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Roadmap
ICT for the Fully Electric Vehicle

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1 Introduction

First successful attempts to electrify the propulsion system of a road vehicle date back to the early 19th century, i.e. some decades before the invention of the combustion engine and its application in the car. Around 1900, electric vehicles were commonplace, particularly in big cities where their advantages over gasoline cars were most obvious: less smell, vibration and noise combined with the ease of operation as no manual effort was needed to start the engine. However, due to the low performance of batteries, electric vehicles were quite heavy and needed long recharging times. With the growing network of gasoline stations promising unlimited range and with innovations like the electric starter enhancing the comfort of the internal combustion engine car, the electric vehicle in the course of time more and more struggled to compete.

For decades, electric vehicles remained a niche phenomenon with typical use being golf carts and milk vans. They returned into the minds of the public only in the 1980ies when peaking oil prices and growing concerns about air quality led public authorities to call for fuel-efficient and low-emission vehicles. In 1990 the California Air Resources Board established (and later modified a couple of times) a zero emission vehicle mandate, requiring that each of the U.S.'s carmakers would be required to make 2% of its fleet emission-free by 1998, if they wanted to continue selling cars in California. In response, several types of electric vehicles were manufactured in small series and given to customers at a lease basis, e.g. the General Motors EV1 or the Toyota RAV4 EV. Even though those vehicles were already quite advanced from today's perspective and offered energy efficiency as high as 100-200 Wh/km[1], carmakers were accused not to promote electric mobility properly in order to give the impression that the costumer would not accept them. After a very few years, all these programmes were cancelled and most of the cars were scrapped.

The recent political debate about climate change in combination with continuously fluctuating oil prices sparked interest in alternative propulsion systems again. Hybrid vehicles like the Toyota Prius became a success story, particularly in the consumer group of affluent and environmentally concerned 'early adopters'. The rise of the hybrid car, however, pointed to an even more radical alternative, being the fully electric vehicle: It has become closer to reality since Li Ion batteries are available providing an increased energy density compared to lead-acid batteries. Replacing gasoline by electricity as the energy carrier makes accessible a multitude of primary energy sources which are more abundant than fossil fuels and can enable massive cuts of CO_2 emissions, if renewables, e.g. wind or solar power are used. Even with electricity from today's European energy mix, the electric power train is causing less CO_2 emissions than the internal combustion engine, because its use of energy is (in a well-to-wheel analysis) at least 30% more efficient[2], and it offers the opportunity to recover part of the brake energy and to reuse it for acceleration. Furthermore, when plugged-in and equipped with bidirectional charging capabilities, the batteries of electric vehicles may play a crucial role as high power transient energy storage which may help to stabilize the grid or to absorb excess energy at times of e.g. high supply of wind power.

Consistently, policy makers and public authorities worldwide, often in the framework of economic recovery measures responding to the economic crisis of 2008, launched funding programmes aiming at a mass deployment of electric mobility within a decade[3]. Vehicle manufacturers worldwide have already launched the first series production of electric vehicles[4] or are preparing for it. The International Energy Agency stated, electric vehicles by the year 2050 will reach 30% of the global

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[1] EVAmerica Performance Results Toyota RAV4 EV and General Motors EV1, Idaho National Laboratory 1998.

[2] European Roadmap Electrification of Road Transport, ERTRAC, EPoSS, Smart Grids, 2009.

[3] COM (2008) 800. A European Economic Recovery Plan, European Commission, 2008. ,
American Recovery and Reinvestment Act, 111th Congress of the United States, 2009.

[4] Press Release, Nissan 27 July 2010; Press Release General Motors 27 Jan 2011.

annual vehicle sales[5]. According to the European Roadmap Electrification of Road Transport published by the European Technology Platforms ERTRAC, EPoSS and SmartGrids, more than 5 millions electrical cars are forecasted in Europe by 2020. Including e-bikes and others a total of 30-40 million new electrically powered mobility means are very likely to be used 2020 in Europe. In the year 2000, Light Electrical Vehicles (LEVs), as e.g. bicycles, scooters, tricycles, mopeds and quad-cycles, accounted for a global production in the order of 100.000 per year, while in the 2010's they are produced in several tens of millions per year as China and Japan are rolling out large scale production addressing manufacturing cost issues. LEVs are now evolving to micro-cars and conventional mid-sized cars. Electrification of conventional cars will follow starting with these smaller vehicles that cover most urban mobility needs.

The large scale deployment of electric vehicles faces a multitude of challenges which will be tackled at quite different velocities:

- The storage and use of energy inside the vehicle is still far from being optimal. Limitations in capacity and lifetime as well as high cost of the energy storage system may hinder the development of an early market for a significant period of time. Recent advancements in the performance of Li-Ion batteries caused energy densities to rise by a factor of two as compared to NiMH with the perspective of another factor of 1.5 (7) in the next five (twenty) years[6]. Also, due to learning effects during the ramp-up phase of mass production, the cost of the battery is expected to drop significantly to an estimated 20% of today's levels as soon as the production volumes exceed one million units[7]. At least in the short to medium term, optimized energy efficiency of the vehicle will be necessary to provide the electric vehicle with the range expected by the consumer.
- At market penetration rates in the order of a few per cent, electric mobility is not expected to cause any significant additional demand of primary energy or additional grid infrastructures. However, a lack of the public (and fast or inductive) charging infrastructure, roaming models and common tariffs may be another significant, at least psychological, barrier for the consumer acceptance of electric mobility. Moreover, playing out the full potential of electric mobility for cutting green house gas emissions and securing energy supply is calling for controlled charging (e.g. at times of high supply of renewable energies) and bidirectional charging (e.g. at fluctuating supply or demand of power). The speed of development in the domain of energy supply, distribution networks and even smart metering, however, is generally far lower than in automotive manufacturing.
- For becoming a means of optimized transportation, the electric vehicle will require seamless integration into the existing mobility world with a clear assignment to solving the individual costumer's need. The required intermodal links range from information about the availability of charge spots or alternative modes of transportation in reach to on-purpose route optimization and even autonomously controlled driving. Beyond technology development and creation of infrastructures, a multitude of issues in terms of regulations, liabilities standards and infrastructures still has to be solved.
- Finally, safety issues specific to electric vehicles have to be tackled. This concerns the functional safety and reliability, as e.g. challenges posed by the electrochemical system of the battery or the high voltages applied, but also the crash behavior of light-weight vehicles or the safety of vulnerable road users due to the low noise of electric vehicles.

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[5] Technology Roadmap Electric and Plug-In Electric Vehicles,International Energy Agency, 2009.

[6] Recommendations for the Next Generation Vehicle Batteries, Ministry for Economy, Trade and Industry, Japan 2006.

[7] HareshKamath, Electric Power Research Institute, Plug-In Conference, 2010.

Especially the challenges concerning energy efficiency, driving range and grid connection will play a major role in achieving user acceptance. Unless solutions for the above mentioned matters are in place, the usable range of fully electric vehicles will mostly be restricted to about 100 km around some fixed charging spot locations. And due to extensive recharge hours, it will only be available for limited periods of time. Even though these constraints hardly affect regular needs of most drivers, particularly for daily commutes and in urban areas, they are considered a psychological barrier ("range anxiety") that may hinder early market adoption of the fully electric vehicle.

On the short term, two different technology paths may be a way out of this issue, (a) a plug-in hybrid with an internal combustion engine applied as a range extender (like in the Chevrolet Volt or the Opel Ampera) and (b) the use of smart systems and Information and Communication Technologies (ICT) at the links to the energy and mobility systems in which the electric vehicle is embedded in (like the range prediction displays of the Nissan Leaf).

It will be questionable whether in the medium term hybridization and driver information alone can help the electric vehicle to meet what costumers and the general public are expecting from it. A particular feature of the fully electric vehicle is that most mechanical control functions can easily be replaced by electronic means and are supported digitally by embedded software. Thus, range extension may also be achievable by increasing energy efficiency, integrating a high degree of electronic control, adaptive capabilities and intelligence to the system. In opposite to hybridization, this approach would increase the efficiency of the energy used in a smart way.

ICT and smart systems may not only be the solution to make electric vehicles more energy efficient and thus master "range anxiety". They may also greatly benefit user acceptance by providing drivers comfort and an adaptable car, enhance safety employing active measures and increase reliability by active material health concepts.

It is the purpose of this roadmap to analyse the potential role of ICT and smart systems for the enabling functionalities which may be key for the environmental and economic benefits of electric mobility in the future.

This roadmap was drafted in the framework of the activities of the ICT4FEV project will after consultations with the European Technology Platforms ERTRAC, EPoSS, and SmartGrid be an integral part of the updated overall European Roadmap Electrification of Road Transport.

2 The Role of ICT for the Fully Electric Vehicle

Information and Communication Technologies (ICT) are an enabler of the fully electric vehicle since they provide means complementary to advances in battery cell performance to solve issues that currently still impede the mass deployment of electric vehicles. They will facilitate the development of a unique European FEV, a safe, affordable, energy efficient car with sufficient range. They will further provide accessibility and adaptability of the car as well as driving comfort. All of these may bolster user acceptability, and thus ensure the ability to seize the opportunities for cutting green house gas emissions and to compete on global markets. ICT, i.e. components and smart systems enabling key functionalities of the future electric vehicle are at the focus of this roadmap.

The key role if ICT becomes instantly apparent when relating to the definition of smart systems by the European Technology Platform on Smart Systems Integration (EPoSS) stating that smart systems

- are able to sense and diagnose a situation and to describe it
- mutually address and identify each other
- are predictive and able to decide and help the user to decide
- operate in a discreet, ubiquitous and quasi invisible manner
- utilise properties of materials, components or processes in an innovative way to achieve more performance and new functionalities
- are able to interface, interact and communicate with the environment and with other smart systems
- are able to act, perform multiple tasks and assist the user in different activities

Smart systems offer the possibility to add synergy and harmonic interplay to the building blocks of the electric vehicle such that e.g., the drawbacks of today's batteries that are lack of energy density, lifetime and affordability, can be compensated.

According to the assessments made by experts from EPoSS, the role of ICT solutions and smart systems integration can be summarized as enabling the full electric vehicle by[8]

- providing aware, caring and robust means of power and energy routing between accumulator cells, battery packs, motors and grids
- applying adaptive control and power electronic converters to electric motors and wheels
- actively enhancing the safety of road transport based on batteries and lightweight vehicles
- making the driver aware of the availability of energy and power and of the resulting restrictions in terms of range and comfort, and
- guiding the driver to the next recharging station in case the car runs out of battery power

The enabling role of ICT for the FEV may go far beyond helping to replace the conventional powertrain by an electric motor, a converter, and a battery: The conventional concepts of vehicle integration which have been developed in an evolutionary and bottom-up process for decades are hindering innovation, particularly for the electric vehicle[9]: The extend to which ICT is used even in the conventional car today does not match the opportunities offered by that technology, e.g. drive by wire and active safety systems have barely been implemented so far. The main reason for this is that adding any new functionality increases the complexity of the system and causes high additional cost because there is a lack of common interfaces between the various on-board systems themselves and to the off-board world.

[8] Strategic Research Agenda, EPoSS 2009.

[9] The Software Car, Fortiss, 2011.

Experience with comparable transitions from mechanically via electrically to electronically and digitally controlled systems (e.g. from the typewriter to the computer) tells that significant cost reduction can be achieved when a complete redesign of the platform is undertaken.

Furthermore, and maybe most importantly for the large scale deployment of electric vehicles, replacing mechanical joints by electronic and digital controls combined with wires or even wireless communication may cause a significant drop of vehicle weight. Thus a substantial gain in energy efficiency, i.e. driving range, may result.

Hence, for developing the 3rd generation electric vehicle that exploits the full potentials for energy efficiency, safety and reliability as well as grid and traffic system connectivity, a real paradigm shift can be foreseen: a completely redesign of the electric, electronic and ICT architecture of the fully electric vehicle from scratch. If complemented by performance gains in the battery and traction system, and by strongly reduced energy demand, e.g. due to radical weight reduction, as well as by a decay of manufacturing costs through learning effects, this may open the path towards a mass deployment of FEVs.

3 Milestones

A European Roadmap „Electrification of Road Transport“ was compiled in late 2009 by the European Technology Platforms EPoSS, ERTRAC and SmartGrids that combine their efforts within the PPP European Green Cars Initiative. This roadmap is dedicated to fully electrified or Plug-in-Hybrid passenger cars.

Milestones covering a time period until 2020 were defined that indicate multi-annual implementation paths for the electrification of passenger cars. Following reviews by the community involved in the PPP, with the support of the ICT4FEV and CAPIRE projects the addition of a milestone for 2025 has recently been proposed for the next update of the roadmap, which is currently in a process of stakeholder consultations with the European Technology Platforms ERTRAC, EPoSS and SmartGrids. Actions to be taken in order to achieve the goals set by the milestones are sorted into the technology fields:

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

Detailed roadmaps for these technology fields set the timeframes to ensure a well-timed, concerted and balanced approach.

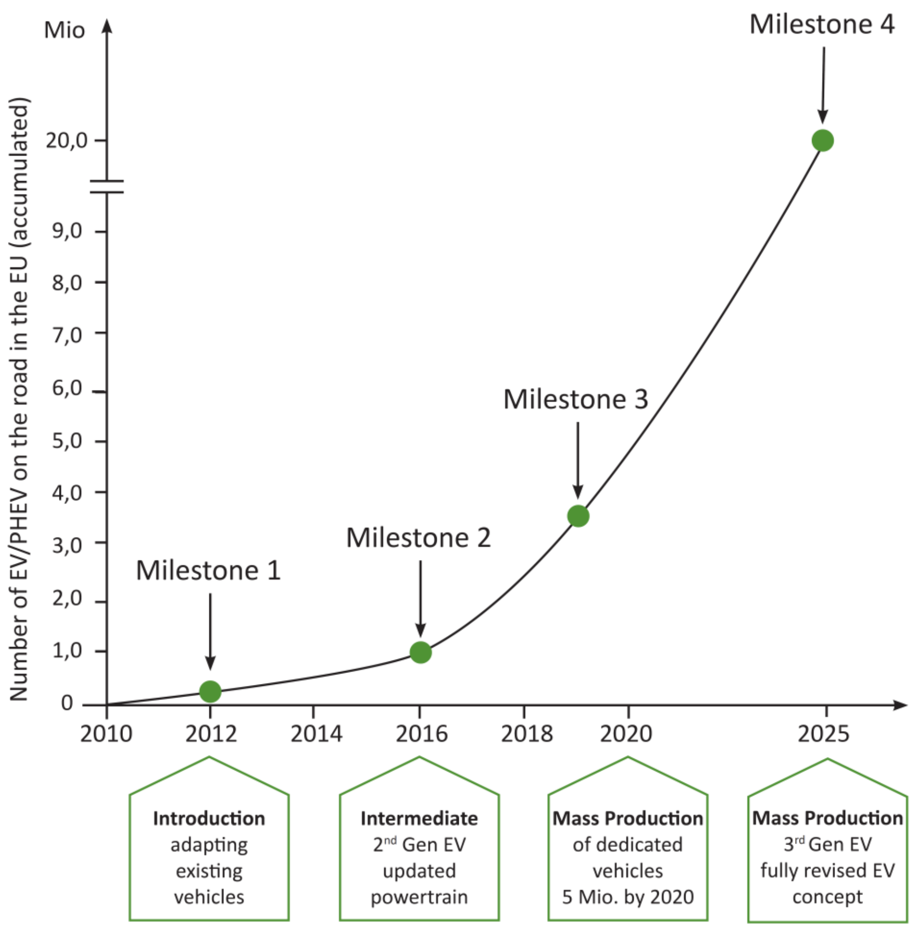


Figure 1 Milestones of the European Industry Roadmap for Electrification of Road Transport.

The identified milestones are (see Figure 1):

- **Milestone 1: Introduction (2012):**
  Currently electric vehicles that are in production or are being prepared for production are adaptations or conversions of existing vehicles with conventional drive trains. They are mainly deployed in pilot projects and field operational tests. Also some fleet applications like, e.g. taxis, car sharing systems, delivery services and other captive fleet, exist or are in planning. Standards for safety, data communication and billing as well as testing activities and actions for raising public acceptance are strongly needed. R&D activities are expected to lead to major breakthroughs in the understanding of underlying technologies and principles and all relevant parameters for safety, performance and lifetime. The drive trains and energy storage systems of electric vehicles and plug-in hybrids of this 1st generation will be optimized for efficient and safe use.

- **Milestone 2: Intermediate (2016)**
  A dedicated 2nd generation electric vehicle will show substantial efficiency gains of all consumers, advanced system integration and high performance energy storage systems. The charging infrastructure will have greatly improved allowing convenient electric mobility in various cities and regions. All safety issues concerning the mass deployment of electric vehicles will have been addressed.

- **Milestone 3: Mass Production (2018-20)**
  At this point mass production of dedicated plug-in hybrid and electric vehicles will be fully established in Europe. This will be greatly supported by the availability of batteries providing about tripled life time and energy density at about 30% of today's cost. Moreover, the vehicle architecture will be based on a novel platform, and highly integrated and cheap electrical motors providing a range comparable to ICE at sharply reduced emissions will be on the market in big quantities. The connection to the grid will by greatly advanced through contactless and quick charging at high efficiencies, and the bidirectional charging will employed for using fleets of electric vehicle for power storage. Active safety systems based on automated driving and car-to-x communication will be implemented.

- **Milestone 4: Mass Production of 3rd Generation EV**

  The 3rd generation electric vehicle will be based on an entirely revised modular platform including a revised ICT reference architecture and middleware. Innovative zero-emission drive train systems will enabled by distinctly improved energy recovery and incorporation of a multi-fuel compatible range extender. The batteries will have enhanced bidirectional and fast charging capabilities and especially contactless charging will be widely spread, and (given the required infrastructure is in place) even en-route charging will be available. The car will be fully integrated into the multi-modal transport system. Automated and cooperative driving functionality will be enhanced and active safety measures greatly exploited.

4 Paving the Way to the 3rd Generation Electric Vehicle

As discussed in the introduction, the fully electric car needs to provide energy efficiency, safety and usability in order to be successful on the market and for climate protection. **Energy efficiency** is besides ecological aspects a question of **range efficiency** which plays a major role for user acceptance as explained earlier. **Safety** refers not only to active and passive passenger and road safety but also to functional safety of components and systems which in turn is directly related to **reliability and robustness**. **Usability and adaptability** are referring to the comfort of driving provided e.g. by features like availability of information about range, charging possibilities and traffic, or autonomous driving. Additionally, connectivity to external information systems and the possibility of integrating external devices is a growing consumer demand. Beyond affordability of investment and ownership, these properties will be vital for the mass deployment of fully electric vehicles.

The vision for a 3rd generation fully electric vehicle meeting the described requirements has been sketched in the description of milestone 4. Its core features are energy efficiency, safety and convenience. As shown in Fig. 2, the required functionalities have been identified for all technology fields and all features. The transverseness of functionalities as well as the interrelation between energy efficiency, safety and usability makes obvious the need for a totally renewed modular platform and a revised ICT reference architecture. This is particularly the case e.g. for Comprehensive Energy Management that concerns all technology fields and facilitates not only energy efficiency, but also safety and usability. This energy management is characterized as comprehensive by managing and coordinating the energy storage system, the energy flow between the traction and energy storage systems, recuperation, integration of the range extender, charging functionalities. It furthermore provides interfaces to the traffic system and to the user. Other examples include energy efficient route planning and driving based on car2x communication, automated, cooperative and autonomous driving, as safe and convenient driving. An inherently transversal issue is the development of wireless and autonomous functionalities.

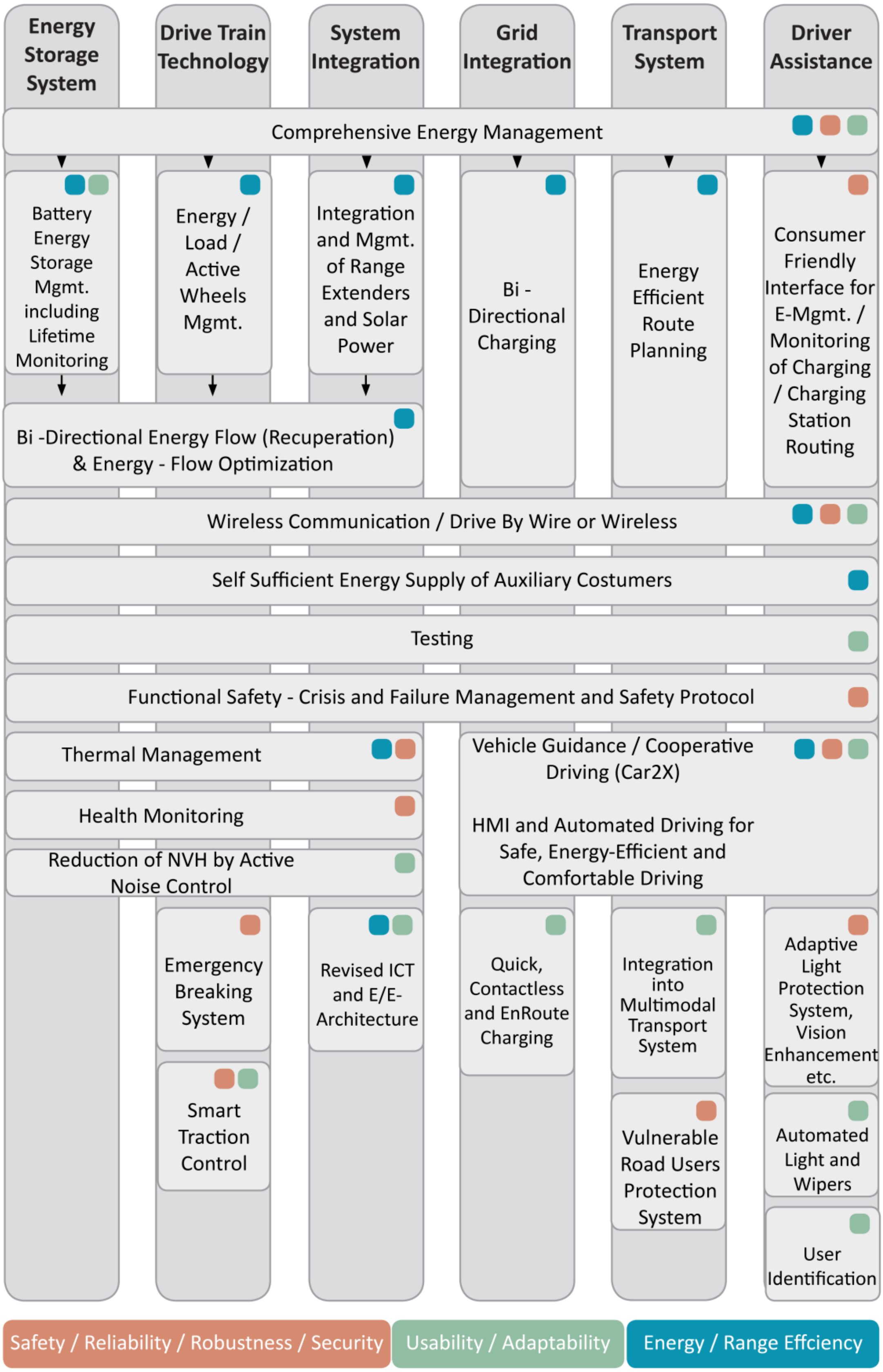
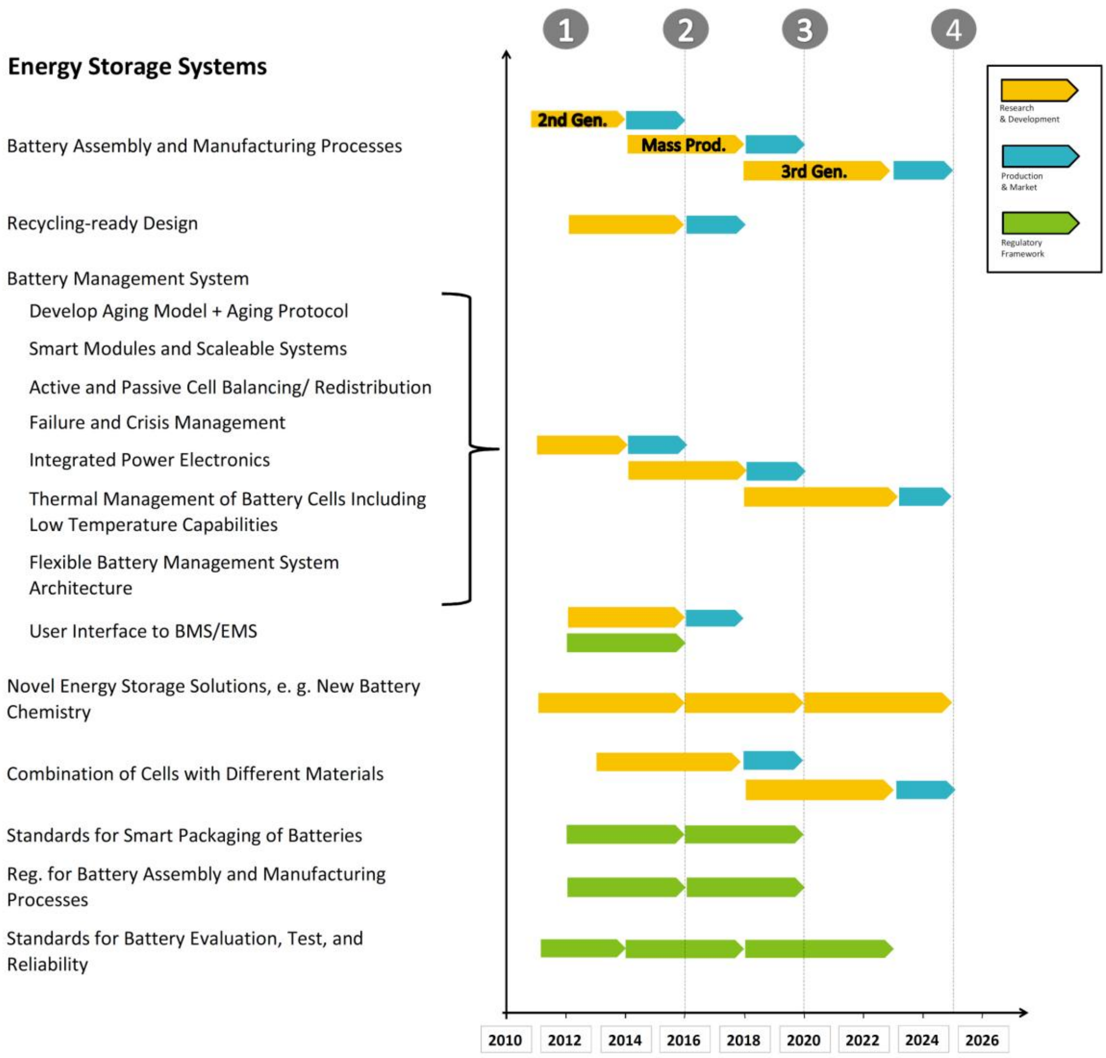


Figure 2: ICT and Smart System Functionalities that enable the energy and range efficient, safe, reliable and adaptable electric vehicle in relation to the technology fields.

5 Roadmaps

The goals defined in the milestones that have been broken down into ICT and smart systems related functionalities have to be further classified into devices and the related research needs and necessary development steps. This has been done in the following roadmaps for each technology field in line with the reasoning of the “Electrification of Road Transport Roadmap”. Additionally a Transversal roadmap has been produced that deals mostly with materials and basic building blocks of smart systems and ICT devices.



Drive Train Technologies

Highly Integrated Powertrain: Functionalization, Integration, Miniturization with Modular Storage Systems

Smart and Robust Traction Control for single and multimotor design, Torque vectoring, Priorisation of functions for safety

Control of In-Wheel-Motors

Optimize Regenerative Braking

Smart and highly integrated ECU

Analysis of Critical Failure Modes

User-Accepted and Safe Drive-by-Wire

Optimize Combustion Engine as Range Extender

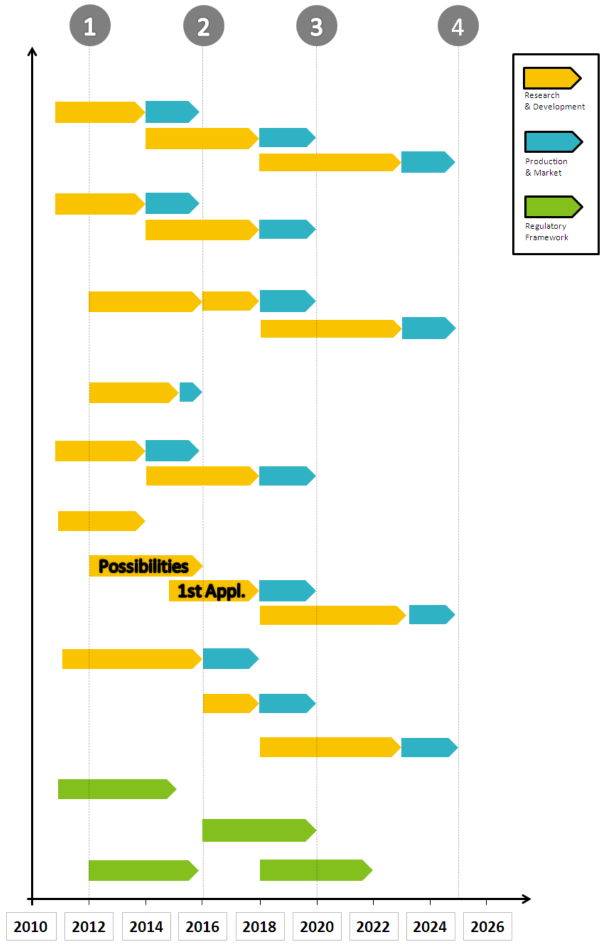
Develop Highly Integrated Range Extenders

Investigate Modularity of Range Extenders

EMC limits and tests for electrical drives

Diagnostics in multi-drive power train architecture

Safety Regulations drive-by-wire for EV



Vehicle System Integration

Comprehensive Energy Management

Active Load Management

Develop Measures for Vehicle Health / Fault Diagnostics

Research Possibilities for Self-Sustained and / or Energy Optimized Auxiliaries

Smart Photovoltaics

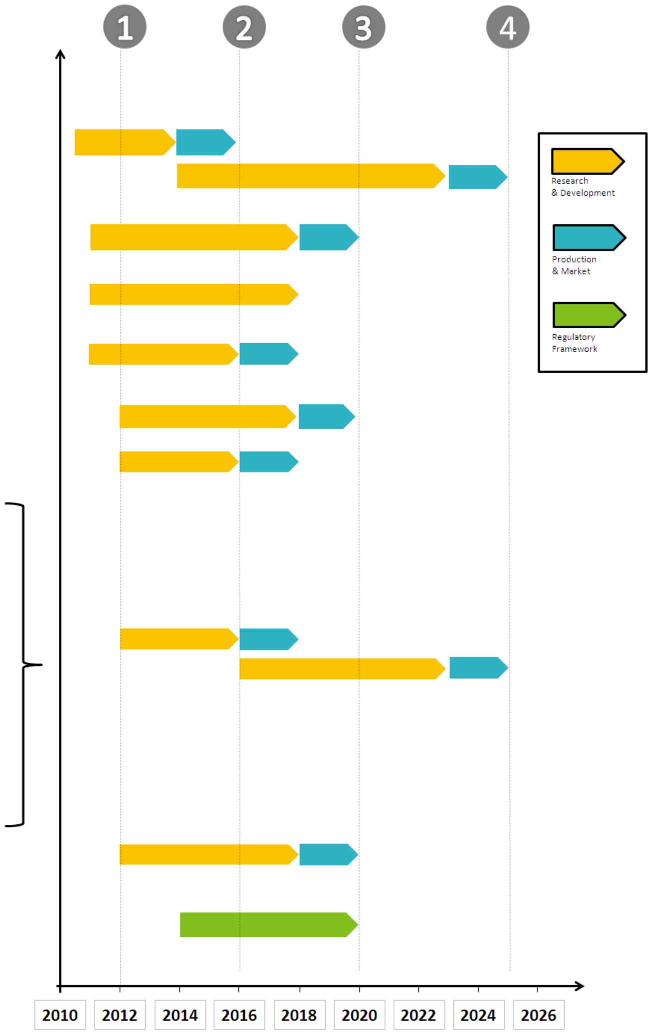
Investigate Possibilities of Active NVH Control

Fundamentally revised E/E- and Software Architecture: Integration, Simplification, Felexibility

- Scaleable CPU
- Hirarchical Decision Making
- Incorporation of Intelligent Sensors and Actuators
- Separation of Hard- and Software
- Implement Plug'n'Play Hard- and Software

Broadband Infrastructure >1 Gbit/s (Transciever/Router/Bus)

Communication Standard for the EV Energy Management System and Associated Components (e.g. Smart Navigation eCharger, Power Train, Vehicle Safety Module)



Grid Integration

Develop Adaptive on- and off- Board Charging Device

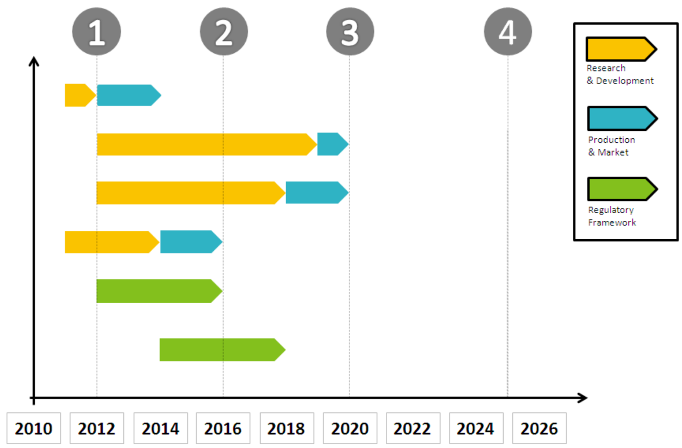
Smart Devices for Bi-Directional Charging

Smart Devices for Contactless Charging

Smart Energy Supply and Demand Matcher

Regulations and Limits for Contactless eCharging

Next Gen car2grid Communication for eCharging Incorporating new Charging Techniques



Safety

Advanced vulnerable Road Users Protection Systems adapted to FEVs

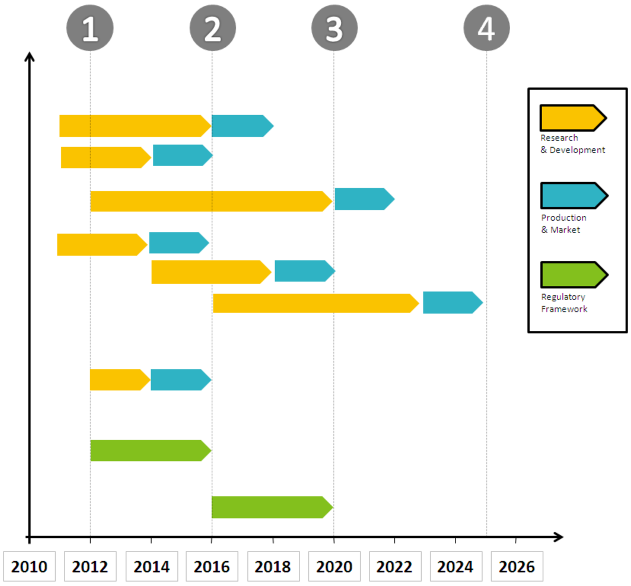
Adaptive Personal Safety System

Functional Safety: HV, Gases, Thermal

Optimized (lower cost) Adaptive Light Protection System / Vision Enhancement

Functional Safety "Designing for Reliability" Standard Addendum to ISO26262; Implementation Guideline EV

Safety Regulations for Autonomous Driving



Transport System Integration

Develop Devices for Automated and Cooperative Driving

Car2Car and Car2Infrastructure

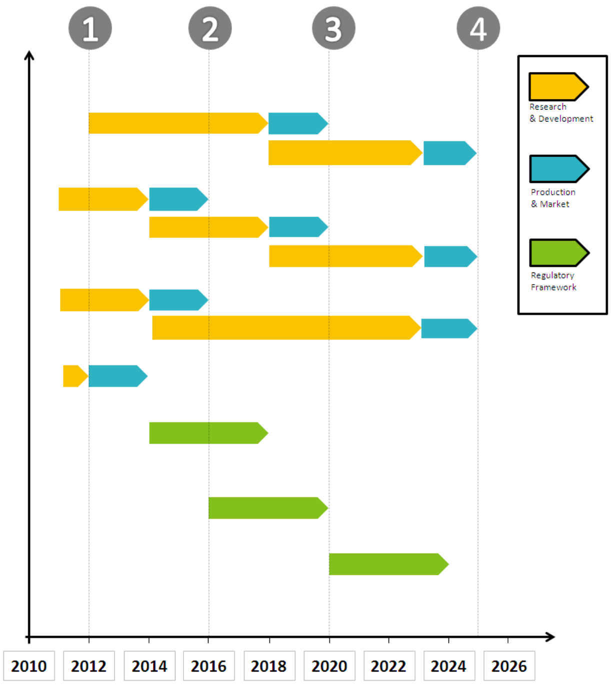
Provide Interfaces for Integration into Transport System Networks

Smart Energy Efficient Router

Next Gen Maps for EV Navigation; Smart Information and Formats, Learn Techniques, Car2Car Protocols

Smart Connectivity to Private Networking (e.g. NFC) and Public Information Systems

Next Gen Car2Infrastructure Communication; Wireless and Secured



Transversal

Autonomus / Wireless Sensor & Actuators

Thermal Stable Electronics / Materials

Packaging Technology (3D, Modules, Flexible / Thin Films Electronics and Photovoltaic...)

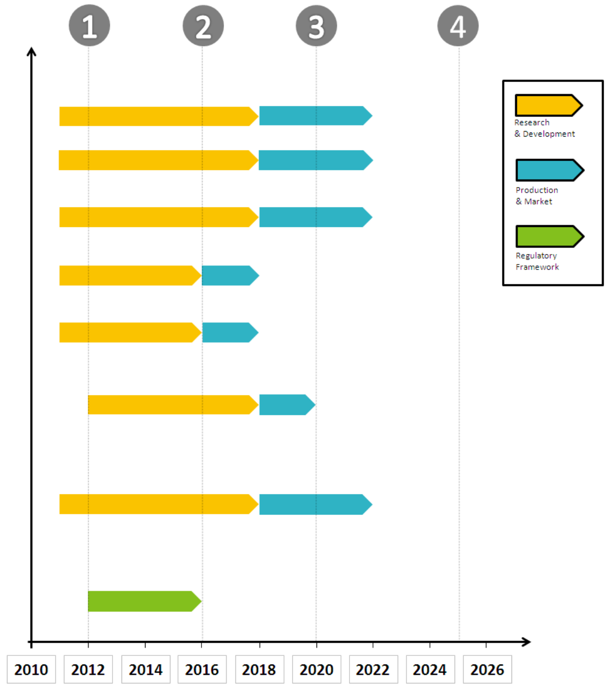
Passive Components

Intelligent Power Electronic Devices (smart IGBTs, Switch / Drive Capabilities for MOSFETs)

Methods and Tools for Design of Components and Systems: Software Solutions, Simulation Models & Tools

Innovative Technologies and Materials (High Bandgap Material and Components, Communication Components for Telematics Products & Services, Embedded Processing Power >100 MIPS, Mechatronics)

Regulations for the Reliability and Manufacturing Tests for the Extended Lifecycle of EV Components



6 Technology Transfer between Aeronautics and Automotive Sectors

The aerospace and automotive sectors are sharing common interests and face similar challenges regarding the electrification of the vehicle and the aircraft respectively. In terms of the roadmapped technology fields mainly Energy Storage Systems, Drive Train Technologies and Vehicle System Integration as well as Driver Assistance offer topics for cooperation or transfer on sub-system and on system level (see figure 3). At the same time, both sectors are driven by different focuses. In the aerospace industry, performance, availability and radiation harshness are the keywords for technology development and production. A much longer time of operation within a much harsher environment, higher safety and dependability requirements as well as mandatory certification set very different standards for aerospace industry compared to the automotive industry, which is driven by low cost and modular and efficient designs. Hence, it is also worthwhile to harmonize requirements, especially those related to environment (vibration, shock, temperature & radiation) to help define common components. For example, the definition of a common temperature range between aeronautics (-55/+125°C) and automotive (-40/+115°C) would help standardizing the references and tests. One could also mention the temperature cycling or the power cycling conditions as other fields where aeronautics and automotive should address the suppliers in the same way.

These topics for co-operation and knowledge transfer as well as possibilities for the harmonization of requirements should be taken into account for proposals of sector-specific R&D programmes, and may also be beneficial for the definition of future directions for common R&D programmes for both, the aeronautics and the automotive transport sector.

Common topics regarding electrification in both sectors concern foremost the electronics domain. Hence, especially regarding components development and manufacturing processes, it is very important for both sectors to get leverage on electronics industry to promote a European supply base for critical components. Such base technologies that are relevant to all technology fields are listed in the transversal roadmap. First steps in this direction have been taken through European Space Agency, European Defence Agency and European Commission to define “European Technology non Dependence” as part of the future FP8 activities.

In order to advance the discussion in the context of the present roadmap document into more detail, the Discotech[10] roadmaps have been analysed for topics relevant to electrification of the vehicle. The Discotech roadmaps, which were designed for the aeronautics and space domain in the field of components, can greatly contribute to the definition of breakpoint technologies common to the electrification of air and road transport, although they were initially meant for defence needs. Figure 4 shows items and respective timelines as given in the Discotech roadmaps that have a high potential for a future dual use in the automotive and aeronautics sector. These have been taken into account for the development of the ICT for the FEV roadmap to identify common breakpoints in technologies as far as electronic components are concerned, and for reference to the timeline as considered in the aeronautics sector. These base technologies are mostly relevant for all technology fields and hence, this analysis bears importance especially for the transversal roadmap.

[10] The Discotech roadmaps have been established for the European Defence Agency and aim at highlighting where components should be specifically developed to fulfil the specific Defence needs.

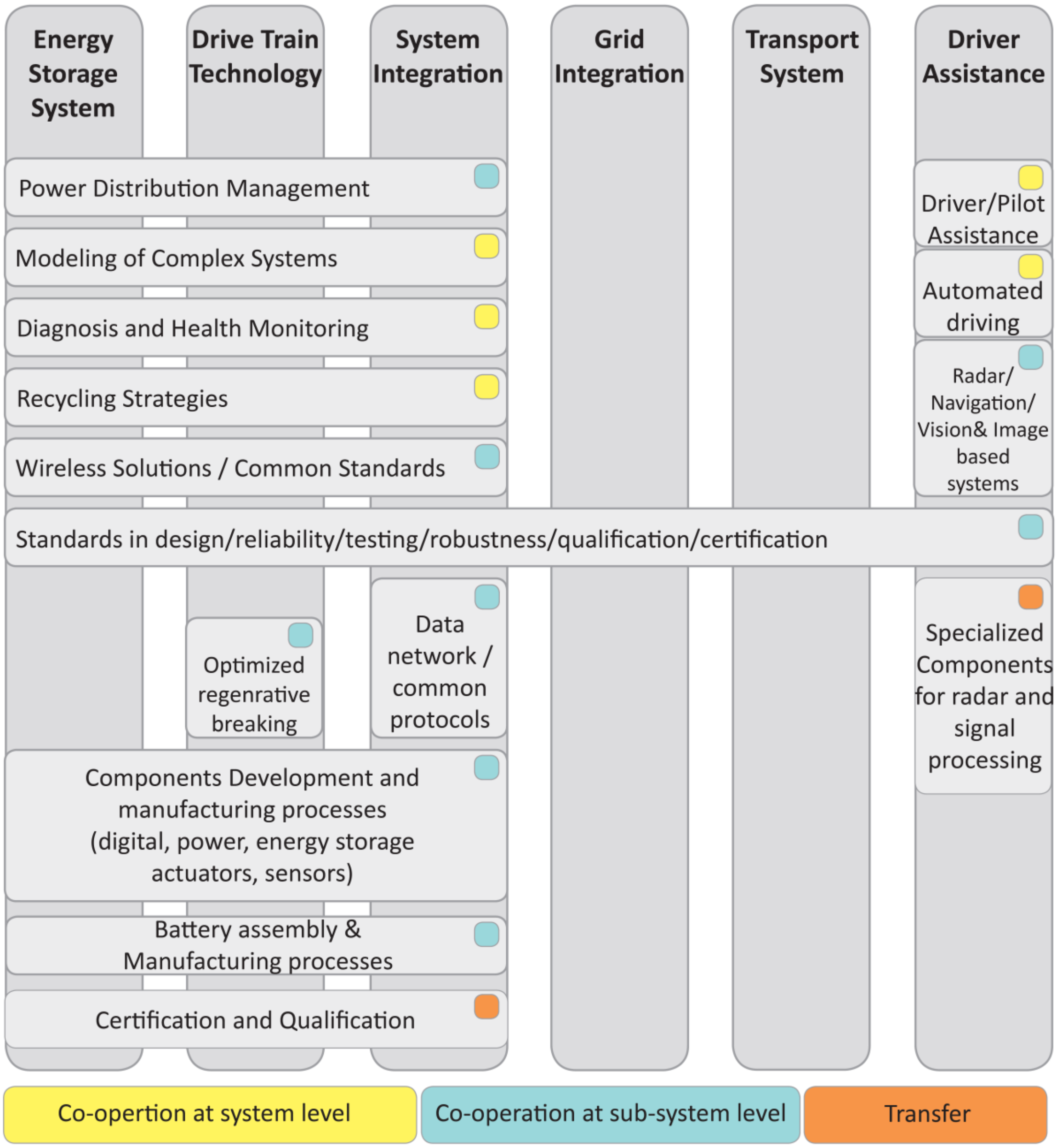


Figure 3: Topics for Co-operation and knowledge transfer between aeronautics and automotive on system and sub-system level

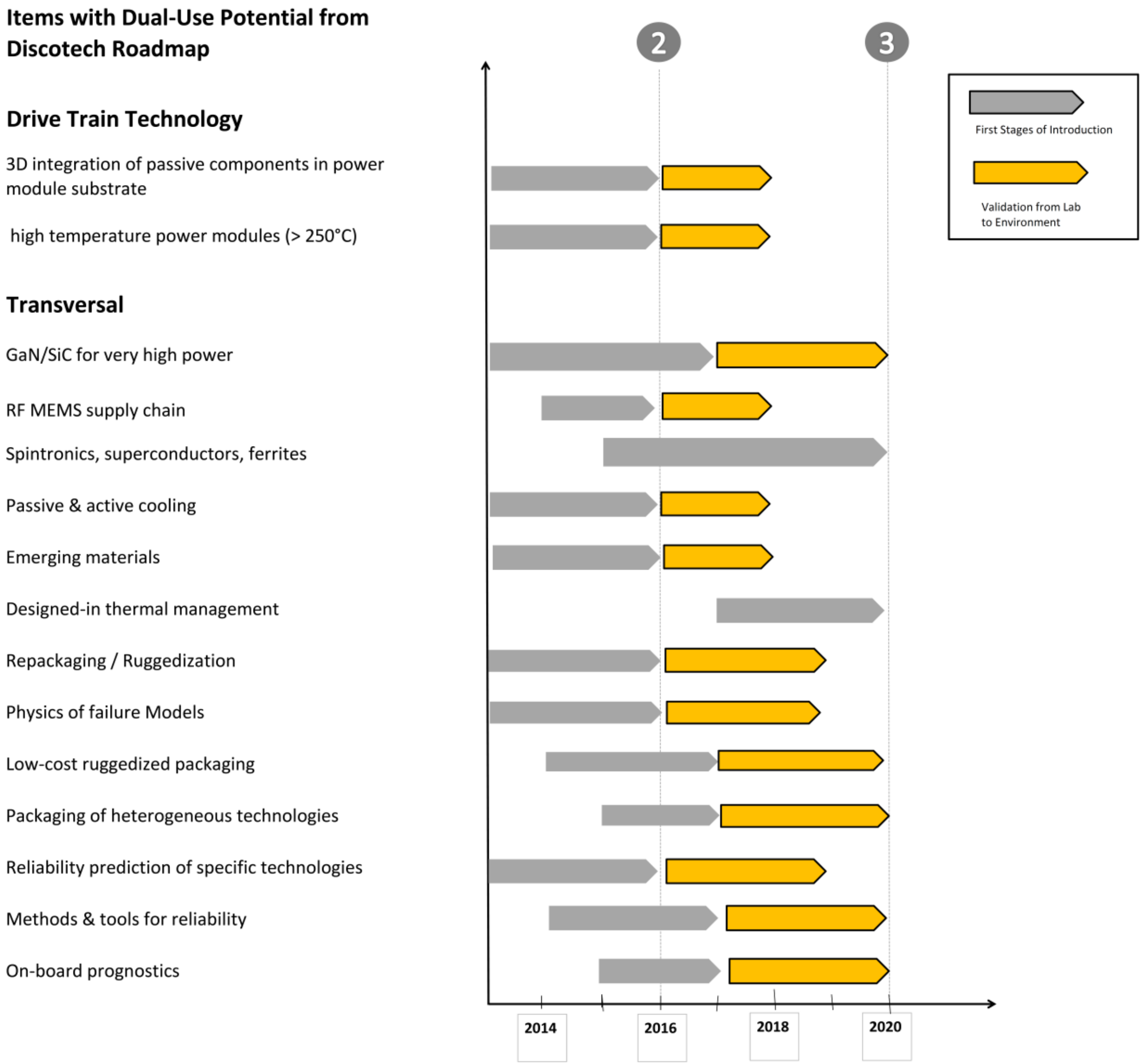


Figure 4 Topics excerpted from the Discotech roadmap that are relevant for the electrification of the vehicle. For indicating the timeframe the Discotech roadmap employed the Technology Readiness Level (TRL) Scale of the European Space Agency which differentiates the R&D phase used in the ICT for FEV roadmaps into 5 levels that were in Figure 4 summarized to two stages for reader's convenience. The TRL 1-3 are listed as "first stages of introduction" and the TRL 4-5 as "validation from laboratory to environment".

As a conclusion, possible topics for technology transfer and co-operation between aeronautics and automotive industry have been analysed starting from automotive needs, which yields an exhaustive list of fields for dual-use. Additionally, concerning the field of electronics, taking the aeronautics viewpoint has delivered a detailed status of breakpoints technologies (as seen from aeronautics) with timeline and figures, which enriches the ICT for the FEV roadmaps.

7 Recommendations

A multitude of ICT related aspects of electric mobility are subject of collaborative R&D projects currently carried out within the JTIs ENIAC and ARTEMIS and within the PPP European Green Cars Initiative after a specific objective on ICT for the Fully Electric Vehicle was part of Calls for Proposals in the context of the 2010 and 2011 ICT Work Programmes. See the table to topics covered in these projects:

Technology Field	**Projects ICT for the Fully Electric Vehicle & JTI* Calls**		
Energy Storage Systems	ESTRELIA	Smart-LIC	SUPERLIB
Drive Train Technologies	E3Car* E-VECTOORC	CASTOR P-Mob	POLLUX* Motorbrain
System Integration	eFuture ID4FEV	MAENAD OpEneR	P-Mob POLLUX*
Grid Integration	eDASH OpEneR	P-Mob IoE*	SmartV2G
Transport System	Ecogem		
Safety	OpEneR		

In this context it should also be noted that altogether more than 50 projects of the European Green Cars Initiative have been started in all technology fields mentioned above. A full list including abstracts is contained in a specific brochure.[11] Also, another 20-30 projects will receive funding through the third call of the European Green Cars Initiative which closed in December 2011.

In light of these current activities, and taking into account the assessments done by the European Technology Platforms of the PPP European Green Cars Initiative, some recommendations can be made on how the topic of ICT for the FEV could be further promoted in the PPP European Green Cars Initiative of FP7 and in its successor within the new Horizon 2020 framework. This shall follow the roadmaps as described in this document, and for a systematic approach start from the ICT and Smart Systems functionalities as described in Figure 2.

2013 Call of the ICT Work Programme

Given the fact that almost all topics of the first electrification roadmaps are covered at least by some activity, this last call of the PPP European Green Cars Initiative provides the opportunity of thinking ahead some of the main systematic aspects of the FEV from the ICT point of view: (a) the (internal) architecture, and (b) the integration of the FEV in the power grid. The following two objective should therefore be included into the work programme.

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[11] Project Portfolio European Green Cars Initiative PPP. ERTRAC/EPoSS7SmatGrids/EIRAC 2011.

(a) Revised System Architecture of the Electric Vehicle

The motivation for his topic is the fact that the electric power train is offering unique opportunities to replace mechanical and mechatronic systems and interfaces by wired or even wireless communication and digital controls. ICT thus will enable greater precision in control, and possibly a drop of the vehicle weight leading to substantial gains in energy efficiency, and driving range. The application of ICT in the current first and upcoming second generations of fully and plug-in hybrid electric vehicles does not yet reflect these opportunities. In contrary, by just adding new functionalities for the control of e.g. motors, batteries and grid interfaces to a conventional electric and electronic architecture, the complexity, weight and cost of the system is increased, and neither the environmental nor the economic potentials of the EV are fully exploited systems, and missing standards for voltage levels. A paradigm shift will be needed to accelerate innovation in the domain EV, which may also be of importance for today's vehicles, by a complete redesign of the electric, electronic and ICT architecture. The work to be carried out under this objective should include both bottom-up and top-down approaches, namely the integration of multiple functionalities in the same single device, and novel designs of the E/E architecture.

(b) Efficient, Safe, Convenient Solutions for Grid and Road Integration of the EV

The rationale behind this topic is the expectation that advanced solutions for charging of EVs which are fully integrated in the grid and road infrastructure within urban environments and at the same time account for the state of the art battery technologies may pave another way towards unlimited range of the fully electric vehicle in the future. Driving range (and battery lifetime) of the FEV can be enhanced e.g. by frequent recharging through connections to the power grid which are widely deployed and accessible in a barrier-free manner, e.g. inductive charging. Continuous or quasi. Reasons for this include e.g. a lack of common interfaces between the on-board continuous charging will also lead to shorter recharge duration, and thus raise usability of the FEV beyond the urban context. High power (fast) charging will also enable range to be increased, although it is essential to account for the faster degradation of the battery which results. Interoperability is key for effective implementation of any new (continuous/fast/inductive) charging systems, and therefore technologies, communication protocols, safety standards need to be harmonized – which is clearly in the scope of ICT.

Horizon 2020

According to the assessments made in the context of updating the European Roadmap on Electrification of Road Transportation, and when compiling this Roadmap on ICT for the Fully Electric Vehicle, a multitude of new research, development and innovation (R&D&I) activities have to be started under the new Framework for Research and Innovation Funding, Horizon 2020, which are particularly relevant for achieving milestone 3 and the newly defined milestone 4. This is in much detail reflected by the technology roadmaps in chapter 5 of this document.

A more general overview of when research and development phases will be needed for the ICT and Smart System Functionalities described in chapter 4 is shown in Fig. 5. It indicates that there will be two dominant development phases of the role of ICT in the FEV under Horizon 2020, namely

(a) ICT to Compensate the limitations of 1st and 2nd generation FEVs (2014 – 2017)

The electrified converted vehicles (e.g. Renault Fluence, BMW Active-E) and genuine FEVs (e.g. Nissan Leaf, Mitsubishi eMiEV) of the first generation will still lack user acceptance because the total cost of ownership is higher than for a conventional car and may be paid off by lower cost of energy only after a couple of years. Also, the limited range will restrict the use to urban driving, and yet underdeveloped charging infrastructures will be a major roadblock. For the 2nd generation FEVs, ICT, components and smart systems will be used not just for improving the energy efficiency of the electric drivetrain and the energy management but also for enhancing the ease of use, e.g. by routing and navigation functionalities, user identification or the integration into a multi-modal transport system. Novel car sharing services which lead to a better utilization ratio of FEVs will be enabled by these acitivites.

(b) ICT enabling the complete redesign of the FEV (2014 – 2020)

A second phase which will start already in parallel to the first one but will extend over the entire duration of Horizon 2020 is aiming at enabling the mass deployment of FEVs through enabling series production and a fundamental resolution of the hurdles in the 3rd generation. Functionality improvement, the reduction of complexity and an overall optimized energy management will be key factors of this development. In particular, a complete revision of the electric and electronic architecture of the FEV has to be undertaken, supported by drive by wire or even wireless communication, as it can lead to weight reductions and leaner production processes. The required research and development activities will not be delivered and implemented into products in short time, also because serious re-organization of the organizations structures of vehicle manufacturing.

Beyond these two development phases, a third trend will be expected for the time of Horizon 2020, namely the overall radical increase of energy efficiency of FEVs by a synergetic combination of developments from a multitude of domains including electrochemical energy storage systems, light weight construction and (which would be the part of ICT) the improved system integration. In order to exploit the full potential of this trend, and to make it use of it for the competitiveness of the European industry, research activities in a multitude of domains need to be coordinated and the required value chains have to be created. Therefore, the technology developments suggested by chapter 5 of this roadmap need to be complemented by innovation at all product layers of a vehicle, as it has been suggested by the European Technology Platforms of the European Green Cars Initiative PPP for Horizon 2020. The options for technology transfer from the aeronautics sector as described in chapter 6 may play a crucial role for this.

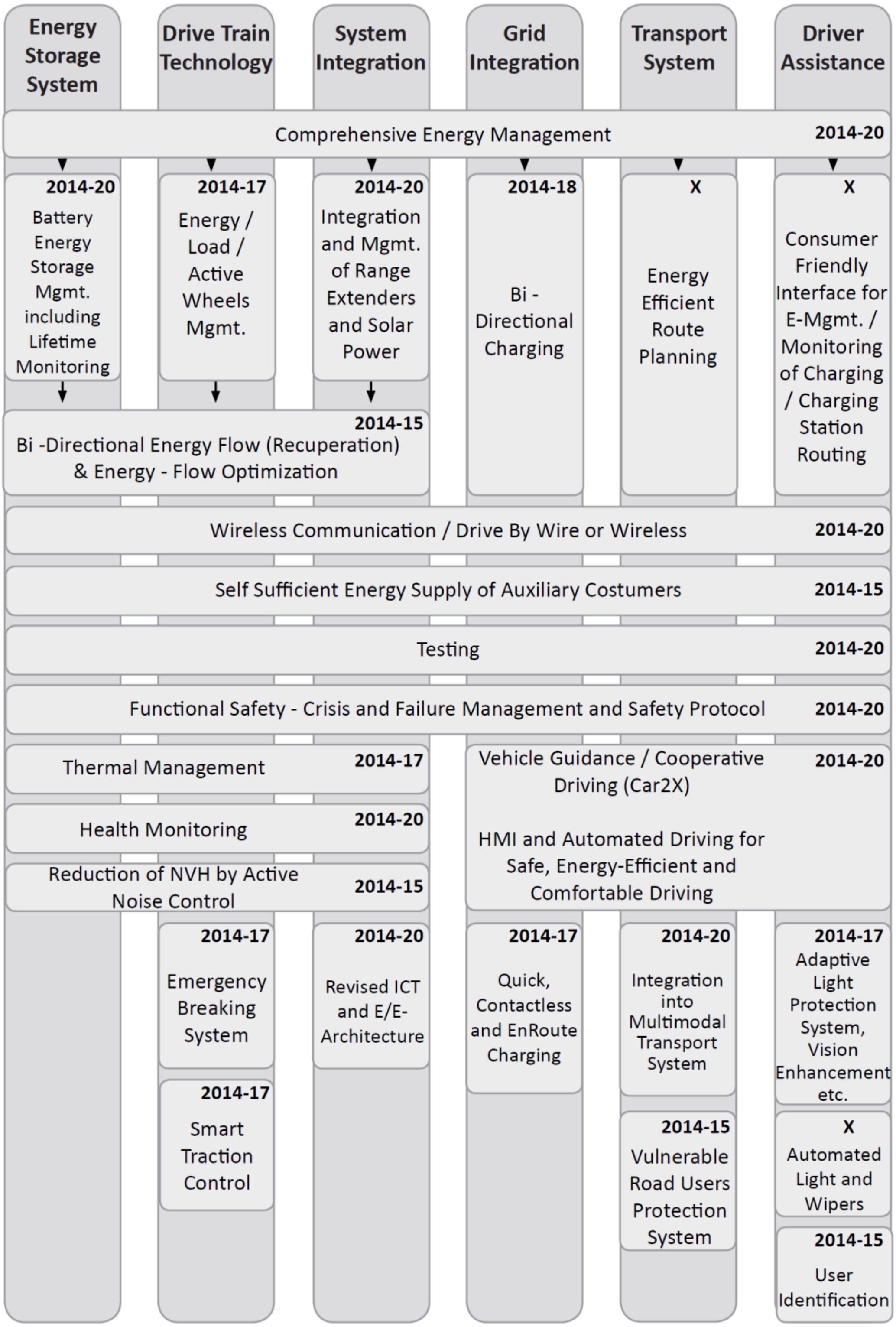

Figure 5: Phases of research and development in the domain of ICT and Smart Systems functionalities for the FEV as projected for Horizon 2020. (X: Implementation phase).