



Multiannual Roadmap for the Contractual Public Private Partnership European Green Vehicles Initiative

September 2013

Introduction

The Public Private Partnership European Green Cars Initiative was originally created in an ad-hoc manner in response to the global economic crisis of 2008 by using the instruments of the 7th Framework Programme. It evolved into a lean, fast and efficient instrument for the funding of research, development and innovation in the field of sustainable mobility. Decision makers from major European companies, representing the European Technology Platforms ERTRAC, EPoSS and SmartGrids, entered into a continuous and constructive dialogue with the involved Directorates General of the European Commission, and made recommendations for the annual FP7 Calls for Proposals of the European Green Cars Initiative published in 2009-2012. Their advice was based on intensive consultations involving industrial and academic stakeholders from all relevant technology domains, spanning the entire value chain, and rests upon the long-term roadmaps and strategic research agendas of the technology platforms. Eventually, about 100 collaborative research projects will have been jointly funded with the EC in the framework of this PPP. Due to the high degree of satisfaction from both the industrial sector and the EC sides, a continuation of the PPP is strived for under Horizon 2020, the new Common Strategic Framework for EU research and innovation funding after 2013. The wish for this continuation is supported by the proven added value of an integrated R&D&I programme at European level, and by the commitment and shared vision of the involved sectors to set objectives not only for the support of key European transport, energy and environmental policies or the sake of technical inventions, but also and in particular for the development of markets, commercialization, production and ultimately employment. The multiannual roadmap at hand reveals the vision, research and development strategy as well as the expected impact of a contractual PPP “European Green Vehicles Initiative” (EGVI) that will contribute to reach the targets set by European Transport, Energy, Environment and Climate Protection policies especially in the field of energy efficiency of vehicles and alternative power trains. The document is taking into account the roadmaps from three technology platforms (ERTRAC, EPoSS, SmartGrids) in a cross-sector approach, and is pointing out the potentially high socio-economic benefits of a PPP. All written comments resulting from stakeholder consultations as well as the discussions at a dedicated event held in Brussels on 25 September 2012 have been considered.

PART I: Vision 2030

- ***Context setting: goals, links with EU policy objectives, and societal challenges addressed***

Energy efficiency of road vehicles and alternative powertrains have been identified by the industry and by policy-makers worldwide as crucial for achieving major cuts in CO₂ emissions and moving towards a sustainable transport system. The European Commission in its 2011 White Paper for Transport¹ set the objective for delivering a competitive and resource efficient transport system which allows substantial carbon emissions cuts and lesser dependence on imported fuels. The challenge of energy efficient vehicles and alternative powertrains relates to several important objectives of the European Union: reduction of emissions and improvement of air quality, CO₂ reduction and prevention of climate change, maintaining energy security, and increased use of renewable energies. Focusing on this challenge, the European Green Vehicles Initiative will thus contribute to reach the targets set by the European policies of Transport, Energy, Environment and Climate Protection: the 20/20/20 targets on renewable energy use, the CO₂ emissions regulation, and the Euro emissions standards for road vehicles. Being by nature a cross-sectors matter, advancements for the energy efficiency of road vehicles will be built on the expertise of three European Technology Platforms, ERTRAC, EPoSS, and SmartGrids, following a system approach integrating the research domains of automotive, energy, ICT, and smart grids.

By developing energy efficient road vehicles and alternative powertrains (“green vehicles”), the initiative will address the societal challenge of sustainable transport, and at the same time have a major impact on the innovative strength and global competitiveness of the European economy e.g. in terms of protection and further growth of manufacturing basis, employment, and skills. The initiative will follow the approach of Horizon 2020² to use research and innovation activities for reaching industrial leadership positions. Considering that Europe’s competitors on the global markets – who are well aware of the leverage effect of public funding – have set up massive R&D support programmes for green vehicles development, Europe cannot afford to lack ambition or to let fragmentation reduce the efficiency of its action on this field. In its recent report³ published in June 2012, the CARS21 High Level Group, gathering European Commissioners, national Ministers and CEOs of the automotive industry, concludes that the foremost challenge for the EU global competitiveness is to launch a specific major initiative on breakthrough technologies. The European Green Vehicles Initiative has been confirmed as a follow-up of the EGCI PPP within the CARS2020 Action Plan recently adopted by the European Commission. ⁴ The instrument considered the most suitable is the contractual Public Private Partnership as described in article 19 of the Horizon 2020 proposal in which both the public and private sides express their commitment to support the development and implementation of a research and innovation activity of strategic importance to the EU competitiveness and industrial leadership, and to address specific societal challenges.

The complexity of the matter requires a well coordinated combination of specific knowledge along the novel value chains of green vehicle technology, building on the involvement of SMEs, regional

¹ COM(2011) 144, White Paper 2011 “Roadmap to a Single Transport Area - Towards a competitive and resource efficient transport system”.

² COM(2011) 809, Proposal for a Regulation of the European Parliament and of the Council establishing Horizon 2020 - The Framework Programme for Research and Innovation (2014-2020)

³ CARS 21 High Level Group on the Competitiveness and Sustainable Growth of the Automotive Industry in the European Union, Final Report 2012, 6 June 2012

⁴ COM(2012) 636 CARS 2020: Action Plan for a competitive and sustainable automotive industry in Europe

innovation clusters as well as big corporations and efficiently using the diverse competencies available at companies, research institutes, and universities all around Europe. Creating efficient links between research, development and innovation with the feedback of user experience e.g. from demonstration sites will continuously be taken into account for the improvement of the initiative.

- **Overall Vision 2030 and research and innovation strategy of the industrial sectors involved.**

The three technology platforms involved in the PPP cover the research and innovation strategies of road transport (ERTRAC⁵), smart systems (EPOSS⁶) and smart grids (SmartGrids⁷). They have specific scopes but their strategies are complementary and match the PPP objectives.

ERTRAC - the European Road Transport Research Advisory Council, has recently revised its Strategic Research Agenda (SRA) by taking a system approach and addressing Grand Societal Challenges. As described in the table and figure below, objectives have been set for an overall efficiency improvement of the transport system by 50% in 2030 compared to 2010. Also specific targets for each of the societal needs are identified: decarbonisation, reliability and safety

	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

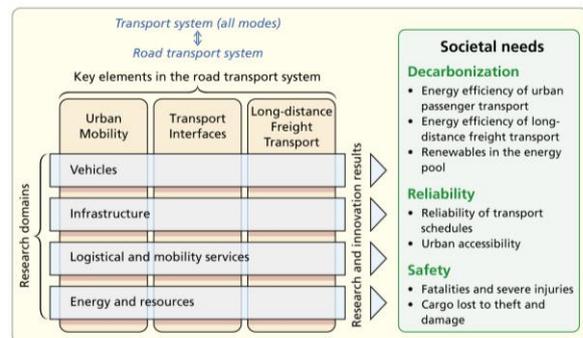


Table 1: Guiding objectives of ERTRAC for 2030

Figure 1: A systems approach to achieving a 50% more efficient road transport system

The ERTRAC SRA is being implemented through roadmaps covering topics for research, development, and innovation framework. Together, the ERTRAC roadmaps cover all aspects of the transport system thus enabling the objectives set in the SRA to be met. The approach focuses on the following three key elements of the transport system: urban mobility; long-distance freight transport; and interfaces between transport means. Together, these elements provide an integrated core transport system that serves the road transport demand of more than 80% of the population. Therefore they are essential for meeting the European societal challenges.

Thanks to its multi-stakeholders membership gathering all the actors of road transport research, ERTRAC is then able to cover the four enabling research and innovation domains: vehicles, infrastructure, logistical and mobility services, and energy and resources. A mix of these domains is usually needed in order to efficiently address one issue and be capable of delivering benefits towards the societal objectives. For the European Green Vehicles Initiative, ERTRAC will extract from its roadmaps the topics needed for the specific objective of the PPP.

⁵ <http://www.ertrac.org>

⁶ <http://www.smart-systems-integration.org>

⁷ <http://www.smartgrids.eu>

EPoSS, the European Technology Platform on Smart Systems Integration focusses on Smart Systems; defined as intelligent, often miniaturised, technical subsystems with their own and independent functionality evolving from microsystems technology. One of the most important applications of smart systems is the automobile. According to the EPoSS SRA, priorities of R&D in this area are clustered around safety, driver assistance and convenience, energy efficient and environment friendly smart power trains and subsystem. A particular focus is on enabling technologies for clean propulsion and electrification. In the electric vehicle the following functionalities will be provided by smart systems: management of energy storage systems, intelligent power electronics, active control of motors and wheels, functional safety of chassis and power train systems, smart integration of range extenders, and advanced vehicle to grid connection systems.

SmartGrids, the European Technology Platform for the Electricity Networks of the Future, focuses on research topics and priorities necessary for the advancement of the electricity networks and intelligent electric systems. It is active in the European Green Cars Initiative but also strongly involved in the European Electricity Grid Initiative (EEGI). Very recently in 2012 SmartGrids has updated its Strategic Research Agenda, covering the needs up to 2035 for research, development and demonstration initiatives both on national and European levels with the goal to advance a SmartGrids based European Energy System.

The Strategic Research Agendas of the European Technology Platforms, together with their detailed roadmaps, provide guiding objectives and milestones. These elements can be used as key performance indicators. For the topic of electric vehicles, this can be done by referring to the milestones described in the “European Roadmap Electrification of Road Transport” jointly published by ERTRAC, EPoSS and SmartGrids. These milestones describe the expected market developments under the assumption that major development technological breakthroughs can be reached thanks to a proper coverage of the technology fields described in the roadmap by R&D&I activities, and compare these with evolutionary developments. The needed advancements include the availability of next generation of batteries, performance gains of drive train technologies, synergies due to efficient system integration as well as the integration of electric vehicles with the electricity grid.⁸ Such roadmap milestones serving as KPIs will be assessed and monitored all along the PPP. Fuel cell electric vehicles and hydrogen as transport fuel are also an important element of sustainable mobility for the future. KPIs for these technologies are described in documents developed by the Fuel Cells and Hydrogen Joint Undertaking (FCH JU).

- ***Strategic objectives of the initiative and role of the PPP in the overall industrial strategy***

As recognized by the Horizon 2020 proposal, a Smart, Green, and Integrated Transport System is to be established in Europe in order to tackle the Societal Challenge resulting from global trends. Its creation implies major innovative steps in a multitude of different technology domains including transport, energy and ICT. The road transport sector is the largest one to contribute to the realization of a Smart, Green and Integrated Transport System, regarding both economic strength and potential for major innovations. In order to achieve critical mass, to deliver tangible results and to attract the required public attention, the PPP European Green Vehicles Initiative of Horizon 2020 should be incorporated primarily in this domain. At the same time, activities in other Societal Challenges, e.g.

⁸ European Roadmap « Electrification of Road Transport », joint ERTRAC-EPoSS-SmartGrids roadmap, 2nd Edition, June 2012, pp. 17-28.

Smart, Clean and Efficient Energy, and selected factors of Industrial Leadership, e.g. Key Enabling Technologies, will be essential for completing the objective, technology focus and process chain of the initiative.

According to ERTRAC, EPoSS and SmartGrids, delivering solutions for the major societal, environmental and economic challenges ahead will require well focused and coordinated research and innovation activities for the next 15 to 20 years. At the same time, a proper level of flexibility has to be kept since fundamental framework conditions in these domains may change rapidly due to adverse events or emerging opportunities. A close interaction in the decision-making between industry and public authorities such as the European Commission will be essential to generate market credibility and to justify the strategic allocation of resources. Therefore a Public-Private Partnership approach is favored. The aim is to accelerate research, development and demonstration of those technologies thus allowing the efficient use of clean energies in road vehicles. Therefore the objective of the PPP European Green Vehicles Initiative in Horizon 2020 will be **Energy Efficiency of Vehicles and Alternative Powertrains**.

Only those topics which are essential for this goal will be in the scope of the PPP European Green Vehicles Initiative. Required technologies will be considered at all product layers from modules to systems and vehicles. Neither the development of resources, nor the creation of infrastructures is in line with the objectives of the initiative, but the integration of these resources and the integration into these infrastructures are in the scope. Furthermore, not only passenger cars are considered but also two-wheelers (or other new light vehicle concepts), trucks and buses (see Figure 2)

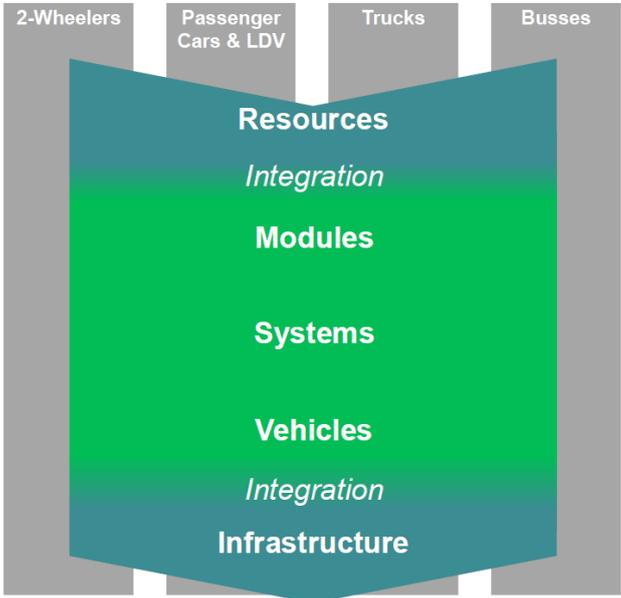


Figure 2: Technology fields covered in the PPP European Green Vehicles Initiative in Horizon 2020 (light green)

By addressing various product layers from the module to the vehicle as a whole, the integrated approach will cover the entire process chain from resource application to demonstration and creation of services, and extend research and development to innovation. Experiences made during this process will be essential for the improvement of technologies. Especially through the steps into innovation, the results of the process chain may raise new questions and feed them back into the

R&D work. At the same time, advice for EU and Member states to address policies regarding transport and energy will be delivered, e.g. indicating when standardization or public procurement would be helpful to the innovation process.

The involved European Technology Platforms have wider domains of priorities which will require substantial research, development and innovation efforts under Horizon 2020 beyond the scope of the PPP and in parallel to it. For ERTRAC, this concerns the development of fuels, the evolutionary development of internal combustion engines, priorities for road infrastructures, the creation of a multi-modal mobility system for passengers and goods, as well as other technologies leading to safety, noise reduction and performance gains. ERTRAC has developed a MAP Multi-Annual Implementation Plan for Horizon 2020, where all these priorities for research and innovation for the whole road transport sector are described and allocated to the pillars of Horizon 2020. For EPoSS, which is dealing with smart systems integration, topics to be covered by other funding programmes includes priorities in the domain of safety and driver assistance as autonomous driving, networked functionalities and human-machine interfacing as pointed out in the EPoSS strategic research agenda. As for SmartGrids, it will be all the topics concerning electricity networks and intelligent electric systems. It is essential to implement appropriate funding schemes for those topics going beyond the scope of this Multiannual Roadmap in parallel to the PPP EGVI.

- ***Commitment of the industry to the vision and objectives of the PPP goals.***

The industry is ready to commit to strategies and objectives shared with the European policy-makers. It has prepared roadmaps to achieve those targets, and is keen to establish annually research priorities and framework conditions for innovation based on a continuous consultation process involving all relevant stakeholders. A public private partnership is considered a necessary commitment from both sides to steer and drive this process forward.

Acting with a PPP at the European level is seen as an added value action complementary to national and local actions, because vehicles and mobility services have to be developed for international markets, using standardized solutions, and need to be able to compete on a worldwide basis.

Why a contractual PPP?

- To ensure a **lasting commitment** of the industry and the European Commission to address the shared objectives, with the ambition to deliver results in a timely and continuous manner;
- To guarantee **critical mass** of funding for topics that are of strategic importance for the EU, tackling specific societal challenges and aiming at industrial leadership;
- To drive forward **innovation** by integrating in a ring-fenced research programme together with actions necessary to accelerate the implementation of research results, towards the deployment of innovative solutions and pushing for production within the EU;
- To set up a **collaborative process** where private and public actors are putting together their specific competences, the public side setting European transport, energy and industrial policy ambitions while the industry identifies research and innovation priorities to fulfill them;
- To best use the **competences** of each side, the European institutions being responsible for the public funding allocation, project evaluation and management, while the private partners concentrate on setting recommendations for research topics, and to monitor and evaluate progress towards the objectives;

- To maintain **transparency** of the priority setting and **openness** for participation in the programme to any interested stakeholders, qualities which cannot be fulfilled if the PPP is further institutionalized. This is a particular requirement for the automotive industry, which includes several competitors and is based on fragmented supply chains including SMEs;
- To guarantee **flexibility** and an ability to adapt the technology coverage of the programme according to research findings, allowing the budget to be always oriented towards the best usages according to real industry situation and the state of the art research.
- To ensure a **lasting cooperation** of the industries concerned (automotive, smart systems, smart grids) and the involvement of the corresponding services within the European Commission.
- To foster the **sharing of information** throughout the network of involved companies and research organizations.

The Commitment of the industry:

The PPP EGVI will contribute to reaching objectives of major EU policies, and in particular the White Paper for Transport: by delivering innovative technologies which will help to reach the EU's target of reducing CO₂ emissions in transport by 60% by 2050.

The PPP EGVI will contribute to the deployment of green, yet affordable and safe, vehicles as described in the roadmaps for electrification, hybridization, buses and long distance trucks. Those roadmaps include milestones of vehicle deployment on the European roads, e.g. an accumulated 5 Million electric and plug-in hybrid vehicles by 2020 and further growth potential thereafter with corresponding potential CO₂ emissions reduction.

The industry is ready to match EU funding with similar private funding. Considering the scope and objectives of the initiative as outlined in this paper, a total programme budget of 3 Bn Euros is necessary for Horizon 2020 (framework 2014-2020) to represent critical mass and reach tangible results. This figure is to be compared with the 30 Bn Euros that the European automotive industry is investing each year in R&D, out of any public support scheme, 2/3 of it being allocated to energy efficiency.

The PPP EGVI shall work with principles of transparency and openness. Using the wide stakeholders basis of the European Technology Platforms ERTRAC, EPoSS, and Smart Grids, a scheme for operation and governance will be set up to organize the tasks of delivering viable research topics recommendations across the community, monitoring project progress and continuously evaluating the efficiency of the measures taken, as well as of building communication channels with the European Member States, and taking into account the user perspective. A legal entity will be created to represent the private part of the PPP, in the format of a non-profit association, to formalize the principles of work and get the commitment of the interested members to the objectives of the Initiative.

PART II: Research and Innovation Strategy

Only topics which contribute to reaching the goal of Energy Efficiency of Vehicles and Alternative Powertrains will be in the scope of the PPP, in particular the electrification and hybridization of powertrains, and their adaptation to renewable fuels. Also the functionality improvement of the vehicle, the reduction of its complexity and weight, and the management of its thermal and other energy flows play an important role. As shown in Figure 2, any technological development supporting these goals at the relevant product layers of the value chain from modules to systems and vehicles will be considered relevant.

- ***Definition of Scope***

The distinction between topics being within the scope of the PPP and those to be covered by other parts of the European funding programmes has to be based on a thorough definition directly resulting from the objectives of the PPP. In many cases, the assessment will require an expert discussion taking into account the objectives of the PPP, particularly for the integration of resources and the integration into infrastructures:

Resources integration in the scope of the PPP:

The development of resources such as new fuels and materials is generally not within the scope of the PPP as it serves a multitude of other purposes beyond the objectives of the PPP like e.g. the efficiency of usage or the independency from imports. However, the advancement and adaptation of resources for application in the green vehicle is fully within the scope of the PPP, as explained below for the case of materials.

Even though research on lightweight materials would not generally be in the scope of the PPP, the application of a new material which could lead for instance to weight reduction of a module indeed would. Within the PPP, the adaptation and processing of the material would be relevant as well as the functionality improvement of the module, the integration into the vehicle structure, the prototyping and testing, the establishment of a prototype line, and finally the demonstration of the product.

A comparable situation applies to energy storage systems: Many electrochemical systems may improve the performance, lifetime or affordability of any kind of battery. Their development starts with pure material research for anode, cathode or separator, i.e. new structures of carbon composites, powders or tubes or new chemistry for separators. Therefore such research and development should be covered by more general funding programmes. However, given the fact that the battery is a core element of electric and hybrid vehicles, any specific research on automotive batteries will be fully in the scope of the PPP, such as the further development, adaption, prototype manufacturing, and testing of a specific electrochemical system or cell design, integration of cells into batteries, integration of batteries into the vehicle structure, charge management, as well as any aspects that enable recycling or second life of batteries.

Other examples of materials integration that can fall into the PPP scope are new materials applied to electric drive train components such as electric motors, power electronics, etc. Another challenge for the energy efficiency of electrified vehicle being thermal management, new materials supporting advanced thermal management could be considered, i.e. materials which enable new highly efficient heating, ventilation and air conditioning systems for electric vehicles.

Infrastructure integration in the scope of the PPP:

The development of needed infrastructures such as electricity distribution capacity or road infrastructure is in principle out of the PPP. However, there are some necessary **interfaces** and other complementary developments that must be addressed to assure the correct **interoperability** and full **integration** to facilitate the eventual large scale deployment of electric vehicles to the power grid. The **Energy efficiency** concept must be considered as a whole including efficient charging devices and charging the EVs interacting with the electricity system in the most **efficient and sustainable** way. In this sense, the EV charging operation must be integrated in the overall electricity system operation allowing ordered and controlled charging methods that maximise the efficiency of the overall Electricity System. This implies the **interoperability** of the elements involved from the EVs to the generation sources that include the establishment of a coordinated communication along the energy chain. The smart EV charging infrastructure should be integrated as any other electricity demand into the distribution system operators' network management systems, thus a correct and coordinated ICT communication system must be developed between the EV, the charging devices and the mobility operator/ DSOs. This would avoid congestions and /or unexpected demand (demand management) that could provoke lack of efficiency and/or the increase of the operational cost of the infrastructures. These developments will directly affect environmental aspects (GHG emissions) or the improved integration of renewables with presence of EVs. As electricity is a highly regulated business, relevant consideration must be given to the impacts on the regulatory models, markets and socioeconomic issues. The **Interfaces** outside the vehicle refer to the charging functions and needs of EVs including charging points, related power electronics and different communication means. Protocols and standards are needed in this area to achieve **interoperability**. The future evolution of the vehicles is directly related to the evolution of the charging devices (quick charging, V2G aspects, contactless, etc.). All these topics will be within the scope of the PPP.

Logistics: not in the scope of the PPP

One theme that was covered by the European Green Cars Initiative PPP, and which is proposed to not be covered in the European Green Vehicles Initiative PPP, is the theme of logistics. It is a recommendation of the European Commission services to have logistics not covered under a transport mode specific initiative like the EGVI but rather to put it under the normal programme as a multi-modal thematic area. This approach is understood and accepted, but ERTRAC recommends however that strong links are kept between the vehicle development part and the logistics part. Collaboration is expected to continue and be developed further between the EGVI PPP and the activities supported by the European Commission on Logistics.

- ***The path towards innovation***

On the path towards innovation, the results of projects within the process chain may raise new questions and feed them back into the R&D work. At the same time, an additional result of the R&D activities within the PPP is advice for the EU to address policies regarding transport, energy, economic development and environmental protection in order to ensure that legislative frameworks are used to best support the goals of the PPP instead of being a bottleneck. Examples include indications when early European and global standardization in parallel to research and development could ensure the protection of sensitive knowledge. Integrating standardization issues early enough within the R&D&I process can indeed support the market uptake of innovative products and services.

Also policy measures like public procurement focused on novel technologies that can be helpful to the innovation process. Indeed, the technology focus and the process chain environment of the initiative should not be limitative but further links need to be developed like standardization activities, education programmes, infrastructure creation, and so on. In particular, efficient and continuous working relations to the other PPPs will be established to identify potential synergies in the coverage of topics from early on. There should be cooperation with the European Electricity Grid Initiative in order to ensure the coverage of integration into the grid of electric vehicles. There should also be cooperation with the PPP Factories of the Future in order to cover issues of high interest for both initiatives, such as manufacturing of cells and batteries or novel materials, modules and vehicles as well as recycling aspects. Similar cooperation activities with other PPPs and Joint Undertakings should be established when considered relevant, a case in example would be the JTI Fuel Cell and Hydrogen which is focused on the fuel cell development but not on other components of the drive train which are similar to electric vehicles e.g. on the electric machine. Another example is the European Innovation Partnership on Smart Cities and Communities which may provide important links to the applications and deployment scenarios for the technologies developed under the PPP. In parallel, the EGVI PPP will benefit from close interactions with other European Technology Platforms such as EuMaT, Manufature or MINAM, which focus on materials, manufacturing or micro and nano-manufacturing.

- **Roadmaps and multi-annual implementation plans**

The long-term technology roadmaps developed as part of the Strategic Research Agendas of the involved European Technology Platforms describe the course of research and innovation leading to the goals of PPP European Green Vehicles Initiative. Their milestones will ensure coherence of technology developments in the relevant technology fields and derive thematic priorities and time scales. In view of the objective of the PPP European Green Vehicles Initiative, particularly the roadmaps on electrification and hybridization are relevant, with in addition specific roadmaps for trucks and for buses.

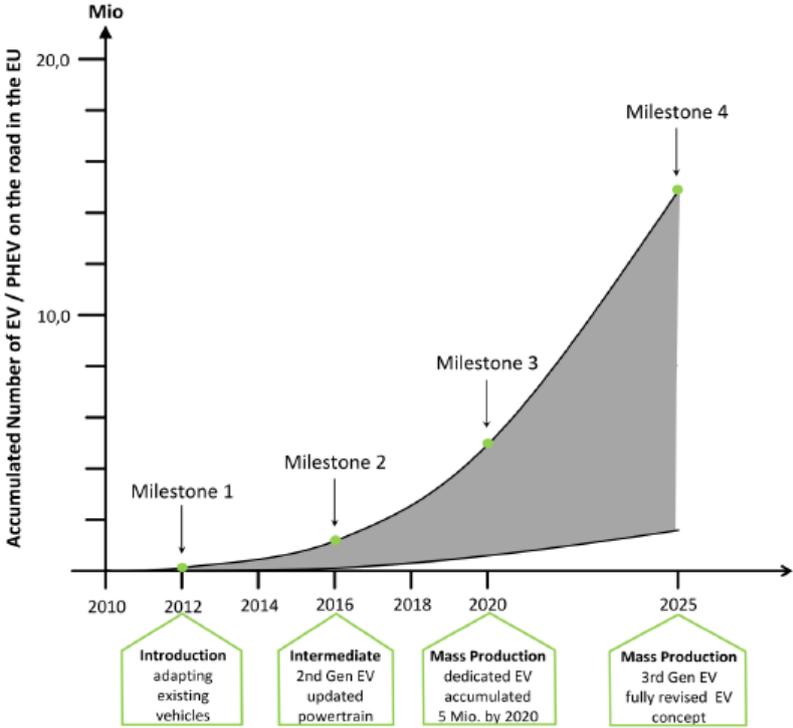


Figure 3: Milestones of the European Roadmap Electrification of Road Transport. Lower black curve: Evolutionary development of accumulated number of EV/PHEV. Upper black curve: Expected development under assumption of reaching the major technological breakthroughs.

According to the “European Roadmap Electrification of Road Transport”, a mass production of dedicated electric and plug-in hybrid vehicles is feasible by 2020 if fundamental progress is made in six technology fields: energy storage systems, drive train technologies, vehicle integration, safety, road integration and grid integration. Mass deployment of the technology will however require significant increases of energy efficiency and reductions of cost which may be provided as of 2025 by a fully revised electric vehicle concept (see Figure 3).

Future customer demands combined with legal requirements will drive the introduction of Hybrid Electric Vehicle (HEV) technologies, increasing the energy efficiency of vehicles propelled by conventional powertrains, while developing enabling technologies for the future large scale vehicle electrification. Without hybridisation, especially with Plug-In Hybrids and Range Extender Hybrids, the goals of decarbonisation cannot be achieved (see figure 4).

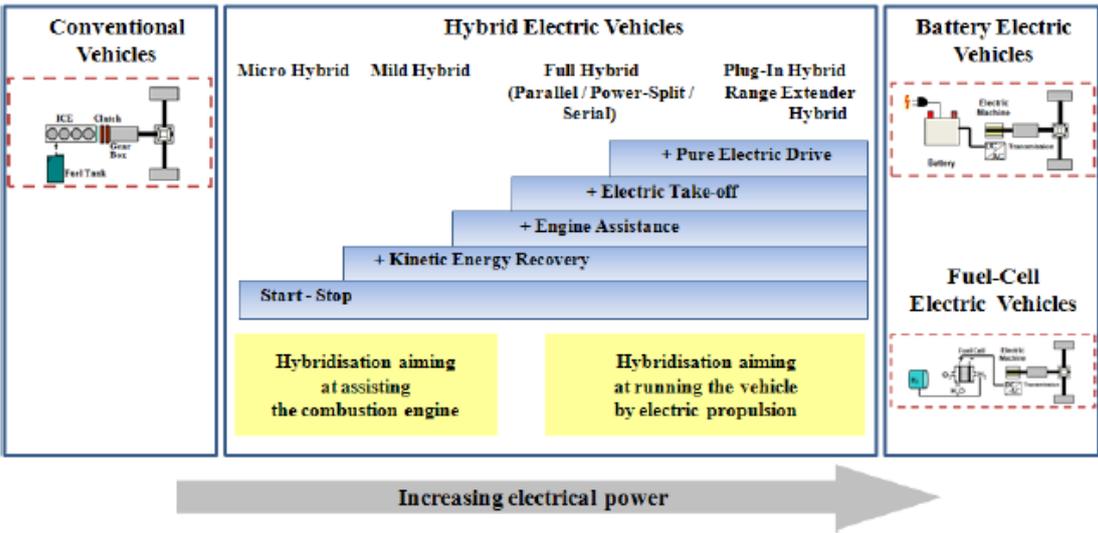


Figure 4: The classification of hybrids

The Multi-Annual Implementation Plan of the PPP EGVI is based on the relevant research and innovation roadmaps developed by the European Technology Platforms. Table 2 outlines the roadmaps which can be used as source for this content. The full ERTRAC-EPoSS-SmartGrids joint roadmap on Electrification of Road Transport is attached as Annex 2 of the present document.

ERTRAC-EPoSS-SmartGrids joint roadmap Electrification of Road Transport
ERTRAC roadmap European Technology and Production Concept for Electric Vehicles
ERTRAC roadmap Hybridisation of Road Transport
ERTRAC roadmap Light-duty Powertrains and Fuels
ERTRAC roadmap Sustainable Freight System for Europe / Heavy Duty Truck

ERTRAC roadmap European Bus System of the Future**EPoSS Strategic Research Agenda chapter Automotive****SmartGrids Strategic Research Agenda****Table 2:** Relevant sources of content for the multi-annual implementation plan of the PPP EGVI.

According to the Automotive part in the Transport and Mobility section of the Strategic Research Agenda of EPoSS, ICT and smart systems can provide the enabling functionalities for energy efficient powertrains and vehicles. Particularly in the electric vehicle most mechanical control functions can easily be replaced by electronic means and be supported digitally by embedded software. Thus, energy efficiency may not only be achievable by innovations in cell technology or by use of lightweight materials, but also by integrating a high degree of electronic control, adaptive capabilities and intelligence to the system. This approach enables range extension or battery downsizing in a smart way. ICT and Smart Systems also provide drivers with a more comfortable and adaptable car, permit better precision in control, facilitate active safety measures and automation and increase reliability by active material health concepts. These features compose unique selling propositions of the electric vehicle made in Europe. Smart systems also offer the possibility for synergies through smart optimization and integration and for adding harmonic interplay to the building blocks of the electric vehicle such that e.g., the drawbacks of today's batteries that lack energy density, lifetime and affordability, can be compensated. Therefore, research and development priorities in the domain of smart systems for energy efficient and electric vehicles are included in the EPoSS roadmaps for Horizon 2020.

Additional roadmaps may be developed by the technology platforms, and used by the PPP, if important missing aspects are identified. Moreover, these roadmaps will be updated periodically: they are snapshot of the situation today, and it will be a task of the partners within the platforms to monitor and continuously update them.

Electrification of Road Transport	
Energy Storage Systems	fully
Drive Train Technologies	fully
Vehicle System Integration	fully
Transport System Integration	partly
Grid Integration	partly
Safety	partly

Table 3: Coverage of roadmap Electrification of Road Transport by PPP EGVI

For the multi-annual implementation of the EGVI PPP, research priorities will be extracted from the roadmaps according to industry recommendations, and bearing in mind the scope decided for the initiative. Some subdomains of roadmaps will fully fall into the coverage of the EGVI, while for others only a part of the topics will be likely to be selected for coverage by the PPP. An example is given in table 3 for the roadmap Electrification of Road Transport.

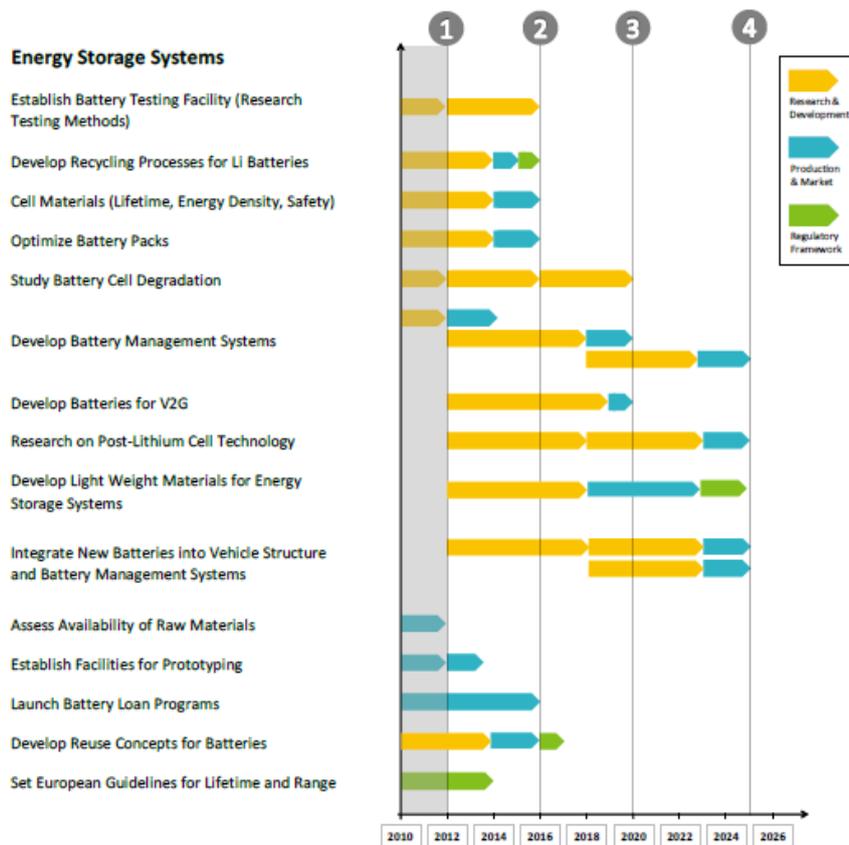


Figure 5: Chapter on energy storage systems of the electrification roadmap

On this basis, the content of the PPP EGVI can already be specified, and broken down into the technology fields covered. Concerning the timeline for coverage of the various subdomains, the PPP will base its work on the detailed roadmaps which state the different types and timelines of activities (research and development, demonstration, support to market introduction, standardization and regulation) which are necessary for the milestones and the objectives to be reached.

As an example, the detailed roadmap for the chapter on energy storage systems of the electrification roadmap is shown in figure 5. In agreement with the described focus of the PPP EGVI the pure materials research aspects in it will not be covered by the EGVI, whereas the application of new materials to cells will be fully in the scope of the R&D strategy. Such detailed roadmap for a subdomain exists for each subdomain of all the ETP roadmaps mentioned above as sources for the EGVI PPP.

The annual recommendations for funding topics will be made on this basis by the new PPP organization, with priorities selected by industrial delegates. The annual selection is therefore a matter for the future prioritization exercise, which should be open and flexible, and allow adaptation according to technology and market evolutions towards 2020. Figure 6 gives some (non-exhaustive) examples of technology content to be covered by the PPP.

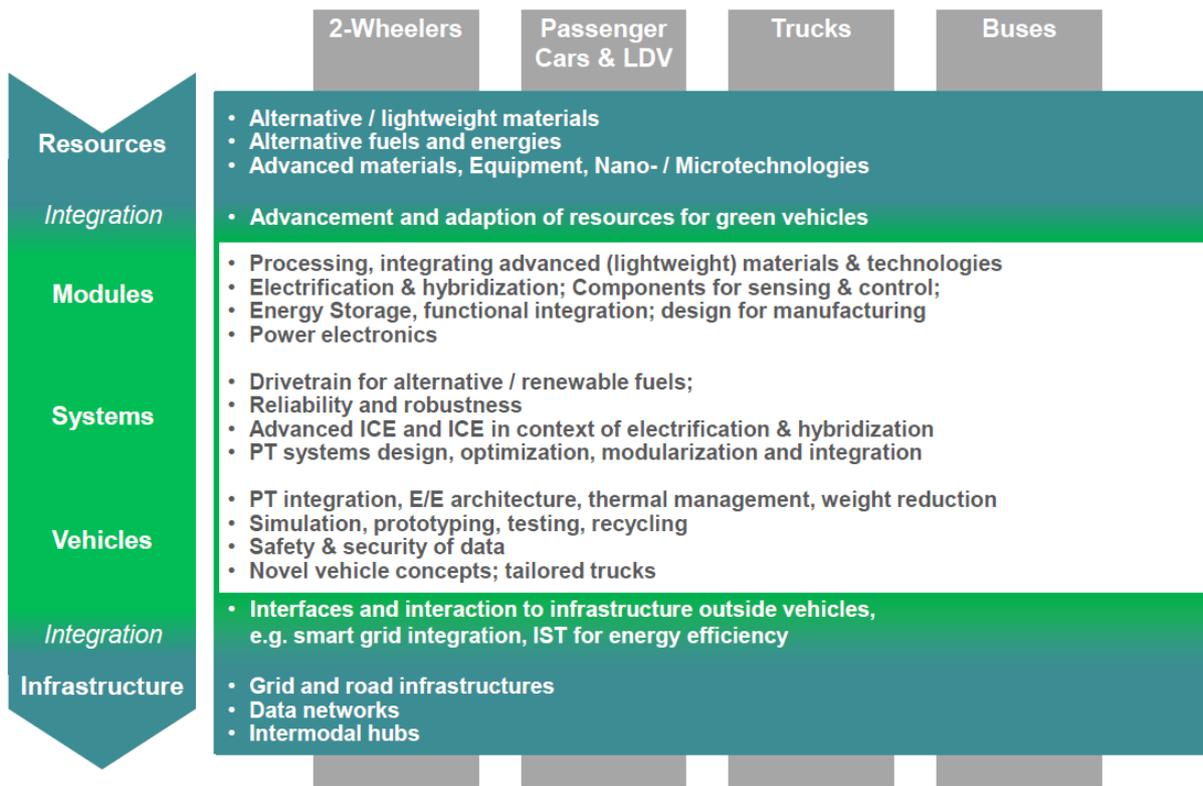


Figure 6: Examples of technology content of the PPP EGVI (light green)

PART III: Expected Impacts

- **Scale of the R&D involved and ability to leverage additional investments in R&D**

The impacts of the PPP have to be considered in relation with the general context of the industry in Europe and worldwide. The European automotive industry invests about EUR 30 Bn per year in research and development, 2/3 of it being currently allocated to improve the energy efficiency of the vehicles. This accounts for more than 12% of gross expenditure on R&D in the EU27⁹, and places the automotive industry at the first rank of the sectors investing in R&D in Europe, as shown by the report of the EC Joint Research Center (JRC) on Industrial R&D Investment¹⁰. With European automotive companies being at the top of this scoreboard of industrial R&D spending, the automotive industry can truly be considered as a European R&D champion.

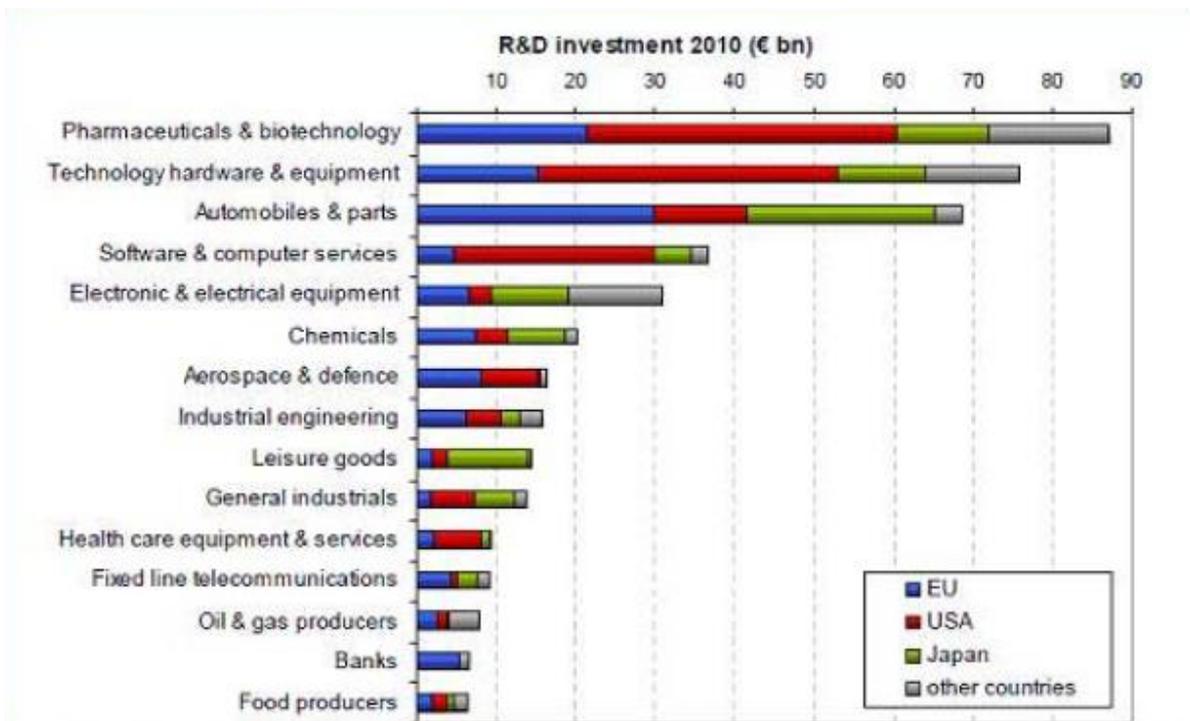


Figure 7: Ranking of industrial sectors by total worldwide R&D investment and share of main world regions for the world's top 1400 companies¹⁰

The JRC report also shows that R&D investments of the automotive sector in Europe are higher than the investments made by Europe's competitors, which proves the very high commitment of the European industry towards new technologies and innovation. The share of smart systems in the expenses for automotive R&D can be estimated to about 30% of total R&D expenses for automobile technologies, and it can be expected that it will even increase in the future.

Considering those levels of investments at European and worldwide levels, and looking at the objectives of the PPP, in the context of key European policies such as the Transport White Paper, a **total 7 years programme budget of EUR 3 Bn** seems necessary all along Horizon 2020, in order to constitute a critical mass and to bring tangible impacts. If one considers a funding rate in practice of

⁹ Eurostat, http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/R_%26_D_expenditure

¹⁰ European Commission, Joint Research Centre, 2011 Industrial R&D Investment Scoreboard

about 50%, this proposal **means a EUR 1.5 Bn EC funding**. Such EU program together with a nearly 5 times higher expected national funding by the Member States amounts to a total of 18 Bn € in public-private research program dedicated to energy efficiency. In order to illustrate the potentially high leverage effect of that funding the sum of EU and national funding can be compared with the 2/3 of the **total R&D spending of the industry** for energy efficiency and alternative drive trains which according to the JRC is **about EUR 30 Bn per year** (see figure above). It means an impact on about EUR 140 Bn of R&D dedicated to energy efficiency and alternative drive trains on average during the seven years duration of Horizon 2020: the EUR 1.5 Bn EU funding in the initiative together with the expected National funding of 7.5 Bn could therefore impact investments just on R&D up to nearly 15 times higher.

Even though there has not been much experience with the leverage effect of the novel instrument of a PPP in the domain of research and innovation so far, it can be argued that the PPP EGVI under optimal conditions could be able to achieve such **leverage effect of more than 10**, which would be remarkably higher than that achieved in regular R&D funding programmes. The reason for this assumption is the fact that the PPP is expected to spark a multitude of breakthrough technology developments. For technology developments which are much closer to market readiness, and which need little to no change in the innovation process, the leverage factor of R&D spending would be around 5 or even below for incremental improvements. In the case of the PPP EGVI, however, where many of the technical areas considered imply technology breakthroughs requiring long term and cost-intensive research and development efforts by the industry, the leverage effect can be much higher if these efforts are expected to lead to market success. Furthermore, the PPP can lead to serious efforts along the innovation chain besides R&D activities, e.g. extensive testing, which is cost intensive, and profound modifications to the manufacturing schemes, with eventually fully new production processes. A company that is spending several millions Euro in research per year on one of the breakthrough technology areas in view of the PPP EGVI is likely to spend easily 20 times more and sometimes even more than 50 times more in order to lead to that technology deployment on the market. These additional investments are secondary effects but could be particularly relevant to the establishment of a competitive electric vehicle battery manufacturing industry in Europe.

Since the EGVI PPP is focused on highly innovative technologies which require risky investments, the EU funding will make a substantial contribution to the overall innovation chain: promising results of European research projects, which are usually in a pre-competitive stage, leading to further investments within companies into in-house or other collaborative research projects, and if successful in development phases, consequently leading to massive investments in the view of production and market introduction of innovative technologies. In particular where significant breakthroughs are envisaged, the EU funding can be a substantial trigger for the overall innovation chain by covering those few % of the total R&D investments that are highly risky for the industry, but that can if successful lead to a cascade of investments towards a successful market introduction.

That funding by the EU has therefore a very important lighthouse role. One has to consider that the societal challenges driving the PPP and its projects are shared within the companies involved, which further invest in house in order to pursue the same objectives. Projects from the PPP can therefore have a high influence on the industry R&D. Moreover, the task of validating technology options by research and demonstration activities is also of very high value, especially because the EU framework programmes allow working throughout the European wide level, delivering an assessment across the

national markets, which is precious for the R&D of companies who are acting across all the EU countries.

In practice, the funding allocated by the European Commission to research and development is being complemented by funding from national and regional authorities. If one takes into account the investment of industry, public funding reaches a level of about only 3%, but of high importance particularly if focused on integration and systems approaches, as the results from this precompetitive research can later be further developed into new technologies, which resulted from a mix a funding, public and private. From this standpoint, the money spent at the European level has a multiplicative effect for the development of products, because it paves the way to investments in many companies in different countries. European research projects have the added value of reducing the R&D spending risk for the participating companies, because if a larger group is working together towards the same goal, then a risk-sharing effect takes place.

With the EGVI PPP, by setting up a well visible European programme for green vehicles, the European Commission will support the research excellence of the sectors in Europe and ensure that innovative technologies for greener vehicles will be developed by European companies within Europe. The realisation of the EGVI will offer the opportunity to strengthen the R&D base of the European automotive industry, which already files around 6300 patents per year¹¹. Also, these investments will benefit the sector of embedded systems and the energy sector, for instance boosting the development of smart grids, which are very key sectors for future growth opportunities in Europe. ICT and infrastructures industries and supply chains can also benefit from new market opportunities and new business models developed together with the deployment of electrified vehicles.

- ***Expected impacts on industry and society e.g. on competitiveness, growth, employment, trade, productivity, climate change and environment***

In addition to its leverage effect on R&D investments, the EGVI PPP will have positive economic and social impacts. In 2008 the launch of the European Green Cars Initiative was part of the European Economic Recovery Plan. Support to R&D in the automotive sector was at that time identified as a key measure to support one of the most important industrial sectors of Europe, which has major impacts on employment and economic activity. In brief, EU policy-makers had understood that supporting innovation in the automotive sector can help improve the entire EU economy and bring Europe out of the economic crisis.

The situation in 2012 is not very much different than the one in 2008: innovation is still seen as a very key aspect for the industry in order to remain competitive, to preserve its markets, and therefore to guarantee further employment and growth opportunities. Projects from the EGVI PPP and the resulting technologies and methodologies will lead to additional investments in Europe in engineering capacities, in production tools, in manufacturing facilities, in infrastructures, in new services, in maintenance services, in training, and so on, which overall constitute a very positive impact on the EU economy and society.

Looking at employment, about 12 Mn jobs, of which a majority are highly skilled, directly or indirectly depend on the European automotive industry¹². This represents about 6% of all employment in the EU. The 16 major car, truck and bus manufacturers in Europe operate 169 vehicle assembly and

¹¹ ACEA, www.acea.be/news/news_detail/automotive_sector_tops_rd_investment_scoreboard

¹² ACEA, Eurostat, mentioned in MEMO/12/419

engine production plants in 16 Member States¹³, often sustaining the economy of complete cities and regions. Automotive suppliers give direct jobs to about 5 Mn employees¹⁴, within large companies but also within a dense network of more than 3000 SMEs located all across Europe. Moreover, manufacturers and suppliers of the automotive industry are important costumers of sourcing industries such as metals, electronics, chemicals, plastics, textiles, glasses, etc, which are highly impacted by the growth rate of the automotive sector. This considerable socio-economic contribution of the automotive industry has to be sustained, and the related European value chains have to be strengthened and adapted to new challenges.

The expected innovations in the EGVI areas should contribute to supporting employment in Europe, for various levels of education: not only the R&D and engineering activities have to be retained in Europe, but also production and supporting services. Education and training can support the availability of a skilled workforce, and suitable measures will consequently contribute to improving the problematic situation in the labour market of many countries like high youth unemployment.

Another point is that only due to innovation will it be possible to compensate the future loss of employment in Europe. Today, most companies are setting production capacities in China, South America and in Europe's neighbouring countries, in particular for products based on conventional technologies and older platforms. From this standpoint, the innovation approach compensates this trend with new products integrating innovative technologies, which are designed for the European consumers, and better fit for a production in the EU. Linked to that aspect, one key target is the improvement of the productivity of the European automotive industry, defining productivity as a measure of the efficiency of production (output-input ratio), which can be impacted by targeted R&D on design and manufacturing. The scale of impact on competitiveness is difficult to quantify but, as also stated in the CARS21 report, it is clear that the technological leadership and high productivity of the EU automotive industry remain its key competitive factor on the global scale.¹⁵ The EGVI PPP will support R&D investments that have an influence on productivity and competitiveness, impacting, in turn, key economic indicators such as jobs, growth and trade.

Concerning trade, the size of the European automotive sector and its global orientation play a significant role in the Europe Union's trade balance. In 2011, there was a positive contribution to the EU trade balance of almost EUR 92 Bn.¹⁶ To a certain extent, the EGVI PPP can support this positive trend by accelerating the development of new technologies and products addressing the needs of consumers worldwide, at competitive cost, meeting expectations in aspects such as quality and reliability, fuel efficiency and emissions, connectivity and comfort, etc, outperforming competitors.

Relating to growth, producing 15.8 Mn vehicles (20% of the world market in 2010) and exporting parts and accessories from Europe worth EUR 33 Bn¹⁷, the European automotive industry involved in the EGVI has important factors for supporting growth and stabilizing the economic cycle in Europe. Growth is expected in various areas covered by the PPP and in particular within the objective of electrification of vehicles, which covers several domains where important new opportunities for growth have been identified (electric drive train components, batteries, novel architectures and

¹³ ACEA, 2011 Annual Automotive Statistics Overview

¹⁴ CLEPA, European Association of Automotive Suppliers

¹⁵ CARS 21 High Level Group on the Competitiveness and Sustainable Growth of the Automotive Industry in the European Union, Final Report 2012, 6 June 2012

¹⁶ Eurostat, mentioned in MEMO/12/419

¹⁷ CARS21 Final Report, Brussels 2012

concepts, ITS, light materials, services for e-mobility, smart grids management, amongst others). Other supporting measures than R&D support linked to the electrification can also have a high impact on economic activity in European, such as investments in infrastructure, public procurement programmes and support to production facilities..

For the overall impact of the EGVI on climate and environmental aspects, references have to be made to the ERTRAC Strategic Agenda, and to the specific roadmaps feeding the PPP. In the ERTRAC SRA¹⁸, decarbonization is considered as a Grand Societal Challenge for the road transport sector, and guiding objectives on energy efficiency improvement have been set, both for urban passenger transport (+80 % in pkm/kWh) and for long distance freight transport (+40% in tkm/kWh) in 2030 compared to 2010 levels. The contribution of the EGVI to these objectives can be assessed as very important, because the scope chosen for the PPP - energy efficiency of vehicles - including electrification, hybridization, advanced ICE's and adaptation to alternative fuels, will constitute a large part of the energy efficiency gains towards these objectives. More details about energy efficiency improvements and CO₂ saving expectations for each technology can be found within the different roadmaps.

- ***Specific objectives of the EGVI PPP***

The specific objective of the EGVI PPP is to integrate and demonstrate at least 40 innovative technologies in green vehicles and mobility system solutions on component, systems and vehicle level. Among them, 20 will concern innovative powertrain systems/technologies, including adaptation to alternative fuels and new vehicle concepts. The other 20 will be in the areas of electric storage systems, electric components and systems, and interfaces between vehicle and infrastructure. These innovative technologies shall lead to an improvement of the energy transport system efficiency by 50% from 2010 to 2030, including +80% energy efficiency of urban vehicles and +40% energy efficiency of long distance freight transport. Another goal is the deployment of alternative powertrains like electric and plug-in hybrid technologies, according to milestones in 2016 and 2020 and matching respective performance parameters, as described in the Electrification roadmap: 5 million Electric and Hybrid Vehicles in the EU by 2020 (0,5 million by 2016); battery life-time and energy density doubled, at 30% lower cost, in 2020 compared to 2009 Li-Ion technology. Moreover, these expected innovations shall lead to the creation of 10 new types of high-skilled jobs through knowledge transfer and training.

Key Performance Indicators:

A number of core key performance indicators (KPIs) have been identified at the PPP implementation level and project impact level. They will serve to analyse the progress towards the specific objectives of the initiative.

At the PPP implementation level, progress will be examined on the basis of the development of new systems and technologies, participation and benefits for SMEs, contribution to the reduction of energy use and CO₂ emissions, number of electric and hybrid vehicles, contribution to the reduction in the use of material resources, development of new high-skilled profiles and new curricula, mobilisation of private investment in relation to the PPP activities, and contributions to new standards. At the project impact level, the key performance indicators correspond to the scale of

¹⁸ ERTRAC Strategic Research Agenda 2010

reduction in energy, material resources and waste, the project results taken-up for further investments (into higher TRLs), the advance of trainings for a higher quality workforce, and the development of patents and activities leading to standardisation.

It should be noted that the assessment of R&D programmes and project according to such KPIs may be complicated due to the lack of predictability of success or failure which forms the basis of any research.

- ***Added value of action at EU level and benefits of a Contractual PPP instrument***

Acting with a PPP at European level is of added value complementary to national and local actions, because vehicles and mobility services have to be developed for international markets, using standardized cross-borders solutions, and need to be able to compete on a worldwide basis. Therefore industrial players from the automotive and energy sectors see such a programme at European level as a necessary step for the development of innovative competitive solutions ready for deployment across Europe.

The Contractual PPP model as proposed for the EGVI offers the best-possible combination of the technological needs of the European industry, the expertise of the leading European stakeholders, and the experience of the EC, in successfully managing large collaborative public research programmes for many years. The EGVI PPP will provide the right contents for the right European programmes and will develop appropriate links with national programmes and other European schemes. These include the EIB financial instruments, the ERA-NET and ERA-NET+ initiatives like as the Electromobility+, as well as if possible with the TEN-T programme; the Structural Funds; and education and skills programs.

The EGVI topics include activities offering significant opportunities but with high level of risk. Consequently it cannot be expected that all results will be achieved exactly as planned. However, without public financial support for these projects, it is likely that there would be much less or no opportunity at all to address these challenges. Furthermore European Programmes such as the Framework Programmes for Research and Innovation are today the only ones where research collaboration with practically all leading researchers worldwide is possible.

Benefits of using a Contractual PPP instrument:

- Secured commitment of industry and the EC to meet critical societal and industrial policy objectives;
- Builds on success of the European Green Cars Initiative in FP7, which has successfully demonstrated the added value of a basic PPP concept;
- Efficient management: leaner and faster organisation and governance, obtaining the benefits from a formalization of the partnership (less time to set up, reduced costs, less legal and administrative burdens) without the efforts of an institutionalization;
- Openness to the participation of a wide stakeholder group, including newcomers and smaller players, in transparent procedures, public consultations and open competitions, and enabling also a wide inclusion of particular experiences from all EU countries;
- Emphasis on defining clear directions and priorities through Roadmaps which have gained wide consensus through the activities of the underpinning Technology Platforms;

- Greater flexibility and agility, capable of responding more rapidly to emerging opportunities in terms of technological development on one hand and to unforeseen, adverse conditions and a shifting economic situation on the other;
- Appropriate structuring of programmes and individual projects in order to guarantee adequate coverage of all research priorities and provide potential synergies in order to enable the pre-determined targets and milestones to be achieved;
- Facilitating the collaboration between competitors on a wider range of topics, thus strengthening the competitiveness of the EU industry as a whole;
- Higher efficiency achieved by avoiding overlapping between smaller competing collaborative projects (CPs) while focusing on complementing rather than replacing the conventional CP programme;
- High degree of accountability, through the continuous review and monitoring of progress over the course of H2020, being a clear task of the PPP, using the roadmaps;
- More opportunities for creating coherence and complementarities with the diverse landscape of member states funding policies in the field.
- Continuity to take advantage of excellent expertise and experience of Commission in its management of collaborative R&D programmes, in view of their policy frameworks;
- Greater focus on the integration of supportive measures like standardization or training and education through dedicated actions.

- ***Proposed arrangements to monitor and assess progress towards the objectives.***

The activities of the PPP EGVI will be regularly evaluated in order to monitor and assess their performance, for example, in terms of the key performance indicators, the leverage effect or the socio-economic impact. In view of the specific structure of the PPP such evaluation needs to be carried out both internally and externally. The internal evaluation comprises a self-regulating mechanism based on the comparison of current project activities and results with the original annual implementation plan. The required steps of project monitoring and program assessment are fully integrated in the feedback loop of program consultations which constitutes the PPP operation. They are thus a core task of the PPP governance organization. The external evaluation assesses whether the impact of the PPP EGVI is progressing towards the objectives set by the European Technology Platforms and the European Commission. It may give direction for necessary adjustments in case of major deviations or changing framework conditions. Such external evaluation has to be based on evident facts about project results and credible information about their use in the innovation chain. It can only be carried out by an independent entity which is well accepted by both the public and the private sides. It will collect information on specific projects on a trust basis, and anticipate their contribution to the goals of the PPP. The findings will be published in a generalized manner as an annual progress report which may also give advice to the European Commission and the ETPs. The independent entity should refer to a group of senior experts and could be constituted by e.g. a contract with the EC and the PPP EGCI Association or in the framework of a specific Coordination and Support Action.

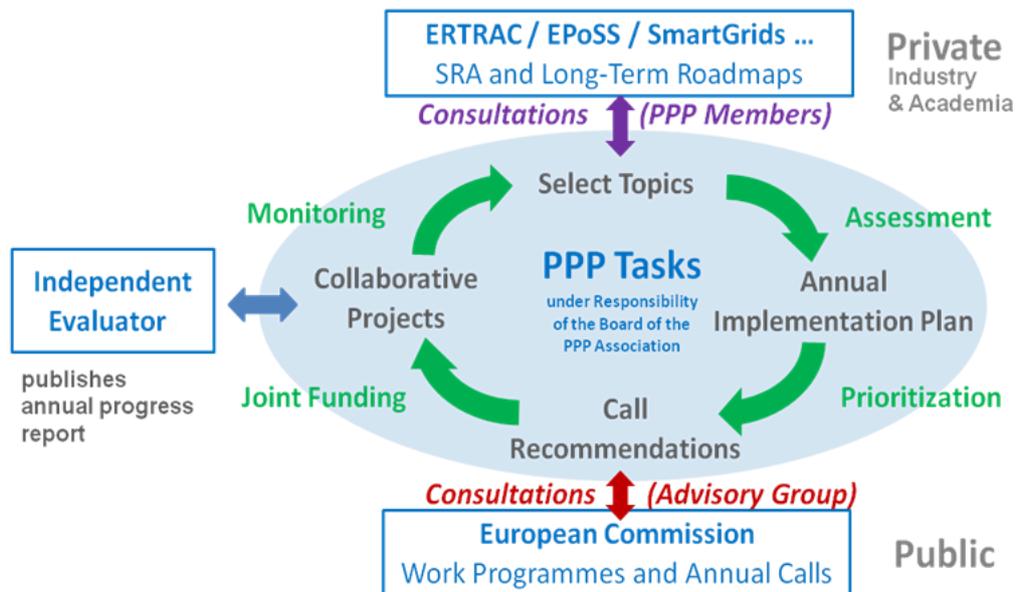


Figure 8: Feedback loop of programme consultations in the PPP

There are comparable initiatives already going on in other economies such as the US¹⁹ and to a certain but limited extent, there are also EC-funded initiatives²⁰ but without the critical mass to cover all the projects and topics in question.

¹⁹ www.starmetrics.nih.gov

²⁰ See CAPIRE report “ Impact Assessment of Publicly Funded Collaborative RTD Projects”, www.capire.eu/public/2011-capire-deliverables/CAPIRE_D12_ProjectAssessment_2012-02-27.pdf/at_download/file

PART IV: Governance

- ***Governance model of the partnership***

The contractual Public-Private Partnership ‘European Green Vehicles Initiative’ will be established based on Article 19 of the Horizon 2020 regulation, through a contractual arrangement between the Commission and the Private Side. This contractual arrangement will specify the roles and duties of the private and public parties, as well as the objectives of the partnership, the respective commitments of the partners and the indicative financial envelope for the European Commission contribution for the years 2014-2020. It will have the nature of a Memorandum of Understanding.

The Private Side of the PPP will be represented by the European Green Vehicles Initiative Association (EGVIA), a legal entity created in the form of an international non-profit association under Belgian Law. The role of the Association is to engage in the contractual PPP with the European Commission and collaborate with the EC services for the implementation of European framework programmes on research, technological development along the value chain, and demonstration. Acting as the representative of the Private Side, it will formalise the principles of work amongst the interested members with the view to developing and prioritizing its research priorities, disseminating information and promoting the partnership and its collaborative cooperation.

The Partnership Board of the EGVI PPP will be established as the governing body of the public-private partnership. It is the main mechanism for dialogue between the European Commission and EGVIA and will act to reach the aims foreseen in the contractual arrangement. Within this body, private and public sides meet on a regular basis in order to jointly prepare the Work Programmes of the European Green Vehicles Initiative PPP. EGVIA will nominate the Private Side members of the Partnership Board, who will represent the wider community of stakeholders involved within EGVIA, particularly the ETPs ERTRAC, EPoSS, and SmartGrids, and be responsible for preparing, in collaboration with the Commission, proposals for topics to be covered in the Work Programmes, as well as any updates of the PPP Multiannual Roadmap. These members will commit themselves to provide advice in their relevant fields of expertise to the best of their ability and in the best interest of Community research.

- ***Openness, transparency and representativeness***

EGVIA is committed to operating on principles of openness and fairness. Using the wide stakeholders basis of the European Technology Platforms ERTRAC, EPoSS and Smart Grids, the Association will organise the tasks of delivering viable research topics recommendations across the community, monitoring program progress and continuously evaluating the efficiency of the activities, as well as of building communication channels with the European Member States, and the research community across Europe.

Any company, institution, research organisation, university or sector association that deals with relevant activities in research & development, demonstration, industrialisation or deployment of technologies and services covered by the EGVI PPP is welcome to join the Association. Its representativeness relies on the great diversity of actors involved: the EGVIA membership includes multiple types of actors, from global companies to SMEs, universities, research organisations, regional innovation clusters and associations. All can contribute to its activities on an equal basis, independently of their size or domain. Therefore, SMEs are also encouraged to engage and be

represented in the Association, either through direct membership or via their participation in sector associations.

All membership applications are presented and considered in a fair and transparent manner at the General Assembly and decisions concerning their admission are taken by the majority of the votes expressed. Today, all categories of members are represented within EGVIA: its membership is composed of 57 full members from both the industry and research sectors, and 7 associate members.

The structure of the Association guarantees that the work is carried out in a transparent manner. The decisions of the Executive Board and of the Secretariat are subject to the scrutiny of, and approval by, all the members. Meeting on a regular basis, the General Assembly is the supreme body of the Association. It approves the general policy of EGVIA on the basis of proposals of the Executive Board and gives recommendations for its implementation. All members can examine, question and decide upon issues affecting the Association.

In addition, EGVIA will implement the appropriate consultation processes to ensure the adequate involvement of all relevant stakeholders in the preparation of the inputs to the Commission and in the projects. Therefore, conferences, workshops and opportunities for the building of consortia will be organized with a principle of openness, all members being invited to all events. Working documents will also be spread across all the members, in order to gather the input from the whole research community working on the EGVI topics, in an open and transparent manner. A Board Observer, representing the research members and directly elected by them, will attend all Executive Board and Partnership Board meetings. Within the Partnership Board, the representatives of the Private Side will work on the basis of the inputs commonly prepared by all EGVIA members and thus guarantee a proper representation of the diversity of stakeholders. They will regularly report on the activities of the Partnership Board at the General Assembly meetings of the Association.

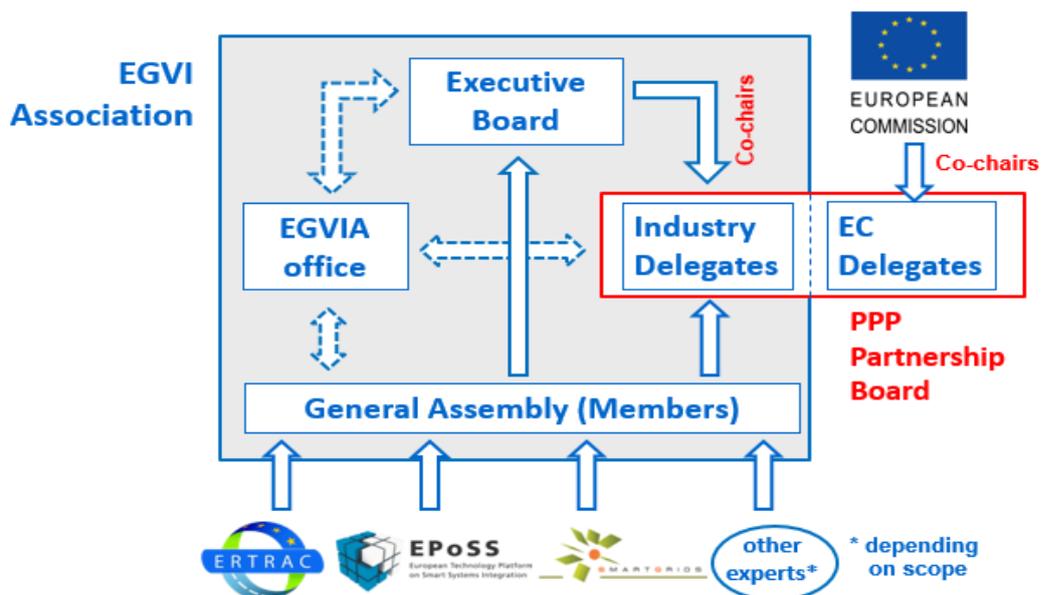


Figure 9: European Green Vehicles Initiative Association governance model

- ***Information and results sharing***

EGVIA guarantees that information is available to the public in an accessible manner, in compliance with the Horizon 2020 Rules of Participation. To achieve widespread dissemination of information on projects and activities, EGVIA will develop a number of communication tools open to the public as well as publications available for free and project reports published on an open-source basis. The findings of the monitoring and assessment process will also be published in a generalised manner in the form of annual progress report which may give advice to the European Commission and the ETPs.

Contacts:

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Annex 1: EG VIA Membership and Bodies

List of EG VIA members

- Automotive OEMs (13): CRF, Volvo, Scania, Volkswagen, Renault, PSA, Iveco, MAN, DAF, Piaggio, BMW, Jaguar Land Rover, KTM
- Automotive suppliers (15): Valeo, Continental, Bosch, Magneti Marelli, Hidria, Mondragon Automocion, Fraunhofer, AVL, IFPEN, FEV, Ricardo, LMS, ESI Group, CIE Automotive, Teknia
- Smart Systems Industry (4): Siemens, Infineon, NXP Semiconductors, ST Microelectronics
- Smart Grid Industry (1): Iberdrola
- Research Organisations (13): CONCAWE, Siftelsen Sintef, IK4 Research Alliance, TNO, IDIADA, Tecnia, Swerea IF, AIT, Virtual Vehicle, Heksagon, ERPC, CERTH, DLR
- Universities (11): Chalmers University of Technology, TU Darmstadt, Mondragon University, Politecnico di Torino, TU Eindhoven, University of Florence, KU Leuven, Vrije Universiteit Brussel, University of Thessaloniki, Valencia Universit, Prague University
- Associate Members (7): CLEPA, Sernauto, ACEM, RECHARGE, FEHRL, EUCAR, MOV'EO

Composition of the Executive Board

- Chairman: Wolfgang Steiger (Volkswagen)
- Vice-Chairmen: Jean-Luc di Paola-Galloni (Valeo), Günter Lugert (Siemens)
- Secretary General: Josef Affenzeller (AVL List)
- Board Observer representing the Research Members: Klaus Kersting (IDIADA)

Private Side members of the Partnership Board

- Volkswagen, Valeo, AVL List, Siemens, IDIADA, CRF, Renault, Volvo, Scania, PSA, BMW, Hidria, FEV, IFPEN, Ricardo, Bosch, Continental, Fraunhofer, STM, NXP, Infineon, Iberdrola
- Secretariats of ERTRAC, EPoSS, Smart Grids

Annex 2: Electrification of Road Transport – European Roadmap

European Roadmap Electrification of Road Transport 2nd Edition



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1 Introduction

Within the last years electrified mobility has been given first priority in the US, Japan, China, Korea and EU. Dedicated national programmes are legion, similarly there is a proliferation of qualitative position papers and reports, while several automotive company executives have contributed to raise the general expectations through announcing the imminent mass production of electric vehicles (EV). The move from 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 of this roadmap is to help quantifying the differences between conventional and new technologies in terms of the much cited aspects of energy and resource security, climate change, public health, freedom of mobility, and economic growth, and to suggest actions that will create an impact on these. Therefore, in the first instance the EV is assessed in comparison with the internal combustion engine (ICE) taking into account:

- Primary energy savings
- Security of energy supply
- Cut of GHG emissions
- Reduction of noxious emissions
- Range and speed
- Cost of technology and constraints on raw materials

Furthermore, based on surveys among major European companies from the automotive and energy value chains, milestones for implementation of the new technologies are set and required actions are indicated in terms of content and timing.

This roadmap builds on the European roadmap “Electrification of Road Transport” as published in October 2009 by the European Technology Platforms ERTRAC, EPOSS and Smart Grids. This roadmap was the result of a Task Force Electrification, which was established at the beginning of 2009 to support the Public Private Partnership (PPP) European Green Cars Initiative. A detailed breakdown of steps towards milestones were formulated in order to assess what benefits electric vehicles bring by when and what actions are required to master the different challenges of deploying electrified mobility on a large scale. A 1st milestone was set in 2012 representing the first step in the implementation of electrified mobility.

With the first milestone being reached in 2012, the time is right for a review of the goals and objectives of the first electrification roadmap. In this updated roadmap the 1st milestone defined as “the introduction phase” is reviewed by mapping current European Green Cars Initiative projects against the defined actions. Furthermore, a new 4th milestone is introduced looking further into the future, extending the timeframe of the roadmap to 2025.

Roadmap scope

Electrification of road transport generally can refer to vehicles of many kinds including bikes, scooters, passenger cars, delivery vans and vehicles for public transport. In this roadmap however the focus is put on passenger cars, and the term electric vehicle (EV) means all kinds of vehicles that provide at least 50km of pure battery-electric range such as pure electric vehicles, electric vehicles equipped with a range extender, and plug-in hybrids, which may provide potential beyond the transition phase, e.g. when combined with biofuels. It shall be pointed out, however, that Light Electric Vehicles (LEV) like e-bikes, motorbikes and

small cars are expected to have a rapidly rising market share and may facilitate the market entry of electric mobility in its entirety. This roadmap is only dealing with vehicles which can be charged with electricity from the electricity grid (Plug in EVs or PLEVs). Thus, this roadmap does not include fuel cell electric vehicles (FCEV). FCEVs are dealt with in other documents, like those generated by the Fuel Cells and Hydrogen Joint Technology Initiative (FCH-JTI) or EUCAR.

This electrification roadmap is part of the long term strategic visions formulated in the Strategic Research Agenda (SRA) of the involved European Technology Platforms, with ERTRAC e.g. presenting the research priorities to tackle the societal challenges of Road Transport, and EPoSS being focussed on ICT and smart systems as key enabling technologies. To implement this vision, implementation roadmaps are developed on key issues. These are concerned with passenger as well as goods transport and the future mobility system as a whole. Some of these roadmaps address topics relevant for electrification, e.g. roadmaps for the future European bus system, light duty freight transport (i.e. modes of transport being responsible for high levels of noise, CO₂ and noxious emissions), and hybrids (which have an enabling role for electrified mobility), heavy duty freight transport (where efficiency gains are rather expected from smart logistics than from electrification) as well as for infrastructures, integration into urban mobility system and European technology and production concepts. These roadmaps complement each other and ensure all aspects of the electrification efforts are covered.

This roadmap aims to serve as one basis for the electrification of passenger cars. It presents the framework for additional more detailed roadmaps on a few topics regarded as horizontal or essential issues for reaching the electrification goals. Identified topics deserving a more in-depth and detailed analysis are simulation, EV manufacturing, grid infrastructure and Information and Communication Technologies (ICT). In a next step detailed roadmaps for these topics will be developed, identifying the steps to be taken in the different areas to reach the common milestones.

EV roadmap purpose and process

This roadmap has been prepared by the members of the European Technology Platforms ERTRAC, EPoSS, and SmartGrids and led by the chairman of ERTRAC. The targeted portfolio of R&D topics in this roadmap is the result of an efficient and fast stakeholder consultation process developed in the PPP European Green Cars Initiative (Fig. 1). Decision makers from major European companies dealing with automotive, energy or mobility topics have gathered in an Industrial Advisory Group, representing the European Technology Platforms ERTRAC, EPoSS and SmartGrids. They entered into a continuous and cooperative dialogue with the involved Directorates General of the European Commission. Their advice and recommendations are based on a continuous process of strategic stakeholder consultations taking place mainly in dedicated workshops. There, the expertise of the members of the platforms can be channelled into the development of this multi annual implementation plan.

The commitment of the involved industries is reflected in collaborative research projects jointly funded with the EC. The approaches and results of ongoing research activities are regularly monitored and matched with the milestones of the roadmaps, in order to gain feedback which is continuously used for the improvement of the advice. Thus, this report is a vital document that is constantly being updated in a broad consultation process. The current update is coordinated and facilitated conjointly by the Coordination and Support Actions CAPIRE and ICT4FEV funded within the 7th Framework Programme.

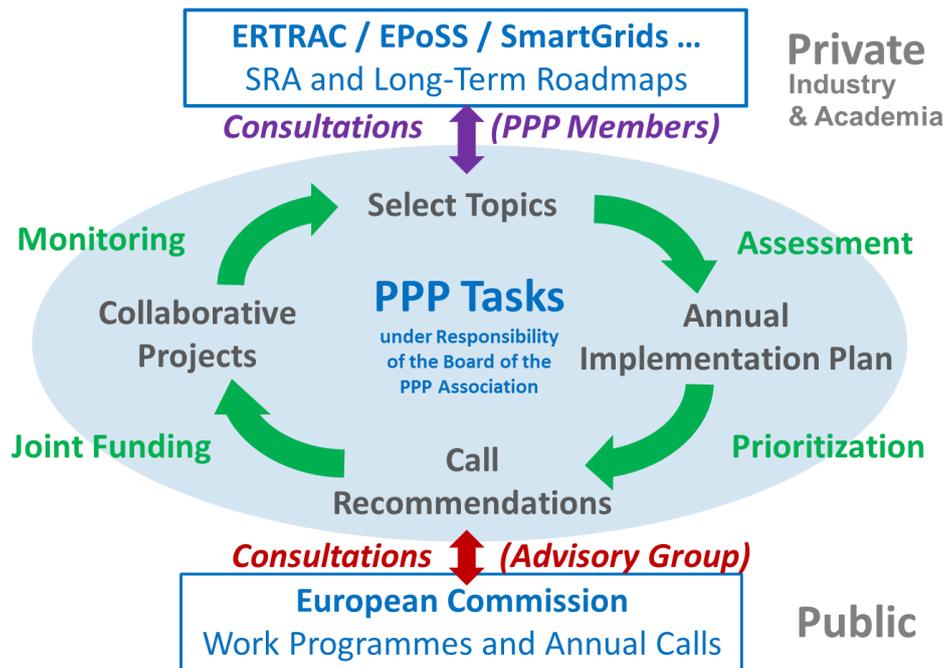


Figure 1: Stakeholder Consultation Process of the PPP European Green Cars Initiative

The mentioned first edition of this report contained recommendations regarding the European 7th Framework Programme. So far, three rounds of calls have been launched and projects are running or starting. The first call published in summer 2009 focused mainly on components and architectures of the electric powertrain, electrochemical storage applications and demonstration of electric mobility. The second, launched in summer 2010, called for projects targeting energy management, stability and safety issues and manufacturing of batteries. Moreover, a joint call of public authorities at Member States and regional level within the framework of ERA-Net Plus was launched. The third call published in summer 2011 addressed electrochemical storage, lightweight material, modelling and simulation, range extenders, smart infrastructure and integration of EVs into transport infrastructure, electric drive and components as well as functional safety. The authors expect that the European Commission and the Member States will continue to refer to this report as a common industry position when setting priorities and timing of actions towards the electrification of mobility and transport as a system. With the current update including the extension to a 4th milestone scheduled in 2025, the basis is provided for recommendations concerning Horizon 2020.

2 Benefits and Challenges of the Electric Vehicle

2.1 Primary energy savings (aiming at energy security)

A growing world population and a growth in GDP will lead to a growth in future primary energy demand. According to IEA the world energy consumption will increase in 2025 with 50%, compared to the level of 2005, 15 billion tons of oil equivalents. This growth will mainly come from non-OECD economies. Oil will remain a long time the basis for fulfilling the world primary energy demand, but gas and renewable energy will gain share by 2030 ⁽¹⁾.

Due to the EU's growing dependency on primary energy sources this parameter is very likely the most motivating one. In the EU, 73% of all oil (and about 30% of all primary energy) is consumed by the transport sector ⁽²⁾. Today, internal combustion engines (ICE) depend heavily on fossil fuel usage, creating depletion of the finite reserve of non-renewable energy sources and creating economic and geopolitical concerns. Biofuels and natural gas are playing a role in securing fuel supply for ICEs, however just for a small fraction. On the other hand, electricity can be produced from many different energy sources including renewable energy sources like hydro, wind solar and biomass.

To quantify the technological evolution that makes electric mobility appealing we take as a reference an ideal vehicle whose energy consumption depends only on mass, aerodynamic drag (frontal area and C_x^1) and tyre/road rolling resistance. In reality, the amount of energy consumed strongly depends on the typology of the powertrain, the chosen cycle, and the energy need for cooling or heating. To compare the electric vehicle and the ICE we take as a reference a mid-size vehicle (1300kg) with aerodynamic factor of $0.7m^2$, conventional rolling resistance tyres, and an ideal powertrain with 100% efficiency, thus consuming 120 Wh/km ⁽³⁾ at the wheels over the New European Driving Cycle (NEDC).

Combustion engines made in Europe are among the most economical ones in the world. Their efficiencies can reach up to 0.45, however varying with speed and load. The extracted oil can be refined into diesel or gasoline with an efficiency of 0.88-0.92. Taking into account real driving cycles and a typical transmission efficiency of the order of 0.9 the overall well-to-wheel (WTW) efficiency of modern powertrains can be set in the range of 0.16 to 0.23 ⁽⁴⁾ ⁽⁵⁾. These values already include the most advanced innovations in fuel and transmission controls. Hence, in reality the consumption of primary energy is between 520 and 750 Wh/km.

The peak efficiency of an electrical motor can achieve 0.95 at defined power and torque values ⁽⁶⁾. It may drop to below 0.6 in extreme cases, but for a large range of power and torque the average efficiency can be kept at above 0.9, thus the electric powertrain can be designed intrinsically less sensitive to the characteristics of the driving cycle, particularly when using more than one motor. The overall combined efficiency of power switches, DC/DC and AC/DC inverters can reach 0.9 whilst that of motors and gears depends on the chosen driving cycle with typical values ranging from 0.8 in case of large excursions of power and torque to 0.86 for smoother cycles. In conclusion from the battery via power electronics to the wheel, the modern electrical powertrain can assure efficiencies in the range of 0.72 to 0.77. For the electric car, the assessment of the well-to-wheel efficiency has to include on the well-to-socket side the efficiency of the generation and the load losses at distribution of electricity. In most EU member states the average efficiency of power plants is at 0.45 ⁽⁷⁾ ⁽⁸⁾

¹ C_x – aerodynamical drag coefficient

,while that of the power grid can reach up to 0.93. Thus considering the whole chain of current conversion efficiencies (power plants, electrical grid, AC/DC inverter, energy-power storage systems in slow charge/discharge modes, power electronics, electrical motors), the well-to-wheel efficiency of the electrical powertrain can be stated to be 0.24 to 0.26 i.e. the consumption of primary energy for the reference vehicle is in between 457 to 492 Wh/km (**Table 1**).

Year	Power Plant Efficiency	Grid Efficiency	Inverter AC/DC Efficiency	Battery Efficiency (Slow Charge)	Power Electr Efficiency (DC/DC, DC-AC)	Motor to Wheel Efficiency (NEDC)	Energy Consumption Ideal mid size car Wh/km #	Total Consumption of Primary Energy Wh/km*
1998 Range 20km°	0.39	0.88	0.85	0.70	0.85	0.65-0.70	120	987-1064 -7% Reg. Braking
2008 Range 150km	0.45	0.93	0.90	0.90	0.90	0.80-0.86	120	457-492 -15% Reg. Braking
2008 Range 150km	Renewable Energy only	0.93	0.95	0.90	0.90	0.80-0.86	120	205-221 -15% Reg. Braking
2008 Range 600km	WTW Powertrain Efficiency of a Conventional Internal Combustion Engine car in reality: 0.16 - 0.23						120	522-750 -10% micro-mild hybrid

Table 1: Evolution of primary energy consumption of electric vehicles, and comparison to the conventional power train. #Energy needed to move an ideal mid-sized vehicle in the NEDC (New European Driving Cycle). °Reduced battery weight. *Cars smaller than the reference vehicle may have less energy consumption.

A comparison with the situation ten years ago shows that in the last decade the technological evolutions have radically changed the impact of the electric vehicle on primary energy consumption: from about 30% higher primary energy consumption as compared to the ICE in 1998 to about 25% energy savings in 2008. These figures do not yet take into account the potential for energy harvesting e.g. by modern low cost on-board photovoltaic technology. The growing fraction of renewable energy in the EU electricity mix will increasingly enable the convergence of CO₂-neutral primary energy sources with electrical mobility.

The well-to-wheel assessments also show that introduction of EVs is less advantageous in countries having power plants and grids with efficiencies below average or when used in the fast charge mode with maximum efficiencies reaching no more than 0.8 at a low state of charge of the battery (**Table 2**). In those cases priority should be given to modernising the sectors of energy production and distribution. Moreover, for both primary energy savings and longer battery lifetime, slow charge should be suggested as best practice until next generation batteries can assure high efficiency under accelerated charging conditions.

Year	Power Plant Efficiency	Grid Efficiency	Inverter AC/DC Efficiency	Battery Efficiency (Fast Charge)	Power Electr. Efficiency (DC/DC DC-AC)	Motor to Wheel Efficiency (NEDC)	Energy Consumption Ideal mid-size car Wh/km #	Total Consumption of Primary Energy Wh/km
2008 Range 150km	0.42	0.80	0.90	0.80	0.90	0.80-0.86	120	641-689 -15% Reg. Braking
2008 Range 150km	Renewable Energy only	0.93	0.90	0.80	0.90	0.80-0.86	120	235-219 -15% Reg. Braking
2008 Range 600km	WTW Powertrain Efficiency of a Conventional Internal Combustion Engine car in reality: 0.16 - 0.23						120	750-522 -10% micro- mild hybrids

Table 2: Primary energy consumption with reduced power plant and grid efficiencies as well as fast charge mode. # Energy needed to move an ideal mid-sized vehicle in NEDC (New European Driving Cycle).

Clearly the convergence of renewable energies (RE) and electrified mobility appears the most appealing for reducing the anthropogenic impacts on the environment as well as reducing the oil dependency. One of the most interesting aspects of the electric vehicle is the freedom to produce electricity from many different energy resources. As a result of the 2007 EU 20/20/20 Energy & Climate strategy ⁽⁹⁾, a binding goal of 20% of EU energy demand to be gained from renewable resources was set by the renewable energy directive in 2009 ⁽¹⁰⁾. Following this, 62% of energy generation investments in 2009 ⁽¹¹⁾ have been dedicated to renewable energies. Member States projections foresee much higher growth rates in the coming years than in the past, which would add up to a share of renewable energies in 2020 that exceeds the targeted 20%. Hence, even if the plans may not be fully met, the way for the provision of renewable energies is paved.

On high-speed highways, full hybrids have higher consumption at full-throttle-operation than conventional ICEs due to their higher weight. But the hybridisation of conventional (mainly) large and mid-sized ICEs can be considered a first step towards energy efficiency through electrification since it allows energy savings up to 25-35% in urban cycles ⁽¹²⁾ compared to the corresponding conventional powertrain. Its implementation on a large scale will thus help to comply with the CO₂ emission targets for cars of the EC for 2012/2015. Thus, in the next 5 years a number of hybrid systems from micro to full hybrids will emerge. At the same time, lighter and smaller full electric cars will be developed requiring even significantly less energy from the battery to the wheel on the NEDC than the reference car considered here.

Well-to-Wheel analysis considers the life cycle of the energy vectors used by the vehicle, but does not consider the whole life cycle of the vehicle. A vehicle's life cycle can be divided into four stages; vehicle production from extraction of raw materials to delivery of the complete product, production of the fuel and/or electricity used by the vehicle during its life, the impact of vehicle use, and finally vehicle disposal at the end of its life. For the purpose of evaluating various powertrain types in terms of environmental impact and primary energy consumption over their entire life time, life cycle assessment (LCA) is a very useful and powerful tool. The general principles for LCA are explained in ISO 14040:2006 and a guide for

practitioners is provided in ISO 14044:2006. ISO 14025 defines Environmental Product Declarations (EPDs). Many vehicle manufacturers are already using LCA to produce EPDs of their vehicles. However there is inconsistency between manufacturers on how the results are presented, and a lack of information provided on input assumptions. This can make it difficult to compare LCA results of vehicles from different manufacturers. Further work is required to achieve commonality in LCA results across the automotive industry and to enable consumers to consider life cycle environmental impacts when making purchasing decisions. EPDs tend to be compiled at the end of the development process as the vehicle goes into production. At this point it is too late to make changes that will significantly impact the vehicle's life cycle environmental impact. Therefore, adoption of a Life Cycle Philosophy from the earliest stages of automotive research and development is required to ensure the appropriate selection of technology for lower environmental impacts. The connection between the purpose of an LCA study and the vital parameters of the goal and scope definition has been explored by Tillman (2000) ⁽¹³⁾. The goal and scope definition of an LCA study is heavily dependent on the intended use of the study and the questions it has been setup to answer. This makes different LCA studies which are not formatted for comparison very difficult to compare indeed, even for seemingly similar product case studies. In order to overcome these difficulties and make full use of LCA as a powerful tool for evaluation of new vehicle technologies, there is a need for increased methodological LCA research, both for general studies as for vehicles studies in particular. An important issue to cover is the selection of a functional unit. The functional unit is the backbone of every LCA as it enables a comparison of different products based on the same provided service. For vehicle LCA the effect of hybridization on different vehicle types and the service they provide should be taken into account when exploring functional units, like in Matheys (2007) ⁽¹⁴⁾. A wide range of vehicle technologies exist. The question is how to treat electric vehicles (with different ranges and batteries), plug-in hybrids, range extenders, strong hybrid vehicles, mild hybrid vehicles and hybrids with various energy sources (thermal engines, solar panel, fuel cell ...). Close to these methodological issues it should be made clear how to perform a sensitivity and uncertainty check in vehicle LCA. Often the environmental impact of a vehicle calculated with life cycle assessment is shown as one single value. This approach approximates the environmental impact of a vehicle, but fails to provide decision-makers with a wide view on the possible effects of their decisions. The complexity, uncertainty and variability of the system are not well approximated with one single value. Uncertainties are an inherent part of LCA and should not be avoided but embraced and made explicit in the result. Identifying and integrating uncertainties in the end result should provide decision makers with a more robust interpretation of the results. An example of a range based vehicle LCA can be found in Van Mierlo (2009) ⁽¹⁵⁾. LCA data is shared on a European level through the Joint Research Center of the European Commission within the European Reference Life Cycle Database (ELCD) and globally within the International Reference Life Cycle Data System (ILCD). The most effective way for LCA researchers investigating electrification of road vehicles to improve data quality will be to use and supply data within these existing networks. Projects directed to data gathering should focus on making production data more specific and detailed on component level instead of aggregated as now. This should also be applied on impact assessment by for instance including geographic information on the emissions of vehicle with a GIS based LCA. When developing new technologies such as electric vehicles, the influence on sustainability parameters should be taken into account. A framework based on case studies on Life Cycle Sustainability should be

worked out. A typical Life Cycle Sustainability Assessment would combine E(nvironmental)-LCA, S(ocial)-LCA and Life Cycle Cost (LCC) aspects in one multi-criteria assessment (MCA).

2.2 Cut of GHG emissions (preventing climate change)

Vehicle emissions are contributing to the increased concentration of gases that lead to climate change. In order of significance, the principal greenhouse gases (GHG) associated with road transport are carbon dioxide (CO₂) and methane (CH₄). In the EU the transport sector causes 26% of all GHG emissions due to human activities ⁽²⁾ ⁽¹⁶⁾. Although these are only 4% of the total GHG emissions they accumulate in the atmosphere because the ecosystem is unable to compensate for them at the same rate as human activities have changed in the last one hundred years. Furthermore, the transport sector is the fastest growing source of greenhouse gases, and of the total from transport, over 85% are due to CO₂ emissions from road vehicles. Therefore, they are considered a major sector to attack for a limitation of GHG emissions ⁽¹⁶⁾.

The differences between conventional mobility based on internal combustion engines (ICE) and BEV in terms of CO₂ emissions are summarised in Table 3. Especially considering the expected development of the European electricity production mix towards renewables, it is evident that EVs may lead to a considerable reduction of CO₂ emissions.

CO _{2eq} in g/km			
	Well to Tank (Batteries)	Tank (Batteries) to Wheels	Total CO _{2eq} Emissions
Conventional ICE Car *	23	120	143
Biofuels	17 - 28	97 - 135	114 - 163
Battery Electric Vehicle 27% Nuclear 20% Renewable 53% Fossils (EU-27 mix 2010)	67 - 84	0	67 - 84
Battery Electric Vehicle (Coal)	126 - 155	0	126 - 155
Battery Electric Vehicle 50% Wind 50% Photo Voltaic (Renewables)	0 - 4**	0	0 - 4*

Table 3: Comparison of WTW CO₂ emissions for conventional gasoline ICE vehicles, biofuels conventional ICE and EVs in relation to the electricity mix. EU-27 Electricity mix derived from Eurostat. Emissions from ⁽⁴⁾. * Definition of conventional ICE car from ⁽⁴⁾. **Emissions for Photovoltaics from EPIA, Wind from EWEA.

Again the impact would not be the same everywhere; for instance in a country where most of electricity is produced by burning coal there would be only minor GHG emission benefit from the EV introduction. The largest reduction is associated with the use of renewable

energies with the lowest values for EVs achieved e.g. in the emerging “carbon free communities”, where the electricity is entirely produced by wind, water, photovoltaic, geothermal energy, biomass or animal waste. However, in a vision where most of new power installations will be renewable technologies, the EV is considered a way towards a radical reduction of greenhouse gas emissions. Deployment of electric vehicles may even help to extend the use of renewable energy if it is targeted at captive fleets in areas close to an abundant supply of stochastic renewable electricity. With the mass deployment of EVs the securing of marginal energy production from sources with low GHG emissions will become important for the GHG balance of EVs.

In order to assess thoroughly the environmental impact of vehicles, a full life cycle assessment has to be carried out, taking into account variability and uncertainty. BEVs powered with wind power, hydropower or nuclear power appear to have very low greenhouse effect, since there are no conversion emissions related to electricity production. They are followed by the scenarios of the European electricity mix and natural gas electricity production, which also have very low greenhouse effect in comparison to diesel and petrol vehicles. In extreme scenarios, in which BEVs are for 100% powered with oil or coal based electricity, the LCA results shows that BEV have climate impacts which are comparable to the ones of diesel cars. As fuel saving technologies are reducing the total life cycle carbon emissions mostly by lowering the WTW carbon emissions, the balance of the carbon footprint between life cycle stages is relatively changing towards the production of the components. In absolute terms, the WTW stage still remains the most important life phase. When a BEV is only powered with renewable energy or nuclear energy, the embedded carbon of the vehicles’ components becomes the majority of the impact on climate change, since there are no tailpipe emissions neither conversion emissions related to electricity production. Different data sources for the carbon footprint of batteries can lead to different interpretations of carbon footprint of electric vehicles. ^{(15) (17)}

2.3 Reduction of noxious emissions (raising public health)

Road transport remains the main source of many local noxious emissions including benzene, 1,3-butadiene, carbon monoxide (CO), nitrogen oxides (NO_x) and particulate matter (PM). Within urban areas, the percentage of contributions due to road transport is particularly high. There is a growing body of evidence linking vehicle pollutants to severe health effects such as respiratory and cardio-pulmonary diseases and lung cancer. In general according to the World Health Organisation the emissions from car exhausts are responsible for more deaths than road accidents. It should be pointed out however, that major improvements in urban air quality have occurred in the past decades, due to improvements in emissions performance from conventional vehicles. This improvement has frequently been estimated to be better than about 95% compared to about 20 years ago. Looking out to 2025, and given the EV penetration shown in Figure 2 in this roadmap, advanced ICE vehicles will still represent more than 90% of the on-road fleet in 2025. So, further improvements in urban air quality to a large extent will have to come from emissions improvements in advanced ICE vehicles. The growing penetration of EVs in the longer term will contribute to the elimination of the side effects, which are due to hydrocarbon combustion in conventional vehicles, provided that they don’t occur during power generation. Some emissions, e.g. due to

tyre/road abrasion however remain and studies will be needed to ensure that they are not worsened because of the different traction characteristics of EVs.

Road traffic is known to be the most important contributor to urban noise levels, which usually exceed the WHO-guidelines and cause major health problems. The noise of electrical vehicles is limited to rolling resistance and air drag. First steps are currently taken to understand the NVH (Noise Vibration Harshness) properties of electrified vehicles, but the road is still long before a similar level of expertise and dedicated numerical and experimental tools are available as for ICE vehicles. Exterior noise at different speeds needs to be studied, for example the effects on road safety caused by low-speed noise levels have rarely been studied so far and need to be further investigated.

2.4 Range and speed (freedom on mobility and the need of fuels)

A mid-sized BEV in use for urban mobility will be designed such that it can be operated for most of the day by a single charge. In contrast, with long distance highway driving and/or at with sustained high speeds, battery capacity may not be sufficient to complete a journey or a full day's driving with a single charge. As a consequence, due to the limitations imposed by affordable costs, acceptable extra weight 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. To cover the full spectrum of mobility needs, whether the vehicle is a full, mild, or micro hybrid powertrain, the use of high energy density liquid or gaseous fuels will remain necessary without alternatives in the midterm horizon⁽³⁾. At the same time, micro hybridisation of conventional mid and large size vehicles will continue and expand on a broad scale.

A need for research is hence foreseen in the direction of integration of compact and efficient ICEs and electrical motors, as well as in advanced fuel cells as a range extender. Higher consumption of fossil fuels in emerging economies is likely to hamper biofuels output at the global level. The search of new routes to new fuels is therefore of paramount importance in view of the ever increasing gap between demand and supply of oil. Further achievements should be encouraged towards novel biofuels derived from algae grown with biowaste nutrients and novel synthetic fuels assigning a priority to solutions that minimise the use of land and freshwater. In the longer term, charge while driving as a solution may remove the need for ICE as range extenders and create full freedom of mobility in a long term perspective. Several techniques and system solutions are now being pursued and developed in the world, and the prognosis of these technologies are that they will be up and running in the period of 2025-2030.

It is however worthwhile to note that about 90 % of the mobility needs in European cities can be satisfied by pure mid-sized EVs as the average mileage is almost always below 100 km per day at low speed. Range and speed are not a strong limiting factor when speaking about urban traffic. Furthermore, since an average vehicle is parked for 20-22 hours of the day, the possibility of low power charging (2-6 kW charging power) and thus the opportunity to satisfy an even higher percentage of Europe's inhabitants driving needs is obvious. But real-world driver experience shows that "range anxiety" is real (especially when considering the range impact of different driving styles and in particular outside temperature) and that thus many drivers do not dare to use the battery capacity fully. In this context more research regarding range anxiety and EV driving behaviour as well as the interrelation with the

availability of infrastructure is needed. Furthermore, innovative ITS services and tools will support the driver with the benefit to enhance his confidence in EVs and their integration with the infrastructure. Another important issue is research on typical driving cycles for specific regions since the battery and hence the range will be influenced by the different regional conditions as e.g. landscape and weather.

2.5 Cost of technology and constraints on raw materials (EU security)

The cost and supply constraints of the battery pack are acknowledged to be the most limiting factors for the wide scale introduction of battery electric vehicles. Making a detailed analysis of the raw materials used in the current state of the art Li-ion technology their selling price may be expected to reach affordable values at below 200€/kWh on cell level in the mid term (18) (19). This is a very challenging target and can only be achieved when learning effects due to large scale productions and further optimisation of the cell structure are achieved. This would very likely lead to the desired price levels in a few years, but the user of the automobile is asking for much more than just lower costs. Progress has been dynamic in terms of design of lightweight chassis, powerful and efficient drive trains, aerodynamic shapes, and sophisticated computer controllers.

Substantial reservations persist about the long-term performance of Li-ion batteries under the extreme heat, cold, humidity and vibration conditions that automobiles have to endure on a daily basis (if not compensated for by appropriate protection measures). For instance the lifetime of a battery is halved every 10 deg of average temperature increase, which requires complex and expensive temperature conditioning including either expensive liquid or forced air cooling of the overall battery compartment.

Still a couple years ago, analysis showed that battery production and especially European battery production will not be sufficient to cover the expected demand by the automotive industry. OEMs reacted and accelerated their efforts to build up their own battery production facilities or build Joint Ventures to secure their battery supply. Presently, the number of production facilities and their announced capacity starts to raise concerns of over supply starting in 2015. These predictions however, are very dependent on the expected market development of EVs. Hence, a stronger take-up of EVs on the market may easily lead to an under supply again. Furthermore, the strengthening of the European production ability should be watched closely.

The second large source of uncertainty is related to the availability of reliable and diversified supply of raw materials, e.g. copper and rare earths for permanent magnets that are necessary to assure high efficiency and high power density, that is compact, electrical motors. While at a research level several solutions are pursued, it seems there is no viable industrial alternative to NdFeB for at least another decade when considering Permanent Magnet synchronous motor designs. The move from few and critical sources of oil to a likely even more critical single source of rare earths magnets should urgently address the development of both new high efficiency motors using a limited amount of permanent magnets and completely new motor designs, as e.g. induction motors. Like for the batteries the production of low cost, efficient and compact motors using permanent magnet technology will not be available in adequate volumes and will be subjected to supply constraints for several years. The issue of rare materials is also important for other parts and components as e.g. power electronics. The Raw Materials Initiative of the European Commission DG Industry and Enterprise has developed a strategy for rare materials supply

⁽²⁰⁾. Automotive specific aspects related to R&D will be considered in detail in the Materials Roadmap described as transversal function in chapter 7.

The issues of batteries, motors, and the scarcity of crucial materials severely threaten the large scale introduction of electrified vehicles as they are pushing back the enormous and crucial economic and environmental benefits that EVs can provide.

3 General expectations

Public perception of the move towards the electrification of road transport is affected by a multitude of motivations like e.g. climate protection, primary energy savings, and public health. Government incentives are also expected to play a major role in accelerating the move towards lower emission vehicles. Governments across the world are providing different economic stimuli to push the development of new technologies. On the other hand regulations on vehicle emissions, force OEM's to pursue CO₂ reducing technologies. The stringent European emission regulations coupled with the high fuel prices provide an additional incentive to develop new and cost efficient technologies. These factors can be an important driver for the European automotive industry to develop the right solutions for the future and secure exports to megacities abroad. At the same time however, there are concerns about high investment costs and scarcity of raw materials. Nevertheless, there is a growing awareness that the underlying technology has gained a sufficient level of maturity which is pushing towards a quick change.

From one side the users are asking for EVs well beyond what the OEMs can deliver, on the other side the spread of unsafe vehicles, bad practices and inefficient infrastructures should be avoided. The number of people living in urban areas has recently overcome the rest of the world population and everywhere the tendency is to avoid the urbanisation of new lands while remodelling the urban area by introducing new concepts of mobility.

To understand the potential current driving factors for the future market of EVs we consider the following EU data ⁽²¹⁾:

- 68% of the EU population including associated states live in urban areas
 - 6 cities have more than 3 million inhabitants (Berlin, Madrid, Paris, London, Ankara, Istanbul)
 - another 20 cities have between 1 and 3 million inhabitants
 - considerably more cities have between 0.5 and 1 million inhabitants
 - 80 cities have between 250.000 – 500.000 inhabitants
- from 7% to 10% of all Europeans live in areas or aggregations of houses that can potentially be transformed into smart communities efficiently using renewable energies.
- 17% of vehicles are purchased by public administrations in the EU

As pointed out previously, urban transport will be the major application for the battery electric vehicle, at least within the short and medium term. However, the challenge of the BEV goes beyond this, and intercity and cross-border driving should be kept within the focus of R&D. In several cities, the experimental use of BEVs has started in public fleets and demonstration and deployment projects. Some of those are connecting infrastructure through whole regions or set the stage for a country wide EV use within the near future. Below some selected examples are given, but many more projects were and are being conducted.

In Germany and Austria within the model regions, infrastructure was installed. EV use schemes and business cases for public transport were set up as well as car sharing schemes. Also, private EV use with their combination depending on the specific regional conditions and requirements were set up. Broader programs were also started in Portugal and Spain.

Within the MOBI.E project several Portuguese municipalities are involved promoting EVs by incentives and the renewal of public fleets. Furthermore, the related infrastructure is installed also along main highways. Similarly, the Spanish project MOVELE aims to promote the countrywide use of EVs with purchase incentives and supports funding the required infrastructure. Another example is France, where a broad EV car sharing project is launched in the urban area of Paris. AutoLib (Automobile Liberty) started with 250 EVs on 250 Stations (180 among them in Paris downtown) and plans to reach 3000 EVs by the end of 2012 which will be shared between 1200 Stations in Paris and 46 cities in the Paris Region (Ile-de-France). Coordination and synchronization of these regional EV deployment initiatives is aimed for at the European level. In the Netherlands, as of March 2012 E-laad.nl and eight other EV infrastructure operators have installed about 1700 charging stations across the country at public places. It is planned to reach 4000 stations at the end of this year. This EV infrastructure can be used with one authentication card within a payment roaming system. Furthermore, the Amsterdam Car2Go EV car sharing fleet operates 200 EVs.

In the frame of CIP-ICT-PSP (22), first deployment projects started January 2012 like smartCEM ⁽²³⁾ piloting EV services in Newcastle, Turin, Barcelona, San Sebastian and Gipuzkoa region with the aim to demonstrate the potential for EVs in urban and interurban contexts and to encourage their uptake through advanced and heterogeneous mobility services (EV navigation, EV efficient driving, EV trip management, EV charging station management, EV sharing management). Besides the smartCEM project, 3 other CIP-ICT-PSP deployment projects are conducted in European cities and countries: Molecules ⁽²⁴⁾ (Barcelona, Berlin and Turin), ICT 4 EVEU ⁽²⁵⁾ (Bristol, Vitoria-Pamplona, Ljubljana-Maribor) and MOBI.Europe ⁽²⁶⁾ (Portugal, Ireland, Galicia-ES, Amsterdam).

The European project Green eMotion ⁽²⁷⁾ draws together the results and experiences of regional deployment projects in order to develop a European electric mobility concept. This work incorporates harmonization of technology, standards, policies and regulations, solutions for recharging infrastructure and the integration of electric mobility services and ICT solutions.

So far the demand for EVs has been generated especially by public funding programs. It can be expected that this demand will constantly rise as more and more cities and regions take up the promotion of EV usage and the installation of infrastructure. Furthermore, the European Commission promotes public procurement of clean vehicles. These demonstration and test projects will form the bridge towards the broader market launch of the EV. Improved public procurement practices can help foster market uptake of innovative products and services, such as EVs, whilst raising the quality of public services in markets where the public sector is a significant purchaser. Mobilizing public authorities to act as 'launching customers' by promoting the use of innovation-friendly procurement practices is therefore an important measure in action plans, taking into account risks and regulatory limitations. In December 2011, the publication of the EC proposal: "Horizon 2020 - The Framework Programme for Research and Innovation (2014-2020)" ⁽²⁸⁾ confirmed procurement of innovation, with both Pre-Commercial Procurement & Public Procurement of Innovation, as a new policy tool to support smart, sustainable and inclusive growth and to foster the business competitiveness in the European Union. State and municipal procurements processes often are designed to follow old paths and thus risk to hinder innovations that would be better suited to meet the needs of society, create jobs and provide new export opportunities for Europe.

4 Timing for development and implementation

In response to the abovementioned public expectations, the involved industries have combined their knowledge and experience in order to assess what benefits of the electric vehicle can be achieved by when, and what actions will be required to master the challenges of electrified mobility at large scale. The setting of milestones refers to passenger cars and considers six major technology fields being:

- Energy Storage Systems
- Drive Train Technologies
- Vehicle System Integration
- Grid Integration
- Integration into the Transport System
- Safety

In all these technology fields, further research and development is needed prior and in parallel to the first phase of market introduction. Besides R&D within the abovementioned technology fields the electrification of the passenger vehicle requires a coherent development and horizontal coordination across the various domains. There is e.g. a need for at least Europe-wide standards to ensure interoperability. Especially in the area of charging the sooner standards are available the quicker the market for EVs can develop, e.g. inductive charging. Furthermore, other areas as manufacturing, challenges regarding rare materials and the development of new materials, implementation of new value chains, education and training as well as studies of customer expectation and the development of new business models have to be considered. Many of these areas are complex and require a high level of coordination and coherence with other fields. Testing, Modelling & Simulations, Information & Communication Technologies, Grid Infrastructure and Materials will therefore be detailed in separate roadmaps. They are within this document introduced as transversal functions (chapter 7). The specific roadmaps will become annexes to this document. Other aspects are roadmapped within the European Technology Platforms⁽²⁹⁾.

Example: Grid Integration

The need for a coherence of R&D activities, business development and regulatory measures across various disciplines and sectors can exemplarily be described for the topic of grid integration of the electric vehicle: For EVs no expensive infrastructures like what would be needed to deliver and store hydrogen are required, however even for the most simple case, that is the conventional home plug, controlled unidirectional charging is desirable, and to take advantage of the full potential of an EV, a smart bidirectional energy flow (Vehicle-to-Grid, V2G) capability may be aimed at the longer term. This will be based on an appropriate interface allowing the exchange of both electricity and data between the vehicle and the grid. Furthermore, the interaction of the EV with the grid is a deal involving the car owner, energy providers and grid operators, public authorities (state, regional and city levels) and utilities, all calling for a positive business case.

A large scale implementation of grid integration requires the definition of safety standards at the charge station as well as regulations to avoid undesired effects when connected to the grid⁽³⁰⁾. The bidirectional energy flow between the vehicle and the grid or V2G will rather be a second step as the timing to get the infrastructure ready will critically depend on the speed the standards and the regulations enter into force, as on the availability of the required

smart grids technology and the necessary investments. In this sense the field operational tests with large fleets appears necessary so that enough data and experience on best practices could be collected prior to implementation.

With the electrification of road transport we are facing a disruptive technology objective that will be backed by massive investments all over the world. Thus major European companies agreed to jointly discuss their strategies and expectations for the largest and most demanding application, i.e. urban mobility, from which other applications will follow. They developed dedicated road maps describing the milestones as well as the actions that have to be taken in order to turn the move towards electrification into opportunities for Europe.

5 Milestones

By setting milestones dedicated objectives and the overall timeframe of the roadmap are identified. Thus milestones define the basis of the roadmap. Within this report, the way towards these milestones is detailed in the next chapter where topical roadmaps specify the individual goals and tasks necessary to reach the milestone targets. Both, milestones and roadmaps are the outcome of a broad consultation process involving the stakeholders from the automotive and related sectors within the European Green Cars Initiative PPP as described in the introduction.

As a kernel for the roadmaps up to the foreseen mass production in 2018-20, a scenario for passenger cars based on two technology paths was considered which can be expected to develop at comparable pace:

- The plug-in hybrid car providing 50km pure electric range, having an energy consumption of about 120-100 Wh/km as well as same comfort and same safety as a conventional car. Studies indicate that customer acceptance can be expected to develop within the next years towards the acceptance of a price of an additional 2000 Euros per unit ^{(31) (32) (33) (34)}.
- The electric car providing 200km pure electric range, seating four passengers, having an energy consumption of 120-100 Wh/km, smart (and on the long run: V2G) charging capabilities, same comfort and same safety. The total cost of ownership will be comparable to the ICE vehicle although the initial cost may still be around 5000€ higher, due to the lower cost of maintenance and fuel prices ⁽³⁵⁾.

During the passage of milestone 3 towards milestone 4 a major innovative step is expected to deliver a profound change in the architecture of the electric vehicle. Hence, the future electric vehicle will move away from the base scenarios defined above and pave the way for an advanced type of electric vehicle:

- Electric vehicle with novel platform facilitating lower consumption and thus providing a higher range. Modularity may even allow a convergence of full electric vehicle and plug-in hybrid.

This roadmap focuses on the electrification of the passenger vehicle. Roadmaps on other vehicle types have been developed by the European Technology Platform ERTRAC, addressing both passengers and goods transportation, and covering the entire mobility system. Many aspects within these roadmaps are relevant and draw links with the electrification e.g. the Hybridization roadmap (having an enabling role for electrified mobility); the European Bus System of the Future; Infrastructures for Green Vehicles; Towards an Integrated Urban Mobility System; etc.

Over the course of the next two decades, the following four milestones related to the focus of this document, electrification of passenger cars, can be identified (see Table 4, Figure 2).

- **Current Situation - Milestone 1: Introduction (2012):**

The first step of implementation of electrified mobility is based on the adaptation and conversion of existing vehicles into plug-in hybrid and electric cars. Beyond demonstration and field operational tests, first fleets are evolving for niche applications like, e.g. taxis, car sharing systems, delivery services and other captive fleets. Standards for safety, data communication and billing are being developed, along with testing activities and actions for raising public acceptance. At the same time, major breakthroughs are expected in terms of the understanding of underlying technologies and principles.

- **Milestone 2: Intermediate (2016)**

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. At the same time, an enlarged charging infrastructure allowing dissemination over various cities and regions will develop.

- **Milestone 3: Mass Production (2020)**

Mass production of dedicated plug-in hybrid and electric vehicles may be fully established in Europe. Batteries providing about doubled life time and energy density compared to 2009 Li-Ion technology status at about 30% of 2009 cost will be aimed for. Highly integrated and cheap electrical motors and power electronics, highly efficient and cheap thermal solutions and particularly batteries, the most crucial component, need to be on the market in big quantities. This will make the vehicles sellable without subsidies. The infrastructure for grid integration may be expected to provide on a broad scale advanced levels of convenience through e.g. contactless and (given the availability of appropriate power lines and batteries) quick charging at high efficiencies. Bidirectional energy flow between the vehicle and the grid has great potential to develop to an interesting option for fleet applications.

- **Milestone 4: Fully Revised Electric Vehicle Concept (2025)**

The exploitation of the full potential of electric cars regarding energy savings and reduction of environmental impact requires to not only “electrify” the common car, but to totally revise the automobile concept. This will lead to increased energy efficiency and enable synergies of improvements in various technology fields (e.g. batteries, vehicle weight etc.) which again lead to step changes in energy efficiency and cost. Hence, the achievement of this major innovative step will greatly contribute to the availability of EVs at the cost of an ICE vehicle without incentives.

The 3rd generation electric vehicle will be based on dedicated integrated platforms including a revised ICT reference architecture and middleware. It is envisioned to feature innovative zero-emission drive train systems enabled by distinctly improved energy recovery and batteries with enhanced V2G and fast charging capabilities. Especially contactless charging may be a widely available alternative for more comfort and widely standardized, and charging while driving may be available in dedicated areas. The incorporation of a multi-fuel range extender may be a solution for enhancing the options provided by an EV. Full integration into the multi-modal transport is required for establishing customer acceptance and new use cases.

	Milestone 1	Milestone 2
Energy Storage Systems	Understanding of all relevant parameters for safety, performance, lifetime and their interplay. Concepts for their proper management.	Manufacturing of long life, safe and cheap energy storage systems with advanced energy and power density.
Drive Train Technologies	Concepts of Drive Train components optimized for efficient use and recovery of energy. First implementation in prototypes.	Manufacturing of range extenders & update of electric motors and power electronics for optimized use of materials and functionality.
System Integration	Solutions for safe, robust and energy efficient interplay of power train and energy storage systems. First implementation in prototypes and product lines.	Optimized control of energy and thermal flows based on hard- and soft-ware for the electrical architecture.
Grid Integration	Charging adaptive to both user and grid needs.	Charging at enhanced speed. Standardization for (fast-)charging in place.
Transport System	Road infrastructures and communication tools encouraging the use of electric vehicles.	Extensive integration of electric vehicles with other modes of transport.
Safety	Electric vehicles (tested and inspected for) meeting (new) safety standards at same levels as conventional cars.	Implementation of solutions for all safety issues specific to mass use of the electric vehicle and road transport based on it.

Table 4.1: Description of the milestones.

	Milestone 3	Milestone 4
Energy Storage Systems	Batteries providing compared to 2009 Li-Ion technology status doubled energy density and lifetime, at 30% of cost compared to 2009 status, and matching V2G in mass production.	Move towards Post Li-Ion batteries. Batteries providing 4-5 times higher energy density and tripled lifetime at 15% cost compared to 2009 technology and cost status. Wide spread fast charging and bi-directional capabilities.
Drive Train Technologies	Implementation of powertrain systems providing a range comparable to ICE at sharply reduced emissions in mass produced vehicles.	Drive Train systems based on innovative concepts. Distinctly improved energy recovery. Use of novel materials. Functionality optimized for varying driving modes/conditions. Zero emission EV. Multi-fuel compatible range extenders.
System Integration	Mass Production of novel platform based in overall improved system integration.	Entirely revised EV modular platform including revised ICT-Reference architecture/middleware.
Grid Integration	Standardized quick, contactless and smart charging with bi-directional capabilities.	Full integration into the grid with charging-while-driving functionality. Wide spread use of inductive charging. Enhanced bi-directional energy flow.
Transport System	Semi-automated driving based on active safety systems and car-to-x communication.	Enhanced usage of car-to-x communication for automated and cooperative driving for zero-accident road safety and highly convenient driving. Integration of EV in multi-modal transport system.
Safety	Safety systems and functionalities following innovations in EV development. Enhanced exploitation of active safety measures for electric vehicles including safety of vulnerable road users.	Active and passive safety measures for EVs used in multi-modal transport. Updated safety systems to enhanced modular vehicle platform with multiple integrated functions.

Table 4.2: Description of the milestones.

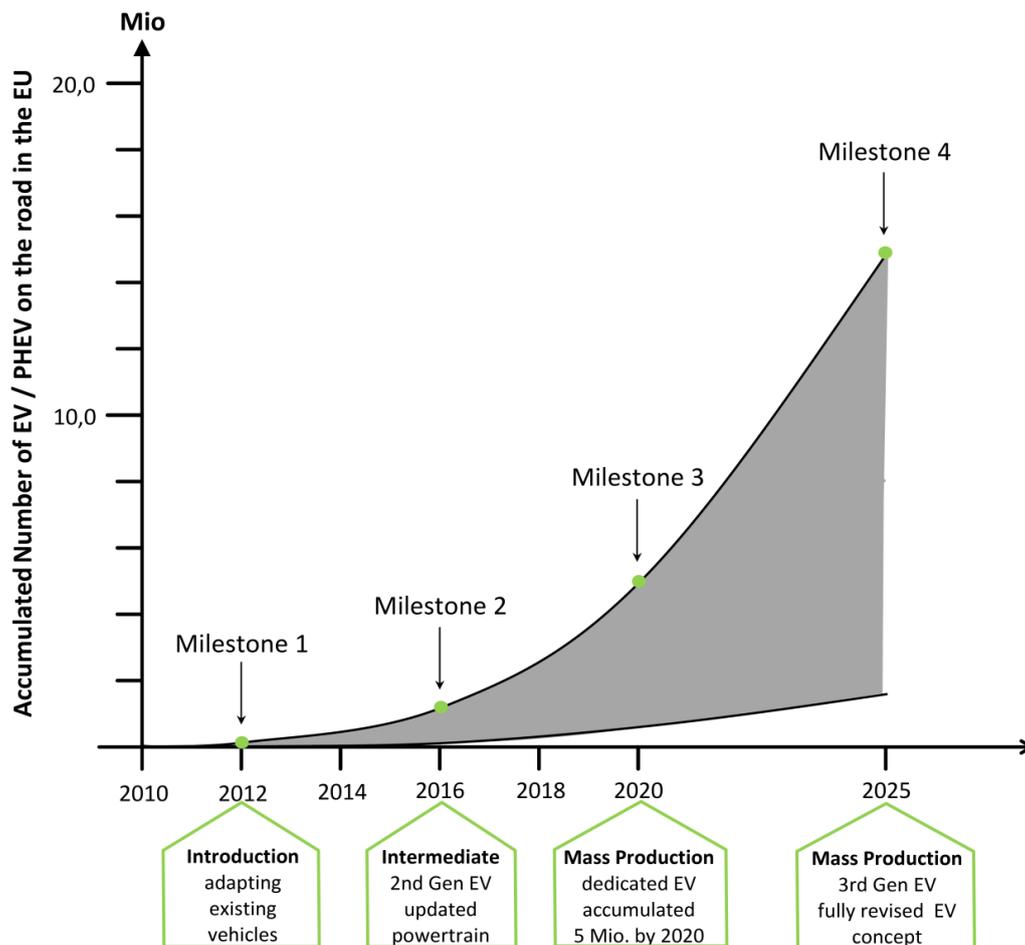
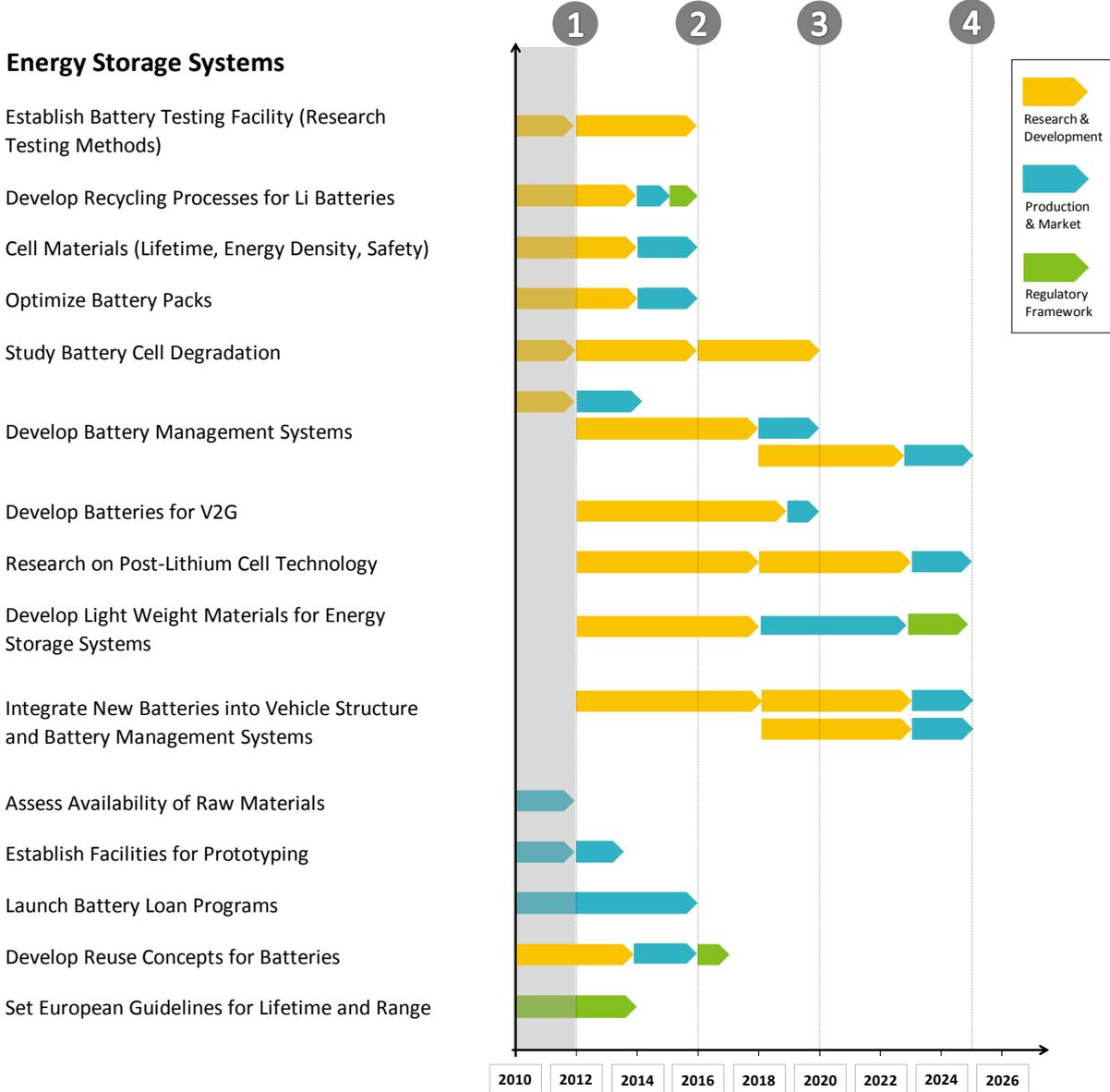


Figure 2: Milestones of the European Industry Roadmap for Electrification of Road Transport. Lower black curve: Evolutionary development of accumulated number of EV/PHEV. Upper black curve: Expected development under assumption of reaching the major technological breakthroughs as described for the six technology fields in table 4.

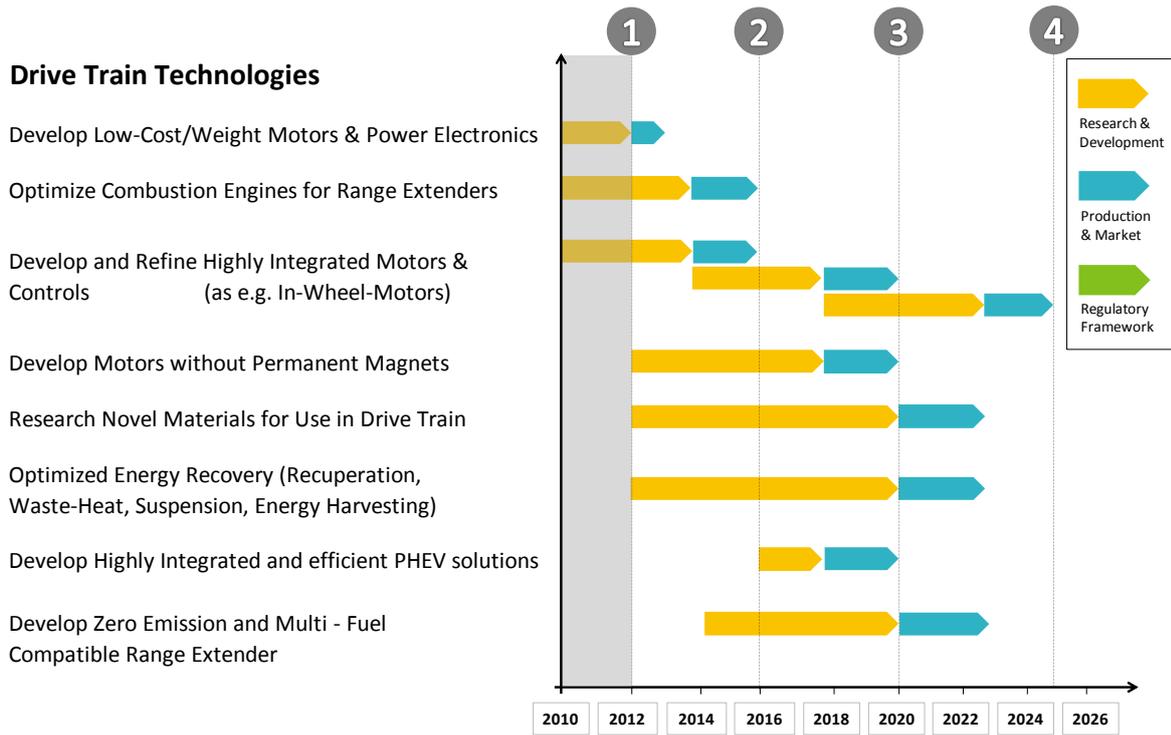
After the initial phase of market introduction and towards mass production the number of electric vehicles will be constantly rising and the accumulated number of 5 million electric vehicles in the EU in 2020 may be reached. Once mass production is reached, the number of produced vehicles will not saturate since further advancements in technology and production processes are expected towards milestone 4. In fact, as described above, following initial mass production of dedicated vehicles a major innovative step is expected leading to a revised EV system and platform which may also open new possibilities regarding production. Thus, the number of produced electric vehicles will continue to increase and considering the lifetime of the vehicles in 2025 an accumulated 15 million electric vehicles may be expected on European roads. Various studies exist regarding the market development of EVs which investigate different scenarios. Under similar assumptions of technology development the derived market development is within the same range ⁽³⁶⁾. Table 4 summarizes the detailed description of the milestones outlining the breakthroughs and developments needed in terms of energy storage systems, drive train technologies, system integration solutions, grid infrastructures, safety systems and road infrastructures as given by the involved companies and organizations from the European Green Cars Initiative.

6 Roadmaps

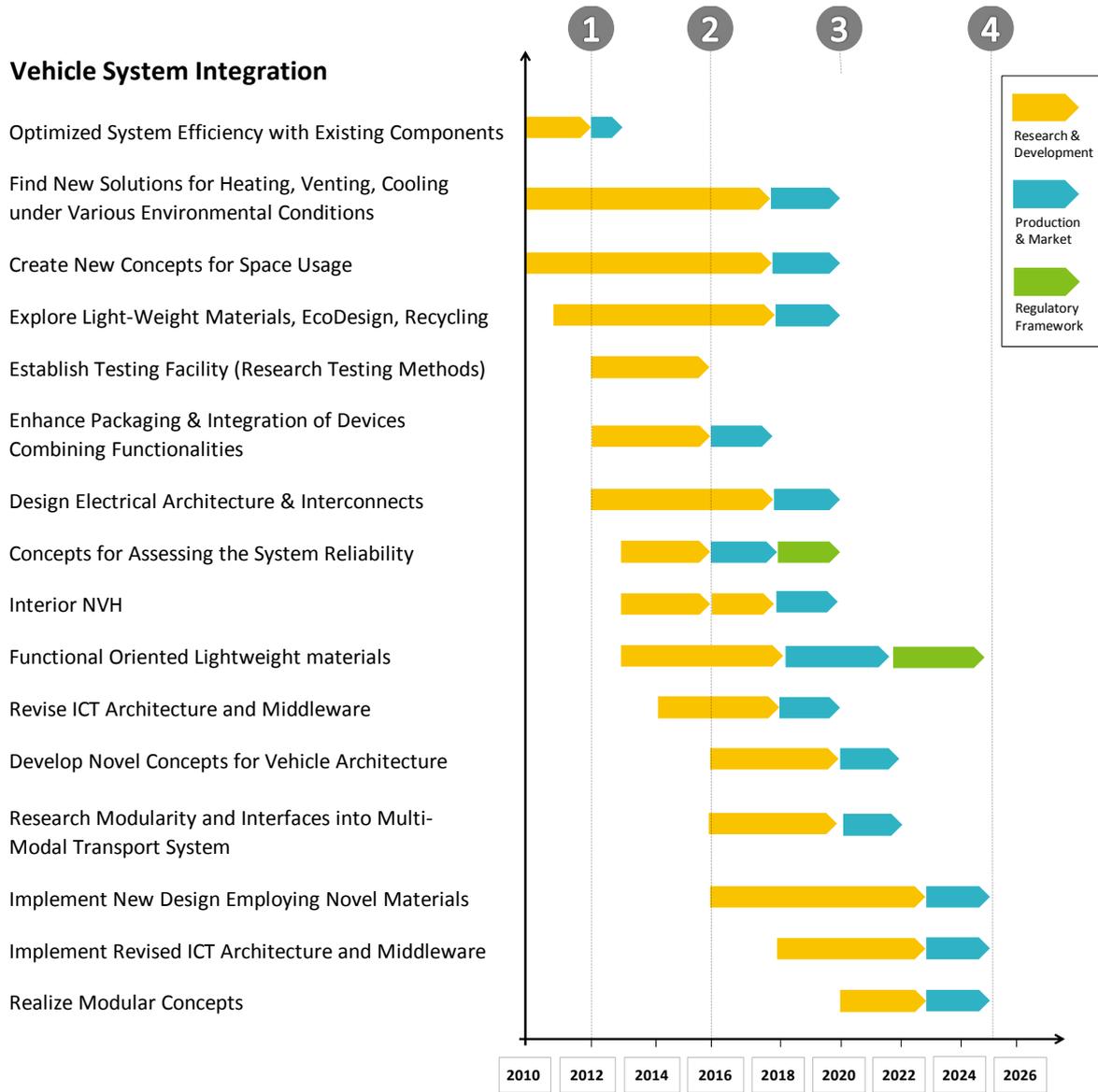
Following the definition of milestones, the involved companies and organisations from the automotive and energy sectors agreed on actions to be taken in order to achieve the stated objectives. Considering phases of R&D, production and market introduction as well as the establishment of regulatory frameworks, dedicated roadmaps were drafted that indicate what has to be done when for a well-timed move of Europe towards the electrification of road transport. Focus topics equal the abovementioned priorities in Energy Storage Systems, Drive Train Technologies, Vehicle System Integration, Grid Integration, Safety Systems, and Integration into the Transport System as a whole (see following figures).



Drive Train Technologies

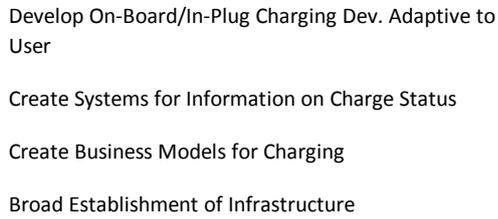


Vehicle System Integration

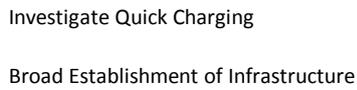


Grid Integration

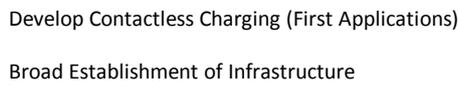
Plug-In Charging



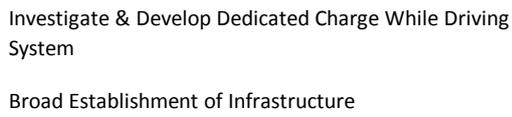
Quick Conductive Charging



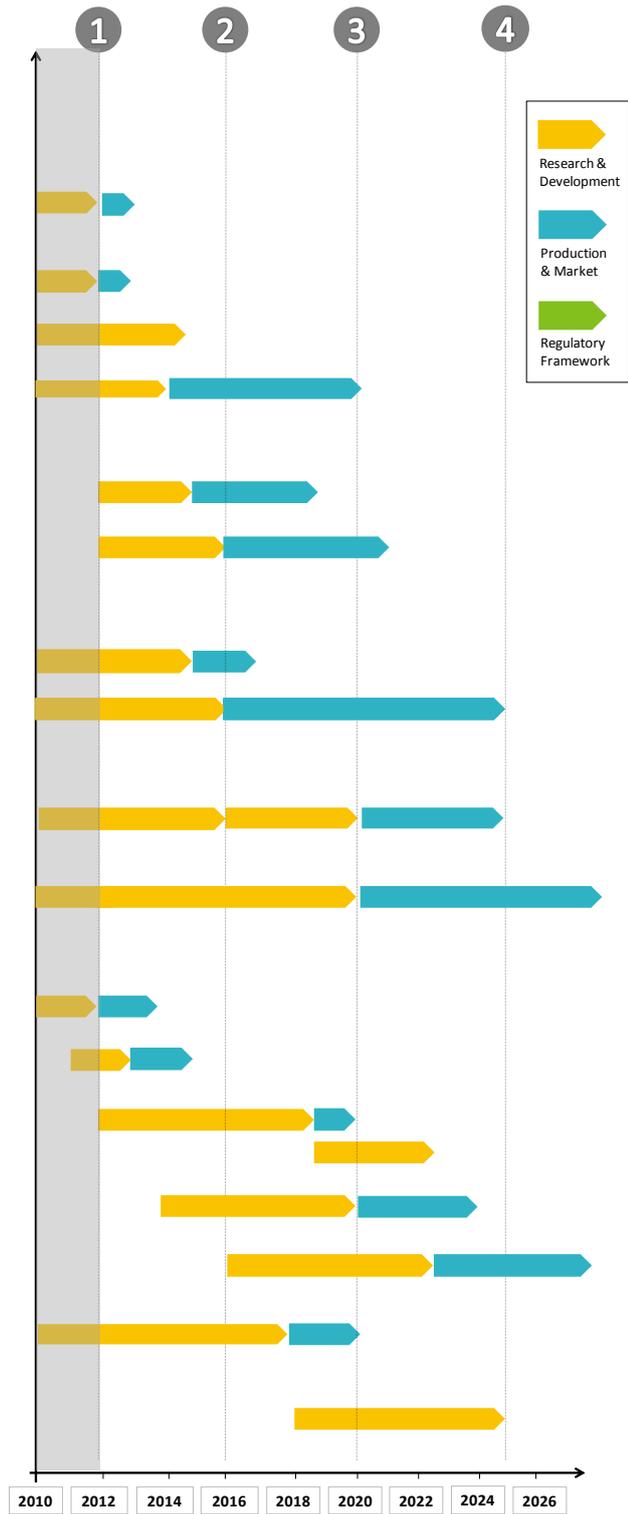
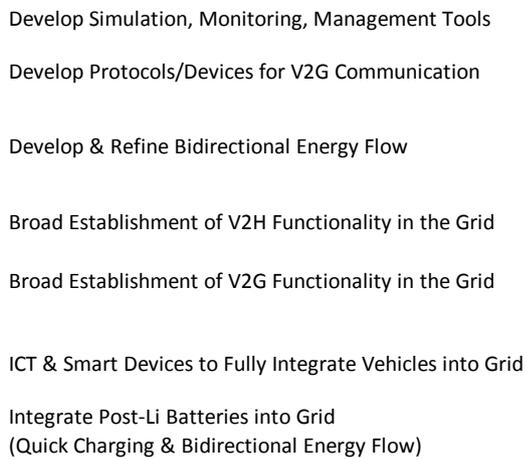
Contactless Charging



Charging While Driving



V2H & V2G



Grid Integration (continued)

Integration with Renewables

Green Corridors, Hubs & Smart Cities

Connect Dedicated Regions by Highways with Charging Spots

Regulatory Aspects

Regulate Coverage with Charging Spots

Regulation on Business models for Charging

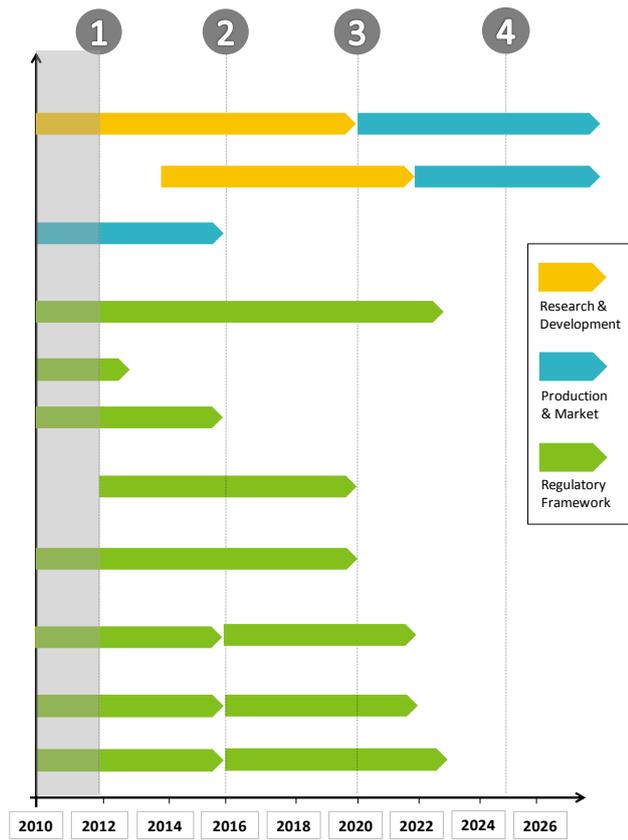
Regulation on Business Model for Bidirectional Trading

Standardization Issues

Interoperability with Mobility Operator, Vehicle & User

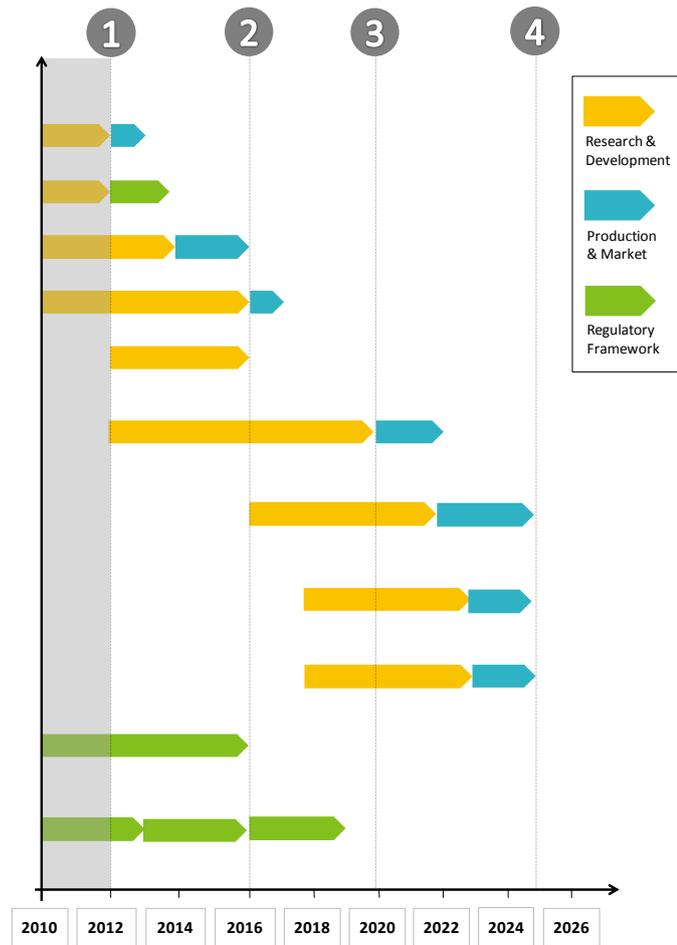
Standardize Service, Billing and Use Concepts

Standardize Interfaces



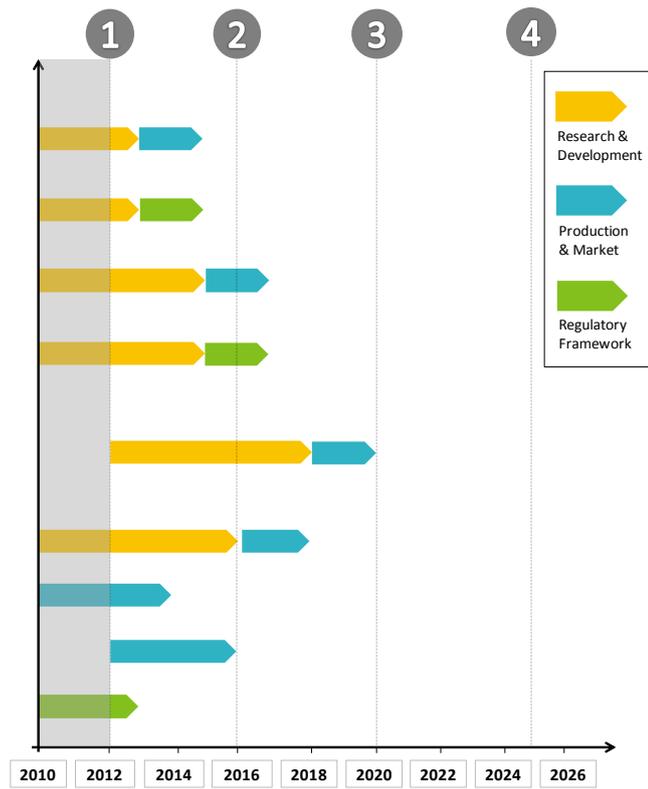
Safety

- Develop Integrated Safety Concept (HV, Fire, ...)
- Study Relation to Roadside Restraint Systems
- Develop Acoustic Perception
- Improve Crashworthiness of Lightweight Cars
- Post-Crash Treatment of Battery & Vehicle
- Active Safety Measures Based on Automated Driving
- Research and Develop Safety of EV's in Multi-Modal Transport
- Safety Issues Related to Integrated Multi-Functionality
- Integrated Safety Concepts for Novel Platform
- Setup Standards for Emergency Handling Including Roadside and Tunnel Safety
- Create & Review Standards for Safety, EMI, Health



Transport System Integration

- Explore Potential of ITS for Energy Efficiency
- Develop Best Practise for Implementation of Road Infrastructure Measures Supporting Rapid
- Provide Convenient Transition Between Modes
- Review Effects of Large Scale Deployment on Future
- Apply & Optimize car2x Communication for Automated and Cooperative Driving
- Integration into Multi-Modal Transport System
- Promote Green Image of Electric Vehicles
- Develop Shared EV ownership concept
- EU Wide Signage of Roads and Vehicles



7 Transversal functions

In order to reach the milestones, a number of topics have been identified that are expected to have an impact on all of the technology areas mentioned above. These topics or support functions are considered to contribute greatly to the success of the electrification efforts and therefore deserve a more in-depth analysis and dedicated roadmaps. In addition to this electrification roadmap, which serves as the base roadmap, additional roadmaps covering these horizontal areas are produced as annexes. The topics identified are:

- Information & Communication Technologies
- Grid Infrastructure
- Materials

These topics will be briefly introduced here outlining their role and the specific challenges they pose for introduction of the EV. It shall be emphasized that there are also other important topics which are partly covered in roadmaps separate from the present Electrification of Road Transport Roadmap. One very important transversal issue for the successful mass deployment of EVs as well as for the securing of Europe's leading position in global markets is manufacturing. Issues within that topic are evolution of production concepts, of supply chains, commodity management, skills etc. These are described in the roadmap European Technology and Production Concept for Electric Vehicles, developed by ERTRAC. It is available for download on the website www.ertrac.org.

ICT for the FEV

The future electric vehicle of the third generation can be envisioned as an energy efficient, safe, comfortable and adaptable electric vehicle. Essential enabling functionalities to develop this 3rd generation electric vehicle are being provided or facilitated by communication technologies and smart systems. For instance, regarding the user's range anxiety as well as cost of ownership, both decisive barriers for the mass introduction of electric vehicles, ICT may greatly contribute to the solution. The replacement of mechanics by electronics e.g. through drive-by-wire will lead to reductions in weight which will complement future advances in battery performance, and also lower the cost of the electric vehicle. This will be further supported for instance by driver assistance systems providing for efficient, comfortable and safe driving, and by ITS providing prediction and connectivity. Hence, in order to tap the full potential of the electric vehicle regarding resource and energy efficiency, emission reduction and user comfort relevant ICT devices and ITS services have to be developed or refined and implemented. The growing number of ICT in the vehicle must not lead to more complexity, but even more simplicity, thus a completely revised ICT reference architecture is required. Thus, the need for a roadmap detailing the research needs in ICT is inherently apparent.

Grid Infrastructure

The widespread electrification of road transport must be accompanied of the adequate electric infrastructure development and the grid integration concept must be widely reached. Even from the very beginning a reliable and minimum critical mass deployment of electricity supply and convenient access to recharging stations must be available for the electric vehicle and plug-in hybrid recharging. For plug-in hybrids, overnight recharging appears to be the main initial requirement, whereas for purely electric vehicles, recharging

opportunities away from home are a more critical concern to achieve widespread demand for and use of vehicles. Efficiency is also an important factor, that will strongly depend on the charging point and charging system. The full integration of these electric vehicles and their flexibility to offer energy grid services must be also correctly addressed.

The mass deployment of the EVs will strictly derive from the adequately and on time development of the infrastructures. The infrastructures needed, should be correctly developed and covered by a coordinated action of the initiatives of the following areas (see also Fig. 4):

- EGCI (European Green Car Initiative), this refers to the part that is directly affecting the car manufacturer and necessary interfaces.
- EEGI (European Electricity Grid Initiative), this includes the part that affects the grid development itself.
- ESCI (European Smart City Initiative), referring to the part that directly affects city mobility, planning and growth.

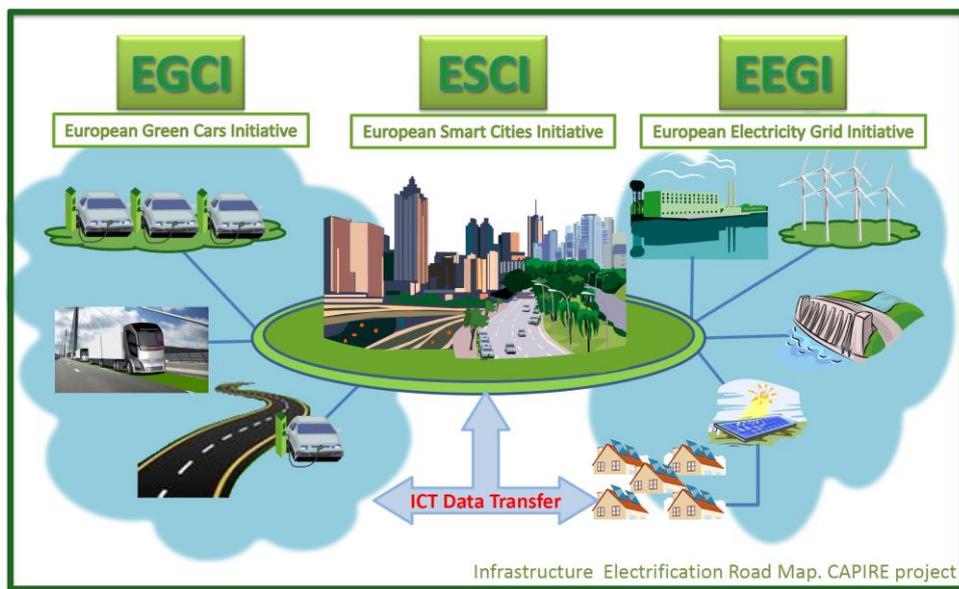


Figure 4: European Technological Initiatives dealing with EV development

When planning the introduction of electrical vehicles on the electricity grid the following issues must be considered:

- Infrastructure planning and costs.
- Quick charging impact.
- Bidirectional energy flow capabilities (V2G).
- Integration with renewable energy.
- Standardization.
- Regulatory aspects (business models, billing issues...)

The Grid Integration Roadmap presented on chapter 6 has only taken into consideration those grid aspects that are affecting the vehicle's design or the necessary interfaces, due to their reciprocal character. Nevertheless, a complete version of the Grid Infrastructure Integration Roadmap will be included in the annexes.

Materials

The European Raw Materials Strategy was initially presented in 2008 and recently updated by the European Raw Materials Initiative. The aims of this strategy are securing access to and a sustainable supply of raw materials for the EU as well as furthering resource efficiency and recycling. Various raw materials are essential in the automotive and especially the electric mobility sector. The materials roadmap will detail research needs regarding possibilities to substitute rare and scarce materials in devices and components, enhance materials efficiency in design and production of electric vehicles, and to maximize recycling options. Furthermore, standards and legislation will be referenced which may help to promote resource efficiency and recycling but also the socially and environmentally responsible resource extraction in compliance with transparency initiatives as e.g. the Extractive Industry Transparency Initiative (EITI).

The second focus will be materials for lightweight construction and functional materials for electric mobility as well as product and process design including manufacturing aspects. Among other, key words will be structural components, functional integration, adaptronics and multi-material design. A link will be made to the work done in the light duty vehicle roadmap prepared within ERTRAC.

8 Review of Milestone 1

With the publishing of the second edition of this report Milestone 1 is reached, and hence, initiatives taken that address roadmap items initially planned to start within the timeperiod 2010-2012 shall be reviewed in the following. In the following figures the respective roadmap items are listed in their technology field and predominantly research projects of the Green Cars Initiative, but also other initiatives (e.g. JTIs ENIAC and ARTEMIS) are mapped against them. The current status is given by colors, where green indicates full and yellow partial coverage, red means that no or very little action has been taken so far.

Energy Storage Systems

Study Battery Cell Degradation	■	AMELIE, APPLES, SmartLIB, SOMABAT
Establish Battery Testing Facility	■	Recommended as Topic for WP 2013
Develop Battery Management Systems	■	ESTRELIA, OpEneR, SmartLIB, Smart-LIC, SUPERLIB
Develop Recycling Processes for Li Batteries	■	AMELIE, APPLES, SOMABAT, ELIBAMA, eCar
Cell Materials (Lifetime, Energy Density, Safety)	■	AMELIE, APPLES, ESTRELIA, EUROLIION, LABOHR, SOMABAT, GREENLION
Optimize Battery Packs	■	SMARTBATT, OPERA4FEV
Establish Facilities for Prototyping	■	Recommended as Topic for WP 2013
Assess Availability of Raw Materials	■	FP7-2012-MATERIALS FOR GREEN CARS
Launch Battery Loan Program	■	EASYBAT, Greening Transportation Infrastructure for Electric Vehicles*
Set European Guidelines for Lifetime and Range	■	

Drive Train Technologies

- Develop Low-Cost/Weight Motors & Electronics ■ CASTOR, Hi-Wi, POLLUX, Wide-MOB,
- Develop Highly Integrated Motors & Controls ■ E3Car, E-VECTOORC, CASTOR, Hi-WI, P-Mob
- Optimize Combustion Engines for Range Extenders ■ FUEREX

Vehicle System Integration

- Optimized System Efficiency with Existing Components ■ E-Future, ID4FEV, MAENAD, POLLUX, P-Mob, WIDE-Mob
- Find New Solutions for Heating, Venting, Cooling ■ ICE, SMARTOP
- Create New Concepts for Space Usage ■ Elva, E-Light
- Explore Light-Weight Materials, EcoDesign, Recycling ■ ECOSHELL, Wide-Mob, E-Light, elCAR

Grid Integration

- Develop Adaptive On-Board/In-Plug Charging Dev. ■ eDASH, ELVIRE, P-Mob, POWER UP
- Create System for Information on Charge Status ■ ELVIRE, OpEneR
- Develop Simulation, Monitoring, Management Tools ■ eDASH, Green Emotion, OpEneR, P-Mob, PowerUP
- Develop Protocols/Devices for V2G Communication ■ ELVIRE, OpEneR, P-Mob, PowerUP, SmartV2G
- Establish 1st Generation Charging Infrastructure ■ GreenEmotion, Greening Transportation Infrastructure for Electric Vehicles
- Connect Regions by Highways with Charging Spots ■
- Create Business Models for Charging ■ ELVIRE, Green Emotion
- Regulate Coverage with Charging Spots ■ PowerUP
- Standardize Service, Billing and Use Concepts ■

Transport System Integration

Explore Potential of ITS for Energy Efficiency	■	Ecogem, Enhanced WiseTrip, PICA V
Provide Convenient Transition Between Modes	■	Greening Transportation Infrastructure for Electric Vehicles
Develop Best Practise for Implementation of Road Infrastructure Measures Supporting Rapid Uptake	■	
Promote Green Image of Electric Vehicles	■	Green Emotion
Review Effects of Large Scale Deployment on Future Infrastructure Developments	■	
EU Wide Signage of Roads and Vehicles	■	

Safety

Develop Integrated Safety Concept (HV, Fire, ...)	■	GC.SST.2011.7-1 Specific safety issues of electric vehicles
Develop Acoustic Perception	■	eVADER
Improve Crashworthiness of Lightweight Cars	■	EcoShell, E-Light, Wide-Mob
Study Relation to Roadside Restraint Systems	■	
Setup Standards for Emergency Handling Including Roadside and Tunnel Safety	■	
Create & Review Standards for Safety, EMI, Health	■	EM-Safety

The first two calls of the European Green Cars Initiative have resulted in the initiation of more than 50 projects. Details on those projects can be found in the brochure “Project Portfolio European Green Cars Initiative PPP” which is available on the website of the Green Cars Initiative ⁽³⁷⁾. The first projects started in the fall of 2010 and are seeing their first results, while others have started more recently. Even though it is early days to assess the real impact of individual projects, it can be assumed that good progress is made towards the objectives set by the first edition of this report.

Especially in the technology areas Storage Systems and Drive Train Technologies several projects work on the same objectives focussing on different aspects. Furthermore, electrification issues are not only addressed within the Green Cars Initiative which is funded under FP7. Various projects within the JTIs ENIAC and ARTEMIS are related to the Green Cars Initiative. Other activities outside of FP7 are e.g. the TEN-T programme of DG Move from which the project “Greening Transportation Infrastructure for Electric Vehicles” has been included into the present assessment, and further projects under the CIP program which are not listed here.

9 Advice on international collaboration for the EV

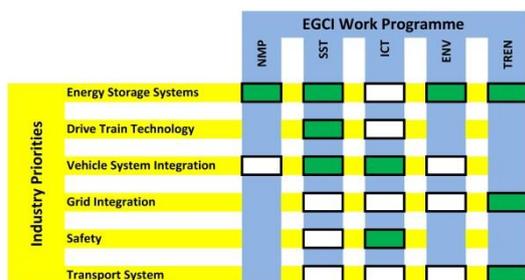
The authors of this roadmap recommend a close cooperation of the PPP European Green Cars Initiative with international partners in the domain of the fully electric vehicle (FEV). Based on their experiences and assessments, the following actions are considered of utmost importance:

- To join the Annexes of the Hybrid and Electric Vehicle Implementing Agreement of the International Energy Agency and its specific working groups.
- To establish an intense exchange of information, people and technology with governments and industry in the U.S. and Japan, e.g. along the electric mobility related roadmaps that have been developed in recent years, and to develop joint programmes and projects
- To establish and strategically manage bilateral contacts of the EU to China and South Korea
- Support exploit, demonstrate and deploy Electric Mobility in megacities, e.g. in Brazil
- To present the European capabilities in the domain of electric vehicle technologies at major international fairs, conferences and events.

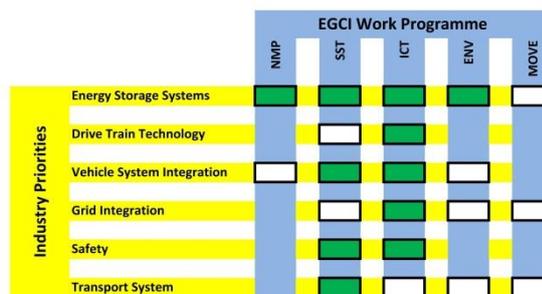
10 Recommendations

Based on the indications given in the roadmaps recommendations can be made on how and when the research needs should be covered by objectives of the respective FP7 work programmes in the European Green Cars Initiative (Figure 5).

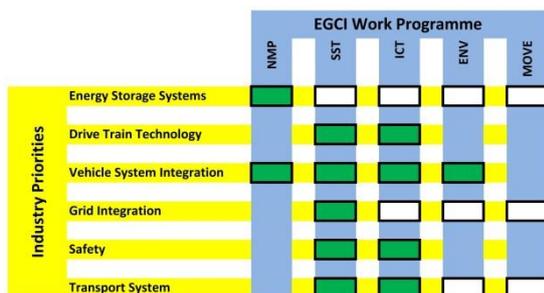
2010 (Status)



2011 (Status)



2012 (Status)



2013

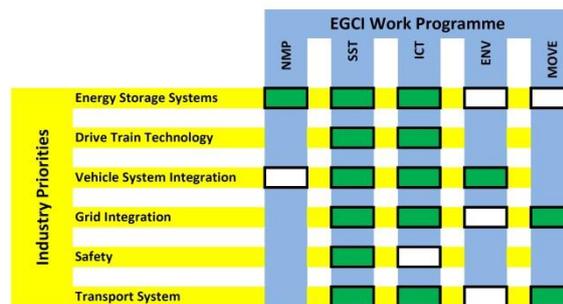


Figure 5: Actual and suggested future coverage of R&D topics in the FP7 work programmes of the Green Cars Initiative (white: match of programme and R&D need, green: suggested objective in resp. year)

Modes of implementation should include the funding of focused industrial and academic R&D projects (STREPS). Furthermore, a multitude of horizontal challenges (e.g. grid integration, transport system integration) will require large scale actions like Integrated Projects (IPs) and Field Operational Tests. Moreover, there is a significant need for coordination between the sectors (i.e. energy, telecom and transport sector) that are coming together in the novel value chains of the electric vehicle. Standardization should be included in the calls where relevant, in order to facilitate market introduction of the results generated by the future projects.

As practiced with great success in the European Green Cars Initiative, also in the future framework of Horizon 2020 industry, utilities, infrastructure providers, academia and public authorities should join their efforts in specific Public Private Partnerships and joint programs horizontally covering all aspects of electromobility, the involved industrial sectors and their interlinks. Furthermore, it will be essential to create complementarities and coherence between the programmes at European Union and Member States levels, to extend the perspective beyond research and development, towards innovation and implementation.

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Note:

This report is considered a living document that will be periodically reviewed, updated, and made available to the community through the websites of the PPP European Green Cars Initiative

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