easy to access by users and have to offer a combination of additional, green vehicle and transport related services, such as trip-sharing/car-pooling and maintenance.

Cars and public transportation

Another main purpose of these interchange- and parking hubs for green vehicles, esp. in the dense urban centres and at the residential areas is to clear the road from parked vehicles and to

reduce the amount of traffic only searching a parking place, thus enabling increased fluidity of traffic and the conversion of parking space.
Enabling easy mode switching, from cars to public transportation services and vice versa is important for the increasing number of commuters, commuting from the suburbs or nearby communities to the city. Space-efficient parking and time-efficient mode switching are crucial requirements to further increase the attractiveness of European cities as workplaces for knowledge workers.

5. Milestones

In response to the mentioned needs, the involved ERTRAC stakeholders have combined their knowledge and experience, in order to assess which benefits of the infrastructure main technologies can be achieved by when, and what actions will be required to master the challenges of Infrastructure for Green vehicles at large scale.

As a kernel for the roadmaps a scenario for the interplay of 'Green Vehicles' and the corresponding 'Green Infrastructure' based on the expected future was considered. A separate detailed roadmap may be developed for an overview on the development of 'Green Vehicles'.

To strengthen and extend the European competitiveness in the field of Green Infrastructure, the 'European Roadmap Infrastructure for Green Vehicles' has defined the necessary milestones and recommendations.

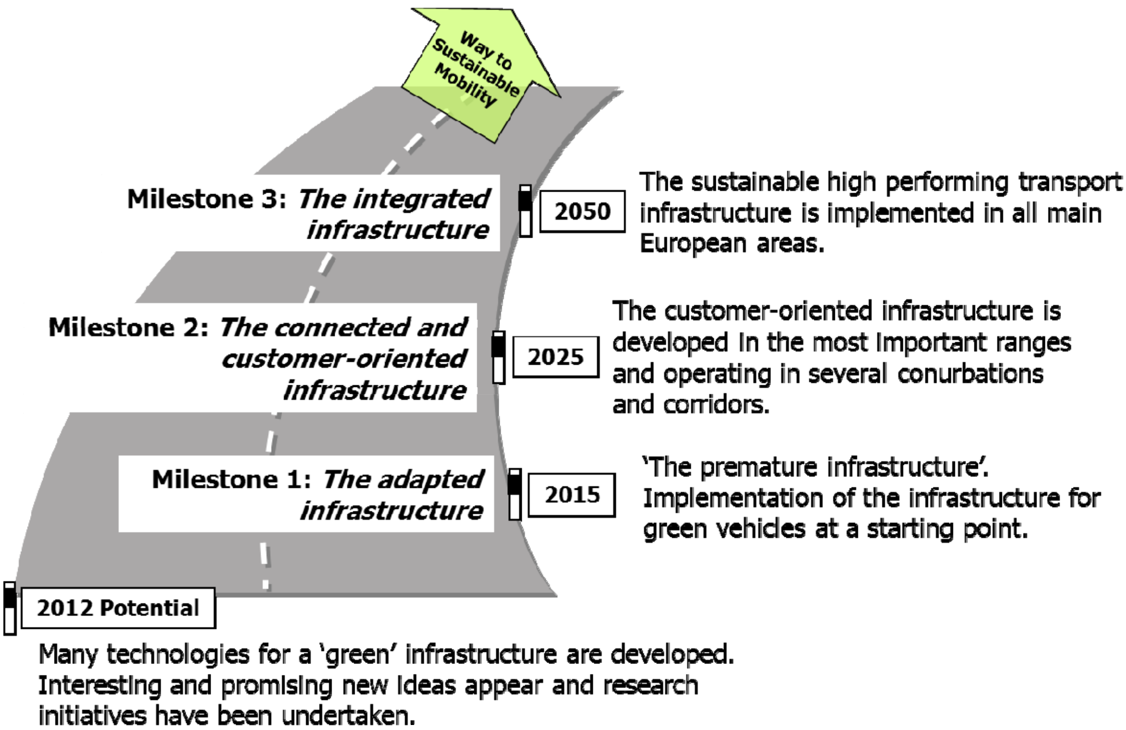


Figure 25: Overview of research milestones for green infrastructure

It is obviously clear that the milestones, with a market introduction expected after another 3 years of series development, have to be seen in the sense of 'Green Mobility' with the clear link between the market introduction and penetration of 'Green Vehicles' and the supply side of green mobility, the 'Green Infrastructure'. It should be considered also, that the milestones describe what we expect to see at this milestone, how the infrastructure should look like at this milestone. Of course there are influences which can change the goals, the milestones. Some influences can be e.g. unexpected technology breakthroughs, missing standards and regulation, society and policy changes, missing customer acceptance, financial crisis. Out of the expectations, of this view, the necessary research needs, the necessary steps could be defined.

The milestones are structured according to the following system:

1. The general description of what should be achieved at this milestone followed by a description with the goals to reach at this milestone.
2. The description of milestones for the major technology & service fields with the necessary business models and the framework on standardisation, regulation and legislation.

5.1 General milestone description

The situation in 2012 is market by a weak developed 'green vehicle market' as well as by a weak developed 'green infrastructure' as instrument to serve the vehicle market and the customer requirements. Many technologies for 'green mobility' are already developed; the necessity for sustainable solutions is seen. But the insecurity on future 'green mobility demand' and the unstable economic situation impede needed development and advancement.

- **Milestone 1: The adapted infrastructure (2015)** [Market 2018-2020]

The first step of implementation of electrified mobility will be based on the adaptation and conversion of existing vehicles into plug-in hybrid and electrical cars. The premature infrastructure will have no dramatic changes in technology and utilisation to the 2011 situation. Incremental improvements in technology and systems are to be seen. Beyond demonstration and field operational tests, first fleets of electric driven vehicles will evolve for niche application, like e.g. taxis, car sharing models, delivery services. For Plug-In-Hybrid, Range Extender and Electric Vehicles, specific standards for safety, data communication and billing will be developed, along with testing activities and actions for raising public acceptance.
It is expected that the base technologies for a dedicated 2nd generation electric vehicle providing efficiency gains of all consumers, advanced system integration and high performance energy storage systems will become available at the intermediate time scale. Major breakthroughs can be expected in terms of the understanding of underlying technologies and principles. At the same time, an enlarged charging infrastructure allowing dissemination over various cities and regions will develop.
Bio-fuels will be more present and have increased the market share, but those bio-fuels of the 1st generation are still in the discussion about fuels versus food and the need of agricultural land to produce them. The market introduction for CNG and LPG cars is still on-going and the share is rising permanently. For long distance goods transport a 15% increase in logistics utility, delivery reliability and efficiency is reached.
R&D activities in bio-technological fuel production in Europe have been strengthened and first pilot plants deliver fuels for advance engine development and testing.
The infrastructure for green vehicles is launched.

- **Milestone 2: The connected and customer-oriented infrastructure (2025)**
  [Market 2028-2030]

The customer orientated infrastructure is established. Base technologies for the generation of vehicle & system integrated electrified vehicles will provide efficiency gains for all consumers, more system integration and high performance storage systems. The charging infrastructure allows the dissemination of Plug-In Electrified Vehicles over various cities and regions. Mass production of Plug-In Hybrids and Range Extender Hybrids has started. Particularly, batteries, which are the most crucial component, have to be available providing about tripled life time and energy density at about 30 per cent of today's cost, and highly integrated and cheap electrical motors need to be on the market in big quantities. Dedicated Hybrid Vehicles competitive regarding costs and benefits will conquer the market. First business models for charging and grid stabilising will be in place.

In order to tap the full potential of electric cars regarding energy savings and reduction of GHG, it is required to not only "electrify" the common car, but to totally revise the vehicle concept. The "missing" combustion engine opens up new possibilities for the design of the car platform. During 2020 and 2025 a major innovative step is expected, the generation of 2025 electrified vehicle will be based on an entirely revised modular platform including a revised ICT reference architecture and middleware. This will on the one hand enable the full electric car to run the highest possible range on its battery load and on the other hand will allow including a sufficient amount of batteries. The modularity may even allow a convergence of full electric vehicle and plug-in hybrid.
Innovative zero-emission drive train systems will be enabled by distinctly improved energy recovery with batteries with enhanced bidirectional and fast charging capabilities.
The incorporation of a multi-fuel compatible Range Extender may be a solution for enhancing the options provided by an electrified vehicle.

Regarding the road transport electrification, a major field in the 'greening' of road transport, one have to consider that the introductory phase, beginning today is most important for the success of electrified transport.

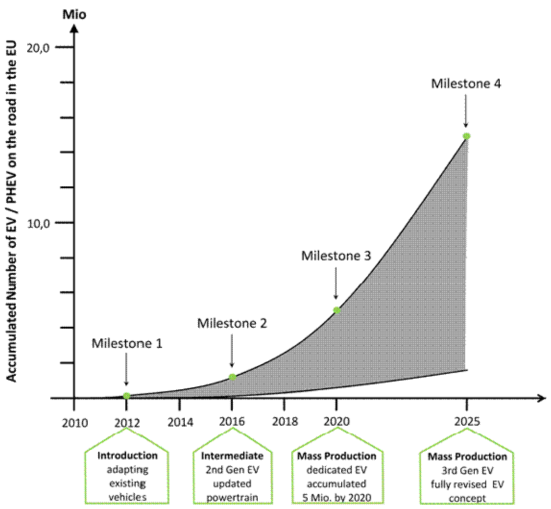


Figure 26: Milestones of the European Industry Roadmap for Electrification of Road Transport. Lower black curve: Evolutionary development of accumulated number of EV/PHEV. Upper black curve: Expected development under assumption of reaching the major technological breakthroughs. Source: European Roadmap Electrification of Road Transport, update 2012, draft version 3, 7 May 2012

The car of the future will be fully integrated into the multi-modal transport system. Automated and cooperative driving functionality will be enhanced and active safety measures greatly exploited.

The infrastructure for grid integration is expected to provide advanced levels of convenience especially through contactless and fast/ultra-fast charging at high efficiencies. En-route charging may be available in dedicated areas and corridors, appropriate infrastructure with power lines provided. The technology is available and first demos are running.

Most vehicles and operators are connected with the infrastructure, (IP address, mobile, nomadic devices). Investments for upgrading are decided for most roads. The infrastructure admits automated transport systems. Concept of sustainable transport systems demonstrated and evaluated within infrastructure. The majority of co-modal transport chains to be found in the service infrastructure. For long distance goods transport a 30% increase in logistics utility, 50% increased delivery reliability and 40% more efficiency is reached.

Also bio-fuels play a mandatory role for long distance transport and for plug-in and range extender powertrains. The new generation of bio-fuels is mainly based on residuals and waste as feedstock - and are fully compatible with infrastructure and engine. More advanced production options, as for example bio-technological pathways, are demonstrated on larger scale.

- **Milestone 3: The integrated infrastructure (2050)**

The sustainable high performing transport system infrastructure shows a high degree of infrastructure modularisation, the necessary investments for upgrading is decided and funded for all roads. Vehicles, operators and infrastructure are connected and integrated with each others; the infrastructure is upgraded for automated and cooperative transport systems and in operation. Transport and traffic in cities and conurbation will be up to 100% based on electrified vehicles with zero emission capabilities for these regions. Beside the electrified vehicles, modular cars and delivery vans, new type of mobility solutions for individual and public transport may be in place, e.g. automated people movers, air taxis. Fuels, gaseous energy and electricity for vehicles are fully produced from renewables, from bio resources. The transport chain is integrated throughout the journey (door to door) - First and last mile, long leg, reloading, etc. High-density co-modal transport chains are to be found in ‘green’ infrastructure. The concept of sustainable transport system is "approved" within the infrastructure.

European wide established business models, standards and regulations. Legislation is harmonised across Europe. Political agreement within transportation issues established and manifested.

5.2 Milestones for the major technology/business fields

For the milestone description some explanations will be helpful:

- Bi-directional charging = charging the battery from the grid – supply battery energy to the grid.
- Plug-in charging = connection to the vehicle through connector plug, manual or automated with electric cable.
- Stationary contact charging = contact e.g. via numberplate, automated contact plate.
- Vehicle to Home (V2H) is the integration of the vehicle battery into the home electricity net, first to charge the battery at best time and second to use the battery electricity for home net peaks.
- All the technology and service fields should be accompanied by European wide and national business models, regulations and necessary standardisation to reach the envisaged milestone.

o Milestones for the Energy Infrastructure

		Milestone 1: 2015 [Market 2018-2020] The adapted infrastructure	**Milestone 2: 2025** [Market 2028-2030] The connected and customer-orientated infrastructure	**Milestone 3: 2050** The integrated infrastructure
Electric Energy Infrastructure				
Charging Infrastructure	Plug-in manual and automated charging	First generation grid plug-in slow charging infrastructure for cities. Fast charging in the wider urban area of major cities projected. Demo projects and pilots for automated plug-in charging for buses are running. First business models for plug-in charging.	Fast and ultra fast, convenient and smart manual charging. Bi-directional and enhanced ultra fast charging for fleet application. First automated plug-in charging possibilities in selected hubs. Business models fully developed for easy use.	Ultra fast charging fully operating. A well distributed and fully operating manual charging system personalised for easy use. Automated plug-in charging in all bigger cities and hubs.
	Inductive charging while parking	First demo projects and pilots are running. Premature business models for inductive charging.	First deployment of static inductive charging devices in cities (private and semi public parking lots, supermarkets). Business models fully developed for easy use.	Inductive charging while parking fully developed. Easy use and access.
	Inductive charging during short stops while driving	Demo projects and pilots for buses are running. Premature business models for inductive charging.	Inductive charging at bus stops deployed. First attempts on inductive passenger car and city trucks charging at traffic light stops.	Full deployment of inductive charging at bus stops in European urban areas. Business models fully established.
	Inductive charging while driving	For hybrid buses & trucks first concepts for intermittently or continuously transfer of electricity from grid.	First deployment of inductive dynamic on road charging devices on dedicated tracks in commuting roads and Highways.	HDT hybrid systems for continuous grid connection on 'Green Corridors' and highways, for buses on 'Green City Corridors'. Business models fully established.

		Milestone 1: 2015 [Market 2018-2020] The adapted infrastructure	**Milestone 2: 2025** [Market 2028-2030] The connected and customer-orientated infrastructure	**Milestone 3: 2050** The integrated infrastructure
Electric Energy Infrastructure				
Charging Infrastructure	Stationary contact charging	Demos and pilots running using trucks and buses with retractable power contact (pantograph) at vehicle stops. First comparison with inductive charging possible.	Deployment of stationary contact charging at vehicle stops on dedicated tracks for inner-city trucks and buses. Standardisation and interoperability between vehicle types.	Network across European urban areas in selected places.
	Contact charging while driving	First experimental deployment (pilots) and test tracks of dynamic charging by using “contact-running systems”, e.g. trolley systems. Examination of ecological and economic benefits.	With positive examination of the technology, first deployment of validated contact-running charging devices on dedicated tracks in commuting roads and Highways. Working Business models for contact-running charging.	Contact charging corridors on main axis across EU. For HDT hybrid systems for continuous grid connection on ‘Green Corridors’ and highways, for buses on ‘Green City Corridors’. Business models established.
Charging Infrastructure	Vehicle to Home (V2H)	First pilots for vehicles and DC/AC common converter for houses lots are available. First pilots for second life battery stations.	Full deployment of vehicle-side hardware (Bi-directional AC/DC & DC/AC Converter). Home-side hardware (DC/AC converter integrated at the home’s network) is available.	V2H including hardware and ICT from both vehicles and house side are fully deployed. Electric devices of vehicle and home are integrated.
	Vehicle to Grid (V2G) (plug-in and stationary contact connection)	Research projects on V2G issues, e.g. information about vehicle battery status to grid operator. Fleet operation tests (FOT) in preparation.	FOT and market preparation. First fleet operators to stabilise the grid via dedicated stations. Premature business models for V2G are available and operational. Easy to understand business models for charging cost bill.	V2G is operational. Business models for grid stabilising in place.
Smart grids (included smart metering)	Grid structures	The need for a new grid structure for renewable electric energies (from wind, solar, water) is seen. First ideas on decentralised grids. First models for an ‘Information Grid’.	Grid for bi-directional charging established in urban centres.	Smart grid established, decentralised, for renewable electricity, for bi-directional, speed and wireless charging. More then 80% of electric energy comes from renewable sources.
	Storage infrastructure for renewable electric energies	Slow extension of the few existing possibilities (mainly pump-storage power-stations).	Adequate storage infrastructure according to produced renewable electric energies in place (e.g. batteries, pump-storage power-stations). First power to gas demos.	Good distributed storage infrastructure working. Power to gas in place. Long term storage possible.

<table>
<tr><th></th><th></th><th>Milestone 1: 2015
[Market 2018-2020]
The adapted infrastructure</th><th>Milestone 2: 2025
[Market 2028-2030]
The connected and customer-orientated infrastructure</th><th>Milestone 3: 2050

The integrated infrastructure</th></tr>
<tr><td colspan="5">Electric Energy Infrastructure</td></tr>
<tr><td>Business models and framework (standards, regulation, legislation) for charging, interfaces, batteries and safety.</td><td></td><td>Pilot projects running with actual energy price as input for smart charging / smart grid control.
European guidelines for battery lifetime and range.
Standardisation and regulation of interfaces. On-going standardisation of the grid-vehicle connection (socket, connector and charging point).
Safety standards in place.</td><td>Full deployment of E-roaming / Clearing house.
Business models for V2H, V2G fully developed. Real-time pricing and forecasting services available.
Standards for charging while driving technologies established. High level Energy Storage System standards developed.
Common interface for grid-vehicle connection ensures interoperability across Europe.</td><td>Further improvements.</td></tr>
<tr><td colspan="5">Liquid & Gaseous Energy Infrastructure</td></tr>
<tr><td rowspan="4">Infrastructure for liquid & gaseous energies</td><td>Production of new liquid & gaseous energies</td><td>Increased production of known bio fuels (e.g. FAME, Ethanol).</td><td>Glucose based bio fuels; 2nd generation bio fuels (e.g. from straw). First demos on power to gas.</td><td>Processes established and competitive for CO_2 & light to fuel, residuals for bio fuels, green electricity to H_2 or CNG.</td></tr>
<tr><td>Supply & distribution of new gaseous energies</td><td>Increase in bio gas will increase the gas stations. Large scale pilots running with Liquefied Natural Gas (LNG) using centralised fuel distribution in captive fleets.
First business case for using bio gas for transport versus blending in gas network.</td><td>Expanded LNG/SNG/DME infrastructure in Europe (H_2 as blend component).
CNG infrastructure in place with the same distribution level as today's gasoline /diesel stations.</td><td rowspan="2">Fully developed infrastructure. Further improvements.</td></tr>
<tr><td>Supply & distribution of new liquid energies</td><td>Known bio fuels (e.g. FAME, Ethanol) continue to be blended with conventional fuel. LPG infrastructure to be enlarged in several European countries.</td><td>High-blends (e.g. E85) could require new infrastructure equipment in some European countries.</td></tr>
<tr><td>Hydrogen filling stations</td><td>First demonstration areas/hubs for green H_2 in place in selected areas, existing refuelling sites.
Some 200 filling stations across Europe are expected.</td><td>Start of H_2 infrastructure at shopping centres, highways, major cities.</td><td>H_2 infrastructure in place. The same distribution level as today's gasoline /diesel stations.</td></tr>
</table>

o Milestones for the Service Infrastructure

		Milestone 1: 2015 [Market 2018-2020] The adapted infrastructure	**Milestone 2: 2025** [Market 2028-2030] The connected and customer-orientated infrastructure	**Milestone 3: 2050** The integrated infrastructure
Service Infrastructure				
Battery service infrastructure	Service stations for battery charging	Few stations on place.	At shopping centres, highways, companies and parking stations.	Network across European urban areas and the landscape. Easy use and access.
	Service stations for battery change	A few swap stations in selected areas on place. First business models for battery change.	Wider market introduction for compatible vehicle batteries in main areas. Battery packs partial standardised. Business models fully established.	For compatible batteries in main hubs across Europe.
	Service for battery emergencies	First business models for standardised replacement batteries, for standardised fast charging service.	Services and business models in place.	
	Business models for batteries	First battery loan programmes and reuse concepts.	Battery loan programmes and reuse concepts established.	
ICT management (V2I, V2V, V2G)	OEM back-end communication	Test and demos, first attempt-systems for mileage info for fleet management, vehicle setting info and remote customer services.	OEM business model back-end communication fully operational.	Further improvements.
	Protocols/devices for V2G communication	Test and demos, first attempt-systems for charging & roaming standards (open charge site protocol); Electric Vehicle Service Equipment (EVSE) operation standards; reference & validation model standards for EV and EVSE;	Fully operational protocols for V2G communication available. Easy use and access.	
	Electric information (about charging infrastructure)	Charge spot identification for sockets and swap stations, navigation and reservation in first fleet tests.	Charge spot identification for sockets and swap stations, navigation and reservation fully operational. Business models established.	
	Eco-driving	Demo of ICT enabled support for eco-mobility, eco-routing etc.	Real-time availability and reservation functionality for eco-mobility, eco-routing etc.	

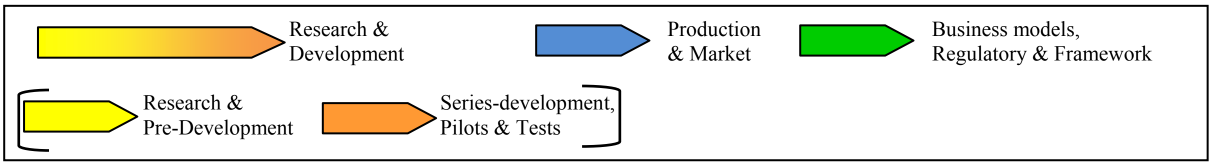
		Milestone 1: 2015 [Market 2018-2020] The adapted infrastructure	**Milestone 2: 2025** [Market 2028-2030] The connected and customer-orientated infrastructure	**Milestone 3: 2050** The integrated infrastructure
Service Infrastructure				
ICT management (V2I, V2V, V2G)	Safety communication V2V & V2I	First demos on V2V communication running	V2V & V2I for fleets (trucks and urban fleets) running in some urban areas. V2V communication in many new cars.	
Freight transport	Green Corridors (long distance)	Capacity needs analysed Concept in existing infrastructure. Some selected corridors with dedicated lanes and (or better) dynamic lane management. ICT support is available. Reliable Infrastructure with maintenance and management regimes.	Common regulatory framework agreed Rollout plans agreed. Scaling: Several European corridors are operating. Selected international cross border corridors adapted, dedicated infrastructure. Some new infrastructure built and ready. High grade of ICT support. Effects verified and communicated.	High density corridors are operating.
	Freight transport in cities, city corridors	Capacity needs analysed Concept in existing infrastructure. ICT support is available. Reliable Infrastructure with maintenance and management regimes. City terminal concepts for last mile electric/zero emission delivery	Common regulatory framework and rollout plans agreed. Scaling: Several European city corridors are operating. Selected international cross border corridors adapted, dedicated infrastructure. Some new infrastructure built and ready. High grade of ICT support. Effects verified and communicated. Noise mitigated “out-of-hours” deliveries	City corridors are operating.
	Regional freight hubs	Capacity needs analysed. Concept in existing infrastructure. ICT support is available. Piloting: First pilots on integrated “Green Vehicle Terminal (GVT)”. A few Driver Villages are established. Driver Villages with facilities for service and maintenance for both the vehicle and the driver.	Scaling: Several European city corridors are operating. High degree of ICT support. Effects verified and communicated. Several Driver Villages are established and connecting several modes.	Multipurpose hubs operating. Hubs with high service level connecting all modes.
	Bus Rapid Transit (BRT)	Adapted infrastructure, bus stops, ticketing and traffic priority for increased transport efficiency	Plug-in hybrid and charging while driving infrastructure demonstrated.	Large scale full electric BRT systems (“Superway” as a complement to Subway)

		Milestone 1: 2015 [Market 2018-2020] The adapted infrastructure	**Milestone 2: 2025** [Market 2028-2030] The connected and customer-orientated infrastructure	**Milestone 3: 2050** The integrated infrastructure
Service Infrastructure				
Transport system	Convenient goods transition between modes	Load units, load carriers, hubs and terminals and ICT in focus. Lack of common international policies and regulations. Some co-modal transport chains in place. Business models evolve.	Load units, load carriers, hubs and terminals and ICT in main parts developed. Some common international policies and regulations. Several co-modal transport chains in place, regional and global. Business models in place.	In operation.
	Terminals, hubs for passenger travel	Piloting: First pilots on integrated interchanges, including services for green vehicles such as for parking, charging, logistics, retail and co-modality information realised in ten European cities.	Scaling: Role-out of modular GVT to major European cities.	Full deployment and export: GVTs established as hubs for Green Vehicles; GVTs deployed in Asian market.
	Integration into multi-modal transport system	First development of road infrastructure and communication tools encouraging the use of electrified vehicles. No agreements for regulations and policy in place. First business models established.	Extensive integration of electrified vehicles with other modes of transport. Regulations and policy agreements in place. Business models in place. Open and transparent information on transport supply and demand.	In operation.
	Semi-/automated and cooperative driving	Test on semi-automated / automated driving and car-to-x communication on-going.	Enhanced usage of car-to-x communication for semi- / automated and cooperative driving for zero-accident road safety and highly convenient driving.	Automated and cooperative driving established for selected areas and green corridors.
Safety Measures	Safety measures for automated and cooperative driving	Research on active safety measures for automated driving. First active safety measures launched.	Active safety measures for automated driving established.	Further improvements.
	Standards for emergency handling, including roadside and tunnel safety	Research on needed standards.	Standards set for the European Union.	Further improvements.

6. Roadmaps for the major technology/business fields

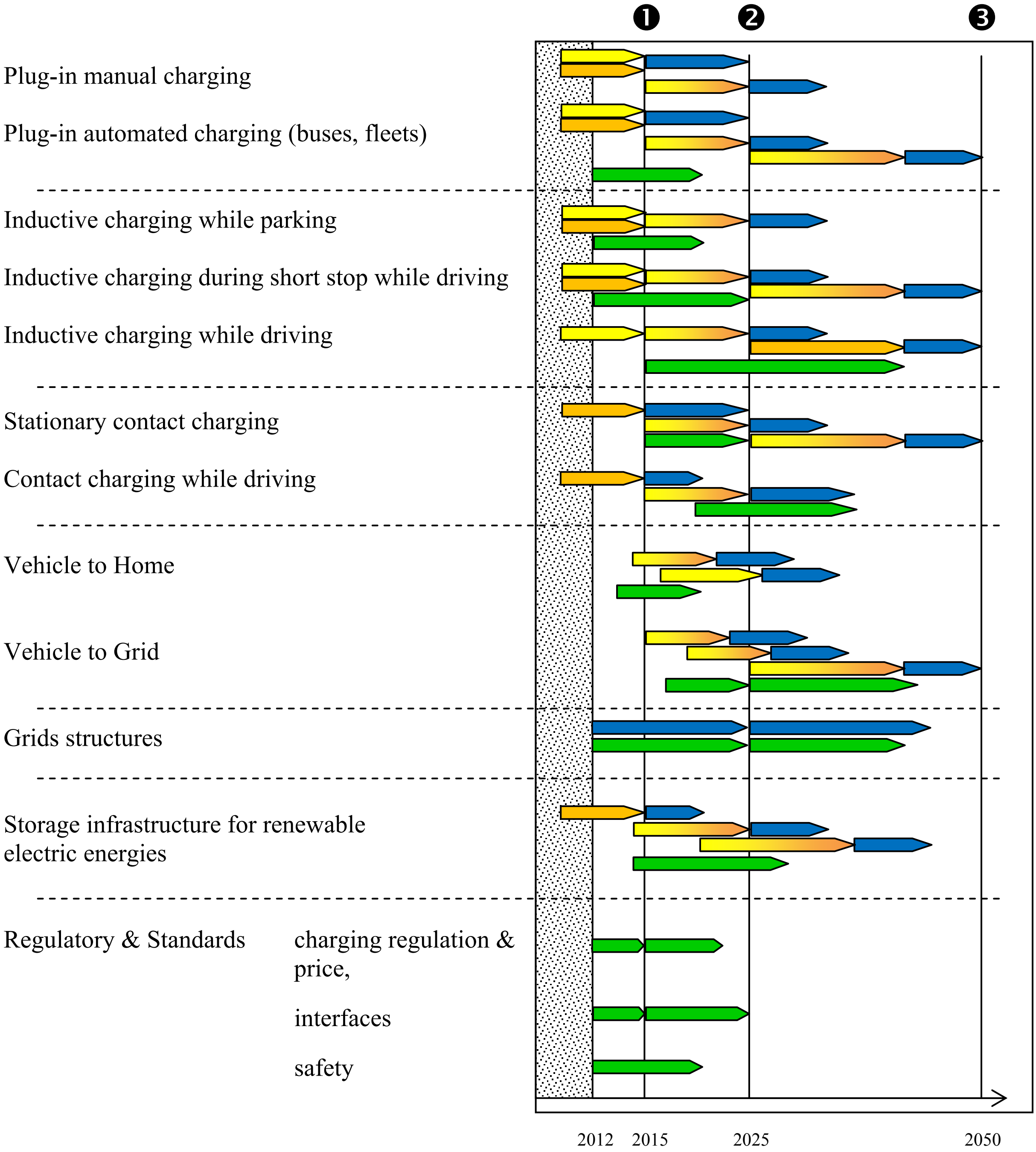
Following the definitions of milestones, the involved companies and organisations agreed on actions to be taken in order to achieve the stated objectives. Considering phases of R&D, production and market introduction as well as the establishment of regulatory frameworks, dedicated roadmaps were drafted. Those indicate what has to be done when for a well-timed move of Europe towards a consumer oriented infrastructure development and thus to a sustainable mobility.

The explanation of the arrows used in the following roadmaps is given below:



❶ Milestone 2015: The adapted infrastructure
❷ Milestone 2025: The connected and customer-oriented infrastructure
❸ Milestone 2050: The integrated infrastructure

Electric Energy Infrastructure



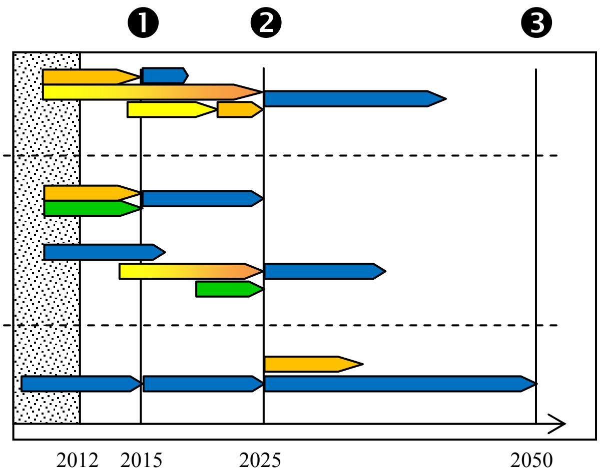
Liquid & Gaseous Energy Infrastructure

Production of new liquid & gaseous energies

Supply & distribution of new gaseous energies

Supply & distribution of new liquid energies

Hydrogen filling stations



Service Infrastructure

Service stations for battery charging

Service stations for battery change

Business models for batteries

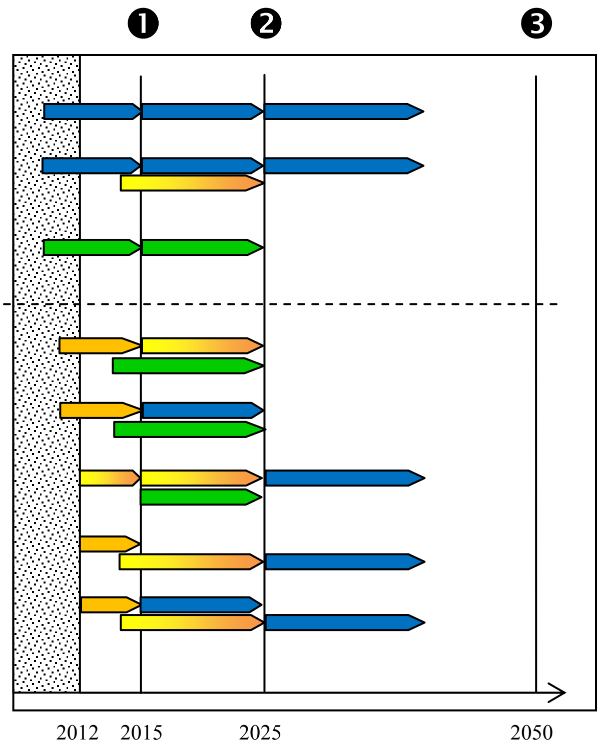
OEM back-end communication

Protocols/devices for V2G communication

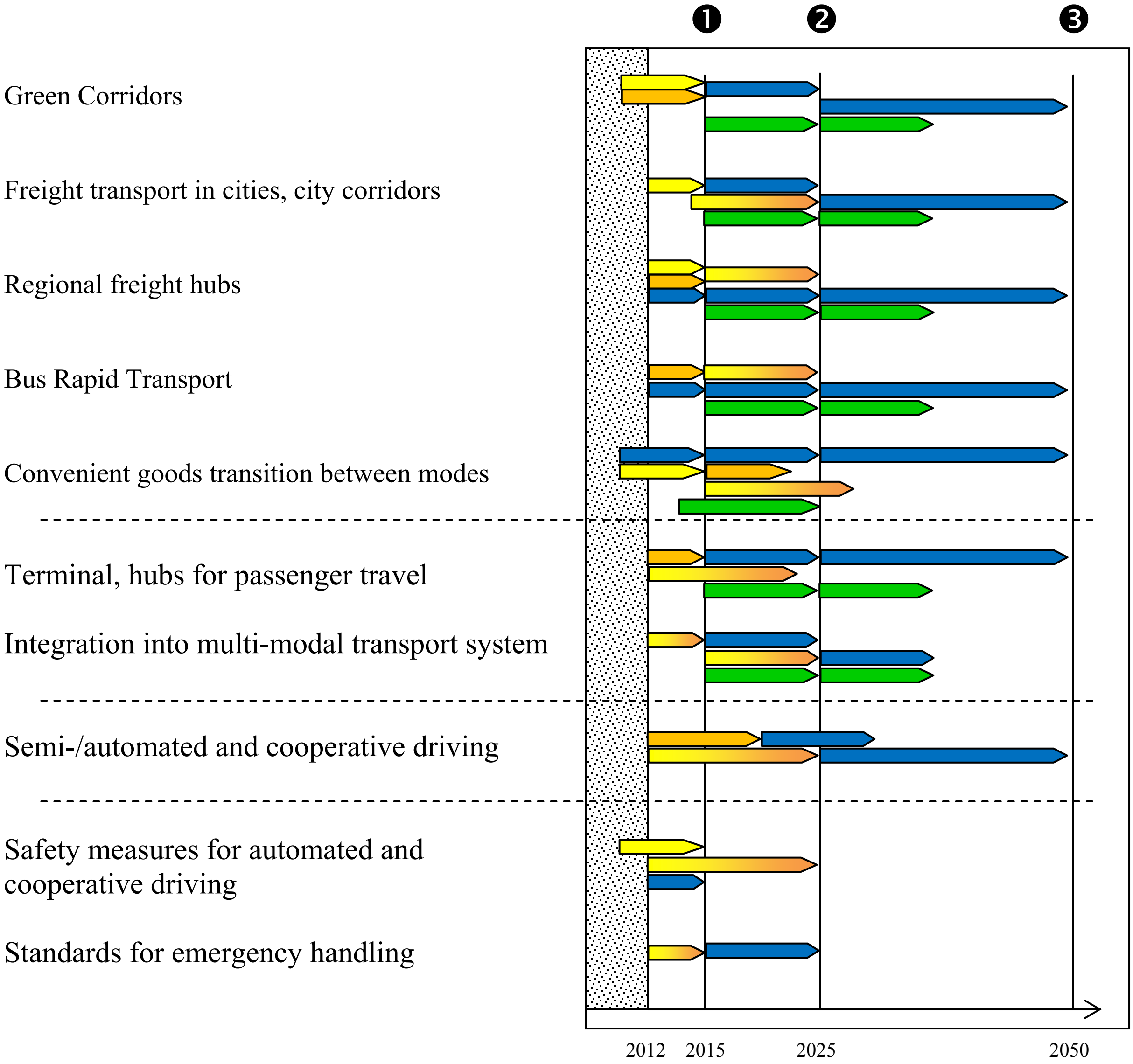
Electric information

Eco-driving

Safety communication V2V, V2I



Service Infrastructure



7. Recommendations

The ERTRAC European Roadmap ‘Infrastructure for Green Vehicles’ is linked with some other ERTRAC roadmaps. The roadmaps ‘Electrification of Road Transport’, ‘Hybridisation of Road Transport’, ‘Sustainable Freight System for Europe’ and ‘Towards an Integrated Urban Mobility System’ as the ones with a direct link and with content influencing the infrastructure. As recommendations for the described areas are given in these roadmaps, it is unnecessary to repeat all of them.
We will give in this roadmap some of the most important recommendations for the infrastructure, influencing the market success of ‘Green Vehicles’.

- **Integration of the charging systems into the grid** (manual and automated plug-in, inductive and contact -both stationary and while driving-, slow and fast charging).

  The success of electrified vehicles in Europe - with the benefit to reduce GHG, improve air quality and mobility in cities and conurbation, reduce the dependence from crude oil, just to mention the most important ones – is strongly linked with the development of the charging infrastructure.

  Immediately the plug-in infrastructure in main city areas has to be installed. Till 2025 a more or less complete charging net over Europe is necessary, including V2H solutions and the integration of V2G.

- **New storage options for inconstantly flowing renewable electricity** (solar, wind).

  The extension of the few existing possibilities (mainly pump-storage power-stations) must be accelerated. The storage and vice versa the provision of electricity in batteries of electrified vehicles with increased storage capacity (V2G) is an option to be followed. Beside these possibilities, new options as power to gas (H_2, CNG) and power to fuel (mainly diesel) are necessary to be developed.

- **Green corridors and dedicated lanes with services for green vehicles**.

  To secure sustainable goods transport, to secure person mobility and the delivery of goods in cities and conurbation, ‘green corridors’ for goods transport on main axes through Europe and as well ‘dedicated lanes’ for green vehicles with support of ICT and charging possibilities will become necessary in Europe. Hybrid trucks with charging possibilities on green corridors, dedicated city lanes for hybrid and electric delivery vans, buses and city cars will help on the way to cleaner roar transport.

- **Integration into the transport system** (ICT support, hubs, multi-modality, semi-/automated and cooperative driving).

  One part will be the development of road infrastructure and communication tools encouraging the use of electrified vehicles and the integration with other modes of transport.

  Load units, load carriers, hubs and terminals and ICT will be in focus to be developed for goods transport, Corresponding for passenger travel will be the development of

'Green Vehicle Terminals', including services such as for parking, charging, logistics, retail and co-modality information.

The enhanced usage of car-to-x communication for semi- / automated and cooperative driving for zero-accident road safety and highly convenient driving is to be supported.

- **European wide accompanying legislation, business models and standards**.

  It is obvious that the change of the road transport system to electrification has to be accompanied by appropriate legislation and business models easy to understand and use, and with comfortable access.
  Examples are business models for charging systems, V2H, V2G, real-time pricing and forecasting services. Standards for charging, service stations and high level energy storage systems. A common interface for grid-vehicle connection ensures interoperability across Europe.

The production, supply and distribution of new liquid and gaseous energies are touched briefly and are necessary to be developed. This research and development area will be content of a separate, new to develop roadmap.

Nevertheless, we should not forget that vehicles with Internal Combustion Engines will be the long to future solution for Long Distance Freight Transport and probably for long distance travel with family cars. Further research to reduce their environmental impact, are obviously necessary.

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9. Acronyms and Abbreviations

AMI	Automatic Metering Infrastructure
APU	Auxiliary Power Unit
BRT	Bus Rapid Transit
BTL	Biomass to Liquid
CCS	Carbon Capture and Storage
CH	Carbon Hydrogen
CNG	Compressed Natural Gas
CTL	Coal to Liquid
DME	Di-Methyl Ether
DSM	Demand Side Management
ECC	Electric City Car (small, light car, operate for most of the day by a single charge)
EV	(Full) Electric Vehicle
EVSE	Electric Vehicle Service Equipment
FAME	Fatty Acid Methyl Ester
FCEV	Fuel Cell Electric Vehicle
GVT	Green Vehicle Terminal
GHG	Green House Gas
HCCI	Homogeneous Charge Compression Ignition
HDT	Heavy Duty Truck

HEV	Hybrid Electric Vehicle
HVO	Hydrotreated Vegetable Oil
IA-HEV	Implementing Agreement – Hybrid & Electric Vehicle
ICE	Internal Combustion Engine
ICT	Information and Communication Technology
IEA	International Energy Agency
IEC	International Electrotechnical Commission
IMO	International Maritime Organisation
IPT	Inductive-Power-Transfer-Technology
ISO	International Standards Organisation
LEV	Light Electric Vehicle (like e-bikes, motorbikes and small cars)
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
OEM	Original Equipment Manufacturer
PHEV	Plug-In Hybrid Electric Vehicle
R&D	Research and Development
RTD	Research and Technology Development
SAE	Society of Automotive Engineers
SNG	Synthetic Natural gas
SUV	Sports Utility Vehicle
V2G	Vehicle to Grid
WPT	Wireless Power Transfer
ZEV	Zero Emission Vehicle