



EUROPEAN
ROAD
TRANSPORT
RESEARCH
ADVISORY
COUNCIL

European Roadmap

European Technology and Production Concept for Electric Vehicles

Version May 2011

ERTRAC Working Group Global Competitiveness

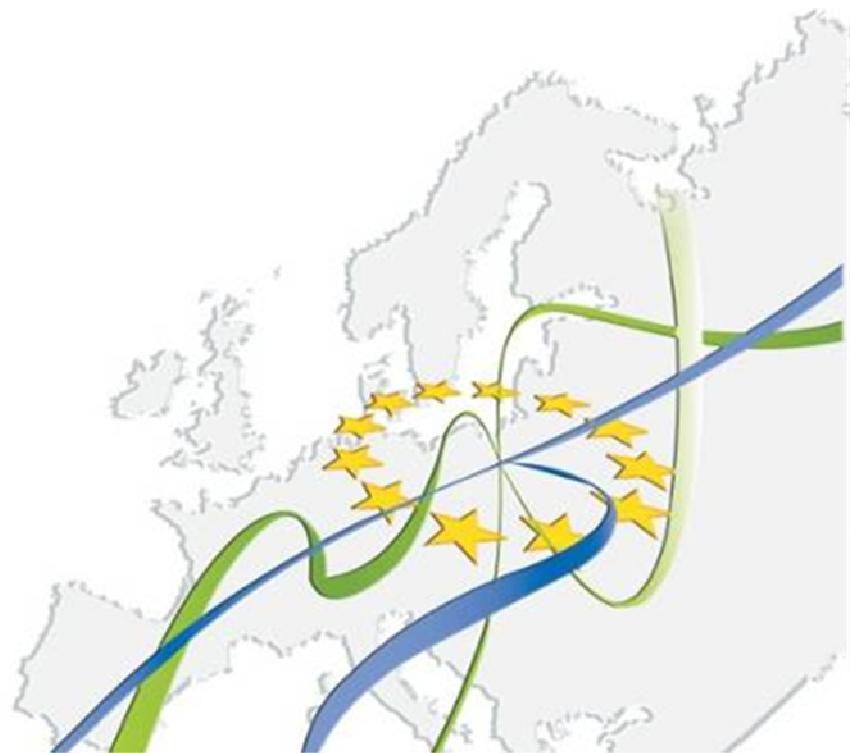


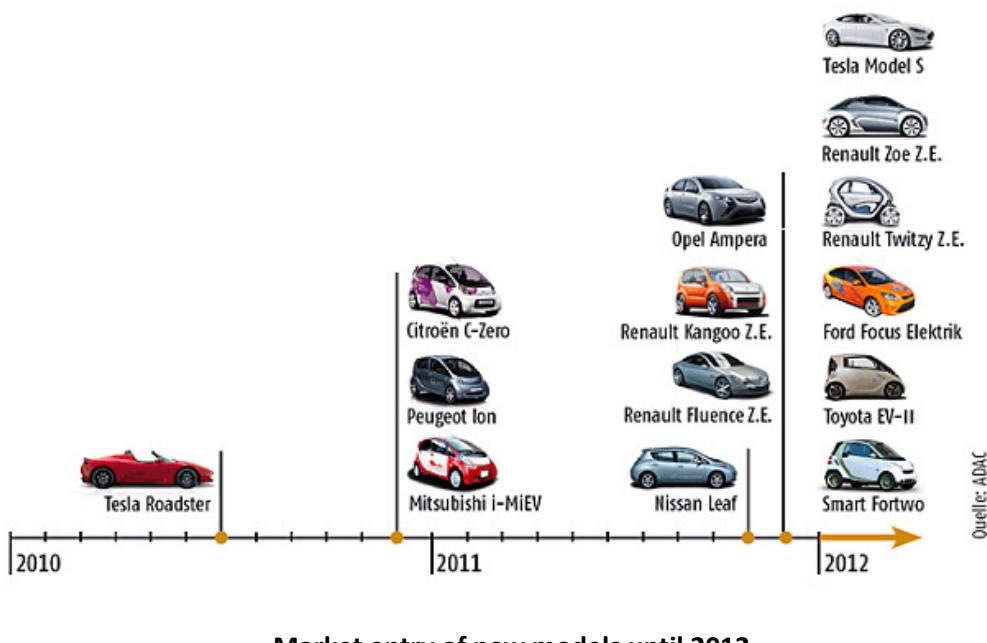
Table of Contents

1. Rationale
2. Electric Vehicles and Europe's Global Competitiveness
3. Sustainability in Global EV Production
4. Building Blocks and Timeline for Implementation
5. Roadmaps
6. Recommendations
7. References

Abstract

The objective of the roadmap on a “**European Technology and Production Concept for Electric Vehicles**” (**ETPC-4-EVs**) is to support the development and implementation of all those global processes, methods and technologies that allow to produce hybrid and fully electric vehicles affordable for and thereby attractive to the customer.

As shown in the figure below, electric vehicles are just starting to enter the market with increasing numbers of models and there are many problems unresolved, so far that might pose a bottleneck to significant market penetration: **first and maintenance cost of the vehicle**, electric charging infrastructure, communication and service infrastructure.



The ETPC-4-EVs roadmap places its focus on the first cost of future “**Plug-in Hybrid Electric Vehicles**” (**PHEVs**) and fully “**Electric Vehicles**” (**EVs**) and in here particularly on those *novel technologies* that are primarily responsible for the costs of the product, which is the *production, supply chain logistics* and the related *business processes* as well as the *social infrastructure* necessary for successful enterprises. In a networked world with changing market volumes and volatile economic conditions the global aspect is of particular importance and was selected as a “file rouge” item throughout all considerations. In consequence, detailed content of work was compiled and edited for the 5 domains:

- “**Out of the Box Design**” (**defines future technology requirements**)
- **Global Production Processes**
- **Global Supply Chain Management & Logistics for EVs**
- **Global Business Processes**
- **Global Education and Qualification**

A set of consistent recommendations concludes the current state of the roadmap with highlighting that a pilot project needs to get started as soon as possible and definitely before 2013 in order to deliver tangible results that can support the industry in due time before the 1st 2020 milestone is reached (taking a 4 years project duration and 2 years project preparation into account).

1. Rationale

Next to the three most obvious “Societal Needs”

- **decarbonization of Road Transport**
- **the reliability of all products, as well as their**
- **safety & security in use**

the **competitiveness** of all products developed and manufactured by European companies on the global market place is of same importance. With regard to the emerging electrification of road transport, it is particularly the area of hybrid and fully electric vehicles where the most immediate needs regarding Research, Development and Demonstration initiative emerge.

This roadmap supports the vision of Electric and Plug-in Hybrid (EV/PHEV) Vehicles achieving the widespread adoption by 2050. Crucial for the mass deployment of EVs and PHEVs that guarantee the continued mobility of persons and goods at minimum energy investment and emissions is the affordability of the vehicles in first price and use. Starting from the technical requirements for future EVs and PHEVs this roadmap sets strategic goals and identifies the steps that need to be taken to

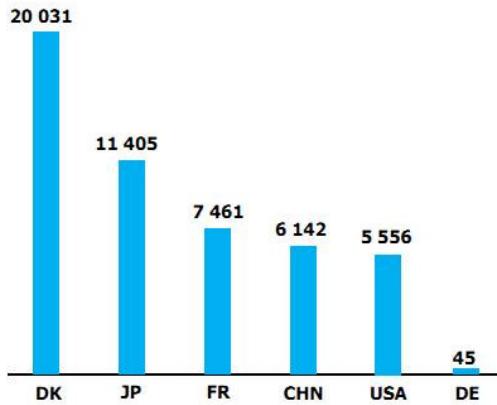
accomplish these goals. This roadmap also outlines the roles and collaboration opportunities for different stakeholders and shows how regulatory and governmental influence can support the overall achievement of the vision. The ETPC-4-EVs roadmap places its focus on the electrification efforts of the automotive sector and does not address pure production aspects, such as factory equipment, tools and robots or general manufacturing processes.

The strategic goals for supporting the widespread adoption and use of EVs and PHEVs worldwide by 2050 cover the development of the respective global market in relation to the economic development and the ecologic constraints. The technology-specific goals include the following:

- The “**Out-of-the-Box**” EV/PHEV Technology scout for the 2020 scenario (3rd EV Generation) and beyond to define the generic scope of products needed for the manufacturing of affordable EVs and PHEVs
- A bottom-up approach to cost-optimized **global production processes** needed to identify the least cost and least environmental impact approaches to global manufacturing of EVs/PHEVs and their systems and components
- A **global Automotive Supply Chain Model**, which takes the specific customer and industry characteristics into account with a particular Research, Development and Demonstration (RD&D) initiative to accelerate the market entry of EVs with cost-effective instruments for both consumers and industry even at volatile market conditions
- The **framework of Global Business Processes** to consequently investigate the consumer needs and behaviours, develop coordinated strategies to include the European industry in the global market introduction of EVs, engage in international policy efforts to secure the availability of natural resources, examine and establish a robust material and commodity strategy
- A global **education and qualification initiative** to enhance the corporate identity throughout the whole workforce of global European companies and to maintain European companies and staff in the global labour market regardless if the market for EVs should take-off outside Europe.

Obviously, the development and implementation of the necessary charging and service infrastructure is of similar importance as is the development of an effective and affordable technology for the electric motor car of the future. These items comprising electricity demand and supply features, communication, charging and management problems need to be tackled outside this roadmap. However it is important to recognize that the development and provision of costworthy vehicles cannot become a success when treated as a singular approach that is disconnected from progress in the field of infrastructure and services. After all, the user of a PHEV or EV will have to bear compound of cost for mobility including first and maintenance costs for the vehicle itself plus the costs for use/electricity and infrastructure.

Regarding market entry and penetration it is also worth mentioning the incoherent global level of incentives which are currently granted:



Maximum incentive per vehicle in [€] Status: May 2011

There is high expectation that further engagement in international collaboration schemes will support the spread of European technologies and processes, world-wide and thereby contribute to keep the European automotive industry and its workforce on the global competitive edge. There are a number of key areas for information sharing and collaboration:

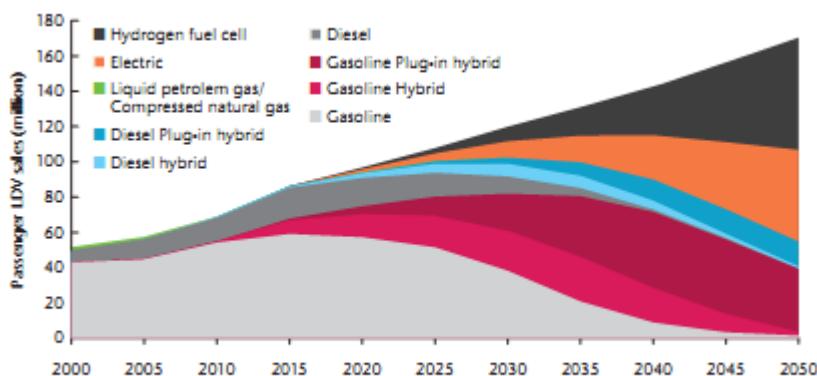
- Research and Technology as well as Demonstration Programs
- Codes and Standards
- Vehicle Testing Facilities
- Setting of Market Development Targets, such as Vehicle Sales
- Alignment of Infrastructure, Charging and Vehicle Systems, as appropriate
- Policy Development and Experience in Implementing Different Approaches.

2. Electric Vehicles and Europe's Global Competitiveness

The most recent economic downturn left the global economy in uncertainty and imbalanced growth in a world split in blocks struggling for resources and trying to master political, religious and environmental threats. The automotive industry managed to survive this economic crisis but suffered deep financial losses and was saved via lay-offs, short-time labour and scrappage schemes before returning after 3 years only to near-boom growth – of which nobody can foretell on how long this will last. The global economy and particularly the automotive markets are no longer predictable beyond a few weeks or months:

- governments, may cap the number of new registrations,
- slow economic recovery in important car markets may restrain the sales,
- conflicts, as seen in the Arabic world and/or the consequence of disasters may lead to soaring oil prices.

In this environment the automotive industry is setting out for the electrification of road transport with huge investment in vehicle technologies and at the same time developing solutions regarding the global production in order to make these new PHEVs and EVs affordable.



Source: IEA 2009.

Figure 1: Co-existence of vehicle propulsion types

A key factor to the economic success of electric drive is the achievement a widespread adoption and use of EVs and PHEVs by 2050. The International Energy Agency estimates that by 2020 global sales of EVs and PHEVs (combined) should achieve at least 5 million per year.

In consequence the automotive industry has to master the enormous challenge during the next decades of handling the co-existence of ICE-powered vehicles, hybrids, PHEVs, as well as EVs and still remain profitable to shoulder the respective development costs (see Fig. 1).

Whereas the vehicle related part regarding the “Electrification of Road Transport” is convincingly outlined in the respective roadmap by the European Technology Platforms **ERTRAC**, **EPOSS** and **SMARTGRID**, it is the purpose of this roadmap to complement the “big picture” perception of electrification of road transport by addressing the “affordability” of PHEVs and EVs. In addition, this roadmap identifies the role for different stakeholders and describes how they can cooperate to reach common objectives.

The ETPC-4-EVs Roadmap places its focus on the **“Research, Development and Demonstration” (R,D&D)** requirements in the areas of future design options, related production and Supply Chain Management needs, the inclusion of most relevant business processes, as well as the social implication and looks beyond the 2nd generation of electric powertrains in intervals up to 2020, 2025 and 2030.

„Electric Drive Vehicles are unlikely to succeed without strong efforts in making vehicles affordable and ensuring that the adequate recharging infrastructure is in place – next to resolving vehicle related challenges”.

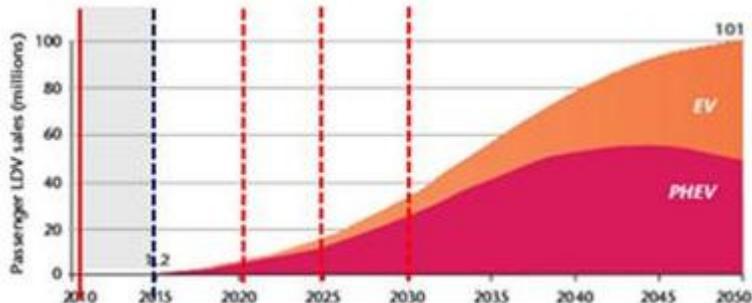


Figure 2: R,D&D Target Time Periods

In 2010 approximately 60 million cars were sold globally with 64.5 million sales predicted for 2011. Important to register, however, that the shares per region shift considerably. According to the prediction of VDA in Germany, China's global market share will rise from 10% in 2008 to 19% in 2011, meaning that one out of five new cars will be sold in China, soon. At the same time, Western Europe and the USA will lose 3% each, while emerging markets, such as Brazil, India or Russia are continuously growing. This assessment is supported by the most recent survey of the International Monetary Fund for 2020, where economic market capacities are clearly shifting to Asia and Africa.

**Figure 3: Economic Market Capacity Prediction for 2020**

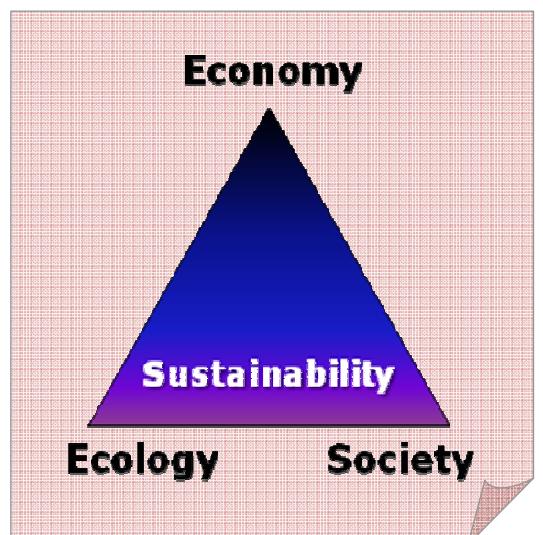
In all these diverse and dynamic regions European manufacturers have increased their capacities in the recent years and they are still busy to explore new sites by following their markets. Experience with currency swaps, political constraints or proximity to customers have supported this move.

3. Sustainability in Global EV Production

For the automotive industry, Sustainable Production of Electric Vehicles means delivering on our global priorities: producing profitable in full consideration of all economic constraints, energy efficiency and social responsibility in global competition. And it means doing all of this while minimizing the impact on the environment, using the earth's limited resources responsibly, relying on renewable sources of energy and fulfilling the industry's fundamental role in moving world economies forward.

To deliver on our global priorities, we need to make sure that vehicles and technology remain affordable, and that a partnership of industries, governments and consumers is in place to advance Sustainable Mobility together.

The sustainability triangle represents the balance between the economic challenges inherent in global production processes of EVs, the ecologic awareness to protect the earth's resources and atmosphere in manufacturing and operating global supply networks, as well as mastering the human development and social implications in operating global workforces effectively.



The European automotive industry is highly innovative and aware of the economic requirements, but in order to remain on the leading edge and to extend their shares in the global market place of the future, they need to incorporate new economic prediction and reaction elements to support the respective operational infrastructure. Most important, however, is the real time inclusion of crucial economic factors, which have essential influence on the production process of EVs, their systems and components, as well as the services (e.g. sourcing, logistics, maintenance, retrofit, etc.), and the recycling after the product's end of life.

In context of a significant improvement of market predictability the impacts of market mechanisms need to be better understood. The capability to measure the improvement by balancing competition amongst market players against possible horizontal inner-industry or cross-industry cooperation is of strong influence in order to correctly assess future shared capacities for all market players.

The **economic wing** of sustainable EV production holds the following challenges:

- global market volatility
- unpredictable ramp-up
- new competitors
- global shift in market volumes
- new technologies draw upon alternative commodities
- real-time reactivity & flexibility
- new rules in global economies
- global services



Figure 4: Economic Challenges

The **ecologic corner** of the sustainability triangle is characterized by the needs for global EV eco-production models, addressing an optimized utilization of energy streams, the reduction of environmental impact and the improvement of resource efficiency. This model of an advanced green manufacturing is complemented by the development of an integrated preventive environmental strategy to process and produce EV components and systems by full inclusion of the aspects of conservation of resources and energy by design aiming at eliminating emissions and waste by point source treatment and recycling. Specific threats and concerns affect the emissions in production and supply chain logistics, the careful use of resources and the energy investment in EV production.

- global road transport emissions
- uncertainty of fossil resources
- global emission footprint in SCL
- global emission footprint production

Ecology

The environmental awareness in production systems regarding factory equipment, tooling, robots etc. is exhaustively covered by the **EFFRA** (Factories of the Future) Strategic Multi-Annual Roadmap. Since future electric vehicles designed to purpose will source and produce their components globally particular attention will be assigned to a highly reactive and robust eco-friendly supply grid.

Buoyant economies outside Europe with strong economic growth attract the automotive industry to produce closer to the customer at lower costs and avoiding high import taxes. Most recent **employment** surveys in Europe indicate that these companies are no longer mere labour cost refugees since employment in the sector were on the rise or at least constant. Important to note, however, is the impact on the European employment structure, which shows a shift from factory workers towards technicians and engineers.



Taking the IMF assessment into account it is obvious that tools and mechanisms need to be developed to allow the highly qualified but relatively small European work force to participate effectively in the global labour market. In this context education and skills of staffs will be of ever growing influence for which expressive indicators have been established by the United Nations' Human Development Index. Traditionally, a job produced output – nowadays, it is a ticket to learn, a

job is a defining feature and rewarding aspect to life and represents therefore an equal element of the sustainability triangle.

4. Building Blocks and Timeline for Implementation

4.1 Substantial Approach

Although few serious technical hurdles seem to prevent the market introduction of PHEVs and EVs battery technology accompanied by ultra light weight solutions are integral parts of these vehicles that still need to be significantly improved. In parallel to the pure technical and engineering challenges to

- increase the battery storage,
- robustness and durability and
- design and build EVs and PHEVs with ultra-light weight materials to purpose

there is another critical challenge, which is reaching an economy of scale in global production and logistics in volatile markets and constrained business scenarios.

To date there is no market volume for PHEVs and particularly for EVs that would allow the establishment of high volume production processes. The automotive industry draws much of its profitability from high production volumes and small margins. Since the roll-out and market penetration of electric propulsion is extremely difficult to predict industry is careful in investing into the development and set-up of mass-production facilities, since these require the presence of the “Economies of Scale”, which is shown for batteries in Fig. 5, where the effect of mass production is related to a cost reduction of 35%.

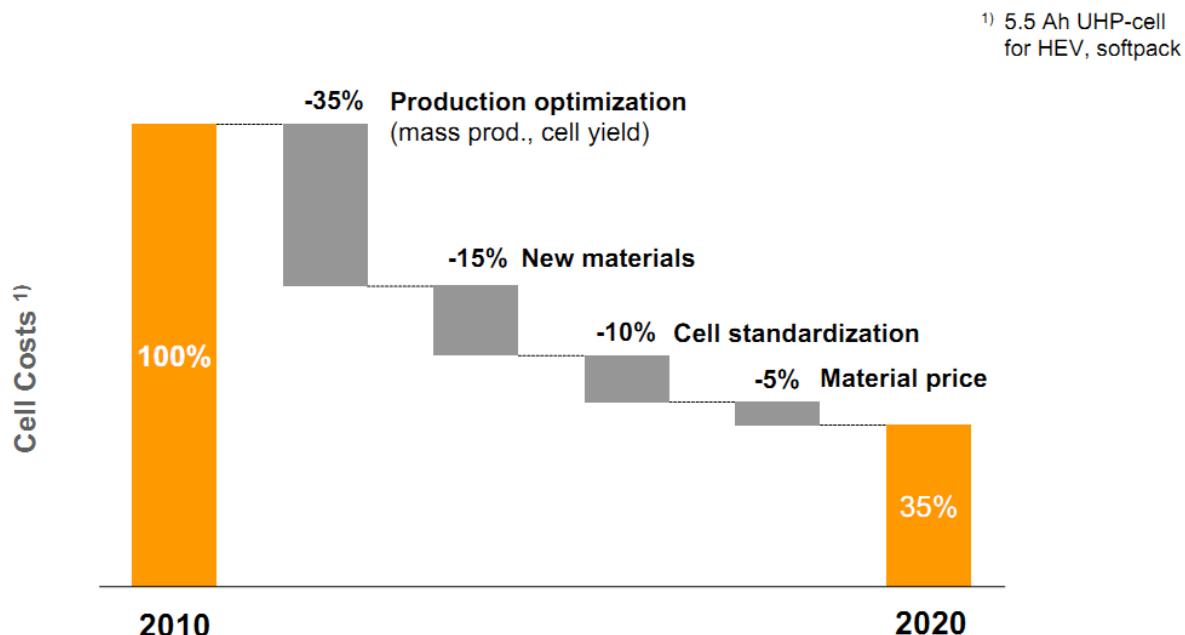


Figure 5: Cost Reduction of Battery Cells by high volume production

“Economies of Scale” describe the reduction in cost per unit resulting from increased production, realized through operational efficiencies. “Economies of Scale” can be accomplished because as production increases, the cost of producing each additional unit falls, as shown in Table 1:..

PHEVs	EVs
<p>Economies of scale:</p> <ul style="list-style-type: none"> Mass production levels needed to achieve economies of scale may be lower than those needed for EVs, for example if the same model is already mass-marketed as a non-PHEV hybrid; however, high-volume battery production (across models) will be needed. 	<p>Economies of scale</p> <ul style="list-style-type: none"> Mass production level of 50 000 to 100 000 vehicles per year, per model will be needed to achieve reasonable scale economies; possibly higher for batteries (though similar batteries will likely serve more than one model).

Table 1: Economies of Scale for PHEVs and EVs

From the industry's point of view a profitable ramp-up scenario is of utmost importance, since this only can guarantee an early return of the investment into the new PHEV and EV technologies. This is of particular importance to the automotive sector, which is characterized by relatively short product cycles and low

margins. Therefore, vehicle model types and sales growth rates will play a crucial role in customer acceptance and market penetration.

It is assumed that a steady number of new models will be introduced over the next ten years, with eventual targeted sales for each model of 100 000 units per year. However, it is also expected that this sales rate will take time to achieve. During 2010 to 2015, it is assumed that new EV and PHEV models will be introduced at low production volumes as manufacturers gain experience and test out new designs. Early adopter consumers are expected to play a key role in sales, and sales per model are expected to be fairly low, as most consumers will wait to see how the technologies and market develop. As a result, it is assumed that from 2015 to 2020, the existing number of models and sales per model will increase fairly dramatically as companies move toward full commercialization.

	2012	2015	2020	2025	2030	2040	2050
PHEV	0.05	0.7	4.7	12.0	24.6	54.8	49.1
EV	0.03	0.5	2.5	4.4	9.3	25.1	52.2

Source: IEA 2009.

Table 2: PHEVs and EVs Deployment Targets [million units]

In order to achieve the deployment targets in Table 2, a variety of EV and PHEV models with increasing levels of production is needed. Figure 6 demonstrates a possible ramp-up in both the number of models offered and the annual sales per model. This scenario achieves 50 000 units of production per model for both EVs and PHEVs by 2015, and 100 000 by 2020. This rate of increase in production will be extremely challenging over the short time frame considered (about ten years).

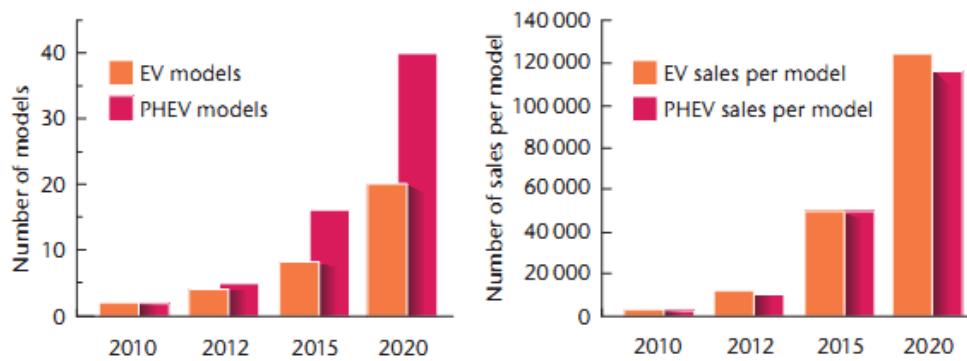
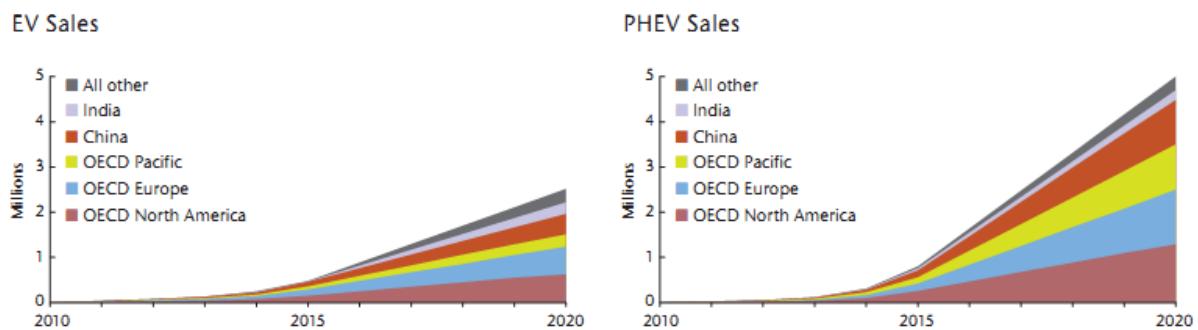


Figure 6: EV/PHEV Number of Models Offered and Sales per Model Through 2020

However, the number of new models for EVs and PHEVs in Figure 6 easily fits within the total number of new or replacement models expected to be offered by manufacturers around the world over this time span (likely to be hundreds of new models worldwide) and typical vehicle production levels per model. A bigger question is whether consumer demand will be strong enough to support such a rapid increase in EV and PHEV sales.

On a regional basis, Figure 7 offers a plausible distribution of EV/PHEV sales by region, consistent with this roadmap's global target of achieving an annual sale of approximately 50 million EVs and PHEVs by 2050. Regional targets reflect the expected availability of early-adopter consumers and the likelihood that governments will aggressively promote EV/PHEV programs. EV and PHEV sales by region are also based on assumed leadership by OECD countries, with China following a similar aggressive path. Sales in other regions are assumed to follow with a market share lag of five to ten years.

It is essential to note that the sales per model must rise rapidly to reach scale economies, but the number of model introduced must also rise rapidly.



Source: IEA projections

Figure 7: Expected EV/PHEV Total Sales by Region through 2020

Although the ramp-up in EV/PHEV sales is extremely ambitious, a review of recently announced targets by governments around the world suggests that all of the announced targets combined add up to an even more ambitious ramp-up through 2020, particularly for Europe. A key question is whether manufacturers will be able to deliver the vehicles (and battery manufacturers the batteries) in the quantities and timeframe needed. To achieve even the 2050 sales targets, a great deal of planning and co-ordination will be needed over the next five to ten years. Whether the currently announced near-term targets can all be achieved, with ongoing increases thereafter, is a question that deserves careful consideration and suggests the need for increased coordination between countries. Since the user will play the crucial role in this respect it is important to consider the influence the "Total Cost of Ownership" that will be imposed on her/him:

Total cost of ownership (TCO)

Customers buy cars for a wide variety of reasons, including purchase price, new vs. second-hand, depreciation rate, styling, performance and handling, brand preference and social image. Calculating the TCO of the power-trains is therefore important because it describes the costs associated over their entire lifetime – on top of which individual customer criteria are applied. TCO includes:

- **Purchase price:** the sum of all costs to deliver the assembled vehicle to the customer for a specific power-train and segment
- **Running costs:**
 - Maintenance costs in parts and servicing specific to each vehicle type and power-train combination
 - Fuel costs based on the vehicle fuel economy and mileage, including all costs to deliver the fuel at the pump/charge point and capital repayment charges on investments made for fuel production, distribution and retail; or for EVs/PHEVs, for charging infrastructure.

TCO Equation:

TCO = Purchase Price	+	Running costs
- Parts Costs		- Maintenance Costs
- Supply Costs		- Fuel & Infrastructure Costs
- Assembly Costs		
- SG & A ¹		
- Margin		

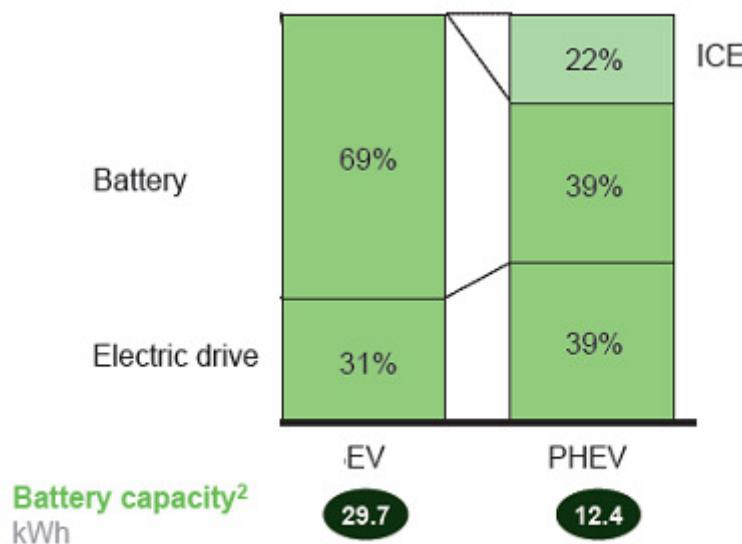
All projected cost reductions for EV components are based on proprietary data and include:

- Improvements in production engineering: operations such as electrode cutting, forming, stacking and contacting of the collectors will gradually grow more efficient through the introduction of advanced laser technologies and a shift from “batch to continuous” production modes. The automation and rationalization of quality testing along the production line will also generate efficiency gains
- Economies of scale from larger production plants (3 million BEVs in the EU by 2020).

EVs and PHEVs are complementary technologies as they share many similar electrical drive-train components, i.e. battery and electric driven as well as components, sub-systems and systems. Investments in EVs therefore also benefit PHEVs and vice versa.

¹ Selling, General and Administrative Expenses. Income statement item which combines salaries, commissions, and travel expenses for executives and salespeople, advertising costs, and payroll expenses

By 2020, the purchase price of EVs is expected to be still several thousand €s more than that of ICEs, but reasonable public incentives on vehicle, fuel and an attractive customer value proposition could be sufficient to bridge this cost gap. The purchase price of PHEVs is lower than EVs. The purchase prices of electric vehicles may vary widely according to market conditions and car manufacturers who may either be further advanced in achieving cost reductions and/or choose to limit the premium. They also depend on branding strategies, with a whole range of purchase prices within any car segment – from lowest cost to premium vehicles.



² Different types of batteries for each powertrain depending on their driving pattern

Figure 8: Relative Total Powertrain Costs of EVs and PHEVs

As outlined in the “European Electrification of Transport Roadmap” mass production of EVs is expected to be reached by 2020 with the 3rd Generation EVs while the 2nd Generation is predicted to enter the market by 2016, already. Obviously, the development of a realistic roadmap on global PHEV and EV production processes requires the placement of focus on the 3rd generation EV technologies and beyond that are needed for the new models. For this purpose, the “**Out-of-the-Box Design**” initiative is introduced, which aims at identifying innovative, discontinuous and radical technologies and concepts for electric road transport of the future.

4.1.1 Out-of-the-Box Design

The purpose of “Out-of-the-Box Design” is to complement the typical mainstream forecast with the identification of generic, more innovative and far-sighted design ideas of PHEVs and EVs in order to provide a perception of the global production and supply chain requirements beyond 2020. Hence, this roadmap element is supposed to give recommendations regarding possible technology features to be considered in mass production and global sourcing processes and by taking the specific customer, market and product characteristics of the sector into account.

An integrated Research, Development and Deployment scheme in the area of Global Competitiveness for EVs and PHEVs requires to look towards the longer term and more radical solutions for EVs and PHEVs alike

"This activity is built around the desire to anticipate a more generic, innovative and far sighted approach than typical of mainstream, evolutionary research".

and to extract the generic preconditions regarding the related components sub-systems and systems and their production, supply chain logistics and business framework. In order to avoid competitive frictions within the industry due to proximity to current developments but still to provide a significant technology forecast a team of

stakeholders will gather in a string of workshops to examine more innovative and far-sighted ideas that:

- are forward-looking rather than immediate in application;
- have specific technology challenges;
- offer a prospect of significant requirements to the global production system and supply chain management;
- offer the prospect of substantial impacts and benefits.

Given the fact that the market introduction of electro-mobility is strongly dependent on global economic and ecologic change it is important to indicate three factors that drive this change:

- ***the demands of the market,***
- ***new technology,*** and
- ***the changes in the economic/ecologic circumstances of the automotive system.***

The basic ideas and perceptions will be screened by assessors against a set of weighted criteria, which in turn will be used to condense and sequence the findings and to connect related subjects.

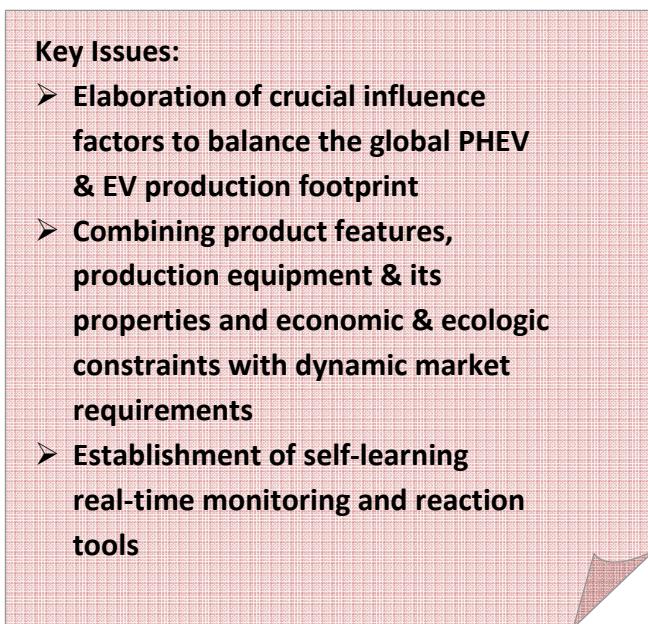
4.1.2 Global Automotive PHEV & EV Production

There are four major columns available for industry that have the potential to fundamentally increase the affordability:

- Optimizing production by enabling dramatic increases in scale and automation
- Materials Improvement
- Design Standardization
- Sourcing

Obviously, global automotive companies will continue to operate according to the economic, ecologic and social constraints when it comes to the introduction of PHEVs and EVs. There will remain the compelling challenges directly resulting from competition and cooperation, local autonomy and global behavior, design and emergence, planning and reactivity, uncertainty and plethora of information. The resulting issues associate a model based on responsive and cooperative manufacturing:

- Responsiveness expresses a generic attitude in production engineering, a continuous quest for solutions that work in reality even under changing conditions. Responsiveness is a repeated effort of mapping projections of the future (i.e., plans) to actual developments and actions in the real world. Responsiveness implies ongoing interaction with the execution environment and requires that the environment can be at least partially observed. This calls for the identification of objects, as well as the monitoring of their behaviour, whether in the real or the virtual world. The innovative use of sensor and active identification technologies enables so-called context-aware manufacturing and lays the foundations for the smart factory thereby leading to responsiveness.
- Where system components interact with each other in a production network, there is a special opportunity to tackle various forms of incertitude (which can be broadly classified as uncertainty, risk, ambiguity and ignorance). This is called cooperation, an interactive relationship that makes possible to harness knowledge of other system components or to make use of their actions in the service of joint interests. Cooperation is the alignment of various, eventually even disparate goals in the hope of some mutual benefit.



4.1.3 Global Automotive Supply Chain Management & Logistics for EVs

The shift from ICE powered motor cars towards PHEVs and EVs will boost the inclusion of electric components and systems, which will trigger new inter-industrial collaboration schemes and require radically new concepts for joint planning and controlling global production and supply networks. Beyond the challenge of becoming profitable even at a very low-volume production of EVs, it is obvious that the step towards the electrification of the powertrain requires the increased inclusion of other key-industries, such as the semiconductor branch and the consideration of commodity (e.g. carbon fibres, etc.) and material (e.g. Copper, Lithium etc.) suppliers.

The configuration of a highly flexible and reactive automotive/semi-conductor supply organism in global context will be crucial to success even in ramp-up and small series production phases. Both the automobile and the semi-conductor industries operate at multiple locations around the world and the critical mass of a site is of higher influence on competitiveness than the critical mass of a product. Therefore, a business model is called for that dynamically integrates company economics in a volatile global economic environment, also in consideration of local resources, such as commodities, energy, labour, etc. Such global governance model actively influences the capacity capabilities and related services according to economic constraints and will enable European companies to offer their customers a broader variety of choice of affordable products and an extended range of services.

Rapidly changing economies demand dynamically adaptive supply networks that operate on standardized data-models, formats & interfaces allowing integrated scalable planning and execution.

For the successful supply of automotive systems and components for future EVs on a global market place where the largest economic growth is most likely to take place outside Europe, the establishment of the respective standards is paramount for the European Automobile industry and its workforce. These standards should be open to all participants and address pan-industrial supply chains, network collaboration schemes and international supply characteristics.

Key Issues:

- **Collaborative planning and real-time management of highly distributed macro/micro production networks**
- **Workflow-based decision making for global site management:**
 - **Resource optimization**
 - **Global Capacity planning & balancing**
 - **Production planning within a highly reactive global supply network**
- **Development of characteristic data-Platforms for real-time decision support, planning and recovery systems**

The establishment of such an integrated macro system combines customer needs and business opportunities across different global market segments and is concurrently interrelated with global economic change. This model of a macro-system takes the technological progress and customer needs into account, as well as product design and customer satisfaction, and includes the overall economic/ecologic market drivers in context of trading and commercial aspects. The elements of fast response and flexibility are the key attributes of the system.

4.1.4 Global Business Processes

In a mid- to long-term perspective the electrification of road transport via PHEVs and EVs will become a key factor to the competitiveness of the European Automotive industry on the global market place. In this context, it is obvious that the conventional “hard” Research and Technology Development of the engineering domain needs to be complemented with “soft” Economic and Business Process Research by including the aspects of globalization, energy and climate challenge, as well as the availability of materials and commodities. Hence the prime objective of the necessary global business processes is to keep the products of the industry affordable to an ever growing number of customers world-wide and with regard to PHEV & EV technology, which has considerable potential to reframe the industry.

The automotive industry is a leading EU export sector with a net trade contribution of almost € 30 billion.

Leading in high-quality products, the industry sells and produces vehicles in all major world markets.

The European automotive industry partnership is highly innovative, but in order to remain on the leading edge and to extend their shares in the global market place of the future, they need to

The automotive sectors' own R&D investment of €32.8 billion in 2008 (without suppliers) ranks 1st, in front of the pharmaceutical sector with €19.8 billion and the telecommunications equipment sector with €12 billion.

incorporate new economic prediction and reaction elements to support the respective operational infrastructure. Most important, however, is the real time inclusion of crucial economic factors, which have essential influence on the production process of EVs, their systems and components, as well as the services (e.g. sourcing, logistics, maintenance, retrofit, etc.), and the recycling after the

product's end of life. In context of a significant improvement of market predictability the impacts of market mechanisms need to be better understood. It is important to measure the improvement by balancing competition amongst market players against possible horizontal inner-industry or cross-industry cooperation in order to correctly assess future shared capacities for all market players.

Beyond the foreseeable requirements of future automotive supply chains, such as:

- **production close to end-markets,**
- **Global Value Chain (GVC) governance regarding rising product complexity, which demands effective adaptability/flexibility concepts,**
- **new forms of GVC collaboration with work shifting to the supply base and a small number of hugely powerful large companies,**

new mechanisms of collaboration need to be developed and implemented that are able to cope with “Joker Events”.

During the past decade numerous “Joker Events” hit the societies globally, and left their deep impact on the economies and industries due to their inter-relation of networked economies:

- **9/11 (2001),**
- **Tsunami in the Indian Ocean (2004),**
- **Hurricane Katrina (2005),**
- **Economic downturn in consequence of the banking crisis (2008),**
- **China steps-up efforts to influence the global commodity market (2009),**
- **Ash cloud of the Icelandic volcano Eyjafjallajökull (2010),**
- **Blow-out of the oil platform Deepwater Horizon (2010),**
- **Uproar in the Middle East (2011),**
- **Fukushima (2011)**

It is undisputed that number of events over longer time periods doesn't increase. However it is the severity of impact of these disasters (events related to climate change are currently still controversial among experts) that demands a radically new approach: in globally networked economies and densely populates areas consecutive disasters affect the technical infrastructure, the crisis management and lastly the industrial structures and effectiveness. Future global business processes have to incorporate that mega-events are increasingly becoming an evolutionary principle.

Future global business processes have to incorporate that mega-events are increasingly becoming an evolutionary principle.

Current commodity markets continue to be influenced by contemporary problems: metal sheets for instance are made of iron which in turn is still overly exposed to market volatility, speculation and deficits in global recycling strategies: an unexpected upbeat of manufacturing data from emerging and developing economies alike may fuel a bounce in industrial metals price and helps commodities rally to new peaks. European governments establish national commodity strategies – some in isolation - others support the **“Raw Materials Initiative – Meeting our Critical Needs for Growth and Jobs in Europe”** of the European Commission. These activities are of cross-cutting nature and apply to all industries regardless their specific needs regarding future commodities and their dependency on rare materials for future developments, as shown in Fig. 9.

ERTRAC Research and Innovation Roadmaps

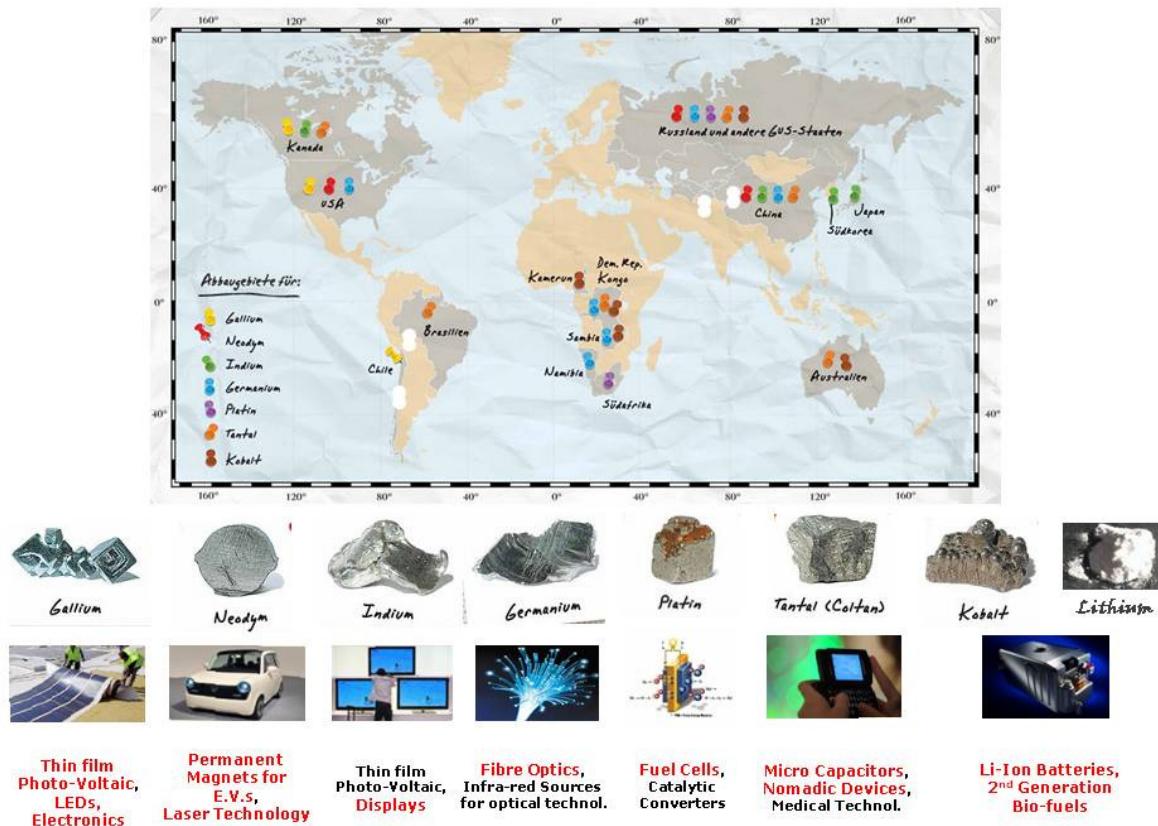


Figure 9: PHEVs & EVs Commodities and their Global Origin

Price volatility in raw materials affects the profitability and competitiveness of many European companies. It is highly unlikely that traditional approaches, including strategic sourcing and volume aggregation, can be relied upon to bring it under control. However an integrated approach to global commodity and rare materials management that utilizes multiple tactics needs to be developed that makes the difference. Commodity and rare materials strategies for the automotive industry on European scale, based on informed insight, will help organizations to manage price volatility and availability with a new level of effectiveness. A novel approach on the buying side and/or the selling side is required that renders European automotive enterprises substantial improvement. Applying integrated commodity and rare material management to procurement and sales can help provide the momentum to make volatility a key differentiator in global competition: positioning it to gain a competitive edge, satisfy crucial stakeholders and thrive in the global market place.

4.1.5 ***Global Education and Qualification***

Triggered by the electrification of road transport in combination with the effects of globalization the market for future powertrain components is expected to more than double by 2030 with an annual growth rate of ~ b€ 460 and creating 420.000 jobs world-wide. This global growth in electro-mobility creates economic growth in Europe, as well, with an expected increase of market volume by factor 2 up to b€ 170 and the need for 110.000 additional jobs for experts in chemical and electric/electronic engineering. In turn, this buoyant market volume causes extensive shifts in the value chain: OEMs and suppliers will have to cope with volatile portfolios of high uncertainty in consequence of spatial and temporal differences in market take-up. Therefore, the automotive industry needs to maintain all technology options ranging from the “Internal Combustion Engine”, via all variants of Hybrids to the “Fully Electric Vehicle” and concurrently develop an effective global “Materials & Commodity Management”, as well as building new “**MeChemTronic**” competence among its staff.

**PHEVs & EVs create growth and employment in Europe:
110.000 Jobs until 2020**

The technical progress towards electrification brings about an enormous challenge in the development of the respective competences in the global staffs of all members of the supply network: the competence profile of the automotive industry workers advances from pure mechanical skills to **mechanic, chemistry and electronic** expertise – the “**Me-Chem-Tronics**”. According to detailed screening of the component groups in the value chain, there is high expectation that the share of staff dealing with mechanical tasks is going to shrink from 80% today down to 60% by 2030. By 2030, the remaining 40% of personnel will be covered by electronic and chemical specialists. The prediction for Europe foresees the need for 110.000 new job opportunities in the disciplines of chemistry, plastic engineering, micro-electronics and software/ICT. This enormous can be achieved, only, in close and early collaboration of industry and education.

Tackling electro-mobility in global production concepts needs to remind that the trade-off between education, opportunity and global labour is at risk in a global knowledge-driven economy, as the opportunity to exploit the talents of all, at least in the developed world, is now a realistic goal. Enduring social inequalities in the competition for a livelihood and an intensification of ‘positional’ conflict must be avoided, particularly when the global spread of work associates such developments and ‘opportunities’ are becoming harder to cash in. The opportunity-cost is increasing because the pay-off depends on getting ahead in the competition for tough-entry jobs.

4.2 Criteria

There are many determinants driving productivity and competitiveness. Understanding the factors behind this process has occupied the minds of economists, ranging from Adam Smith's focus on specialization and the division of labour to neo-classical economists' emphasis on investment in physical capital and infrastructure, and, more recently to interest in other mechanisms such as education and training, technological progress, macro-economic stability, good governance, firm sophistication, and market efficiency, among others. While all of these ideas are likely to be important, they are not mutually exclusive – two or more of them can be true at the same time.

With respect to the objectives of the current roadmap for the “**European Technology and Production Concept for Electric Vehicles**”, it is obvious that the issues of relevance need to be focused on a:

- substantial technology related core – defining the ***basic requirements***,
- commercial and strategic framework – outlining the ***efficiency enhancers***,
- workforce inclusion – inter-relating ***innovation*** with societal aspects (see Fig. 10).

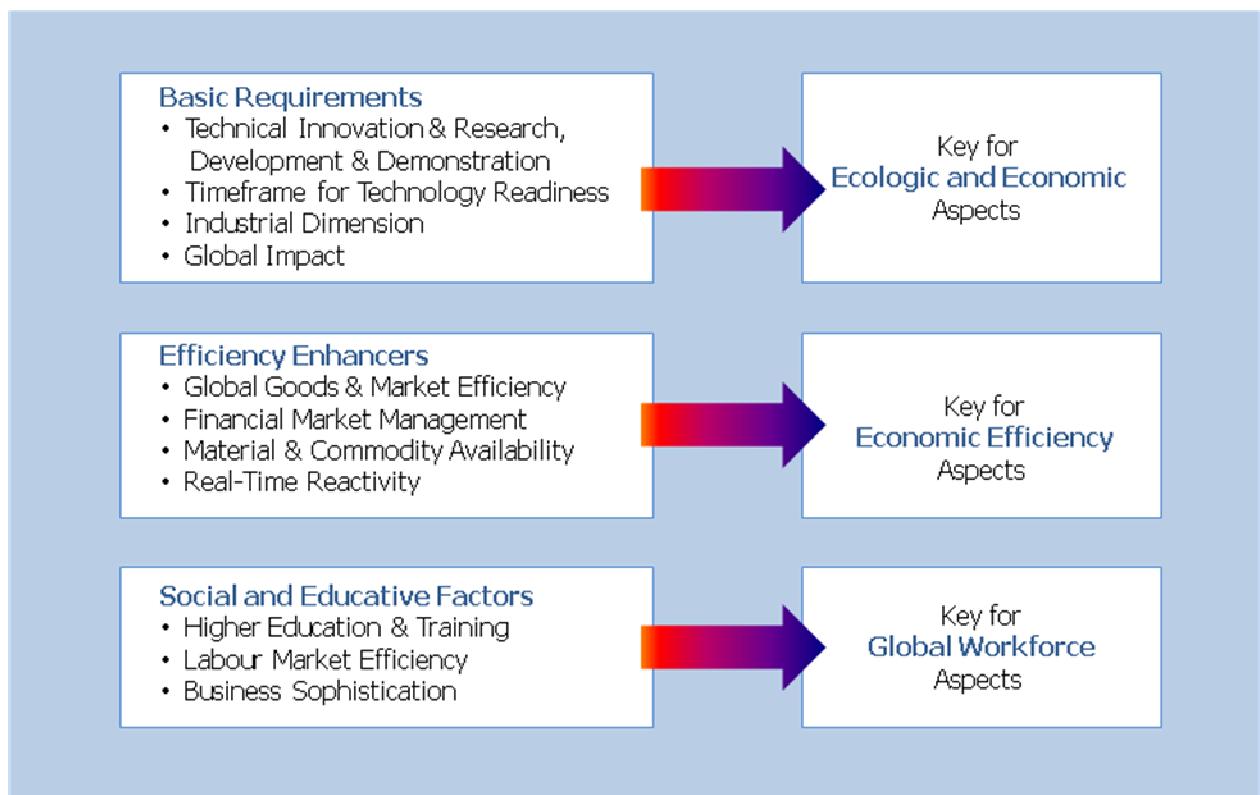


Figure 10: Requirement, Efficiency and Innovation Driven Key Factors

All items proposed to be included into the 5 RTD avenues of ETPC-4-EVs roadmap were submitted to a set of **Selection Criteria** according to the matrix above.

In more detail these criteria include as basic requirements:

- the **technical and scientific ambition**, e.g. no issues that are already addressed elsewhere or that are incremental improvement rather than fully fledged development or that are lacking a demonstration and roll-out scheme
- the **time horizon for implementation**, e.g. 2020 (near-term), 2025 (mid-term), 2030 (long-term); as a rule of thumb: project preparation: 1 year; project proposal development, submission, evaluation, negotiation: 1 year; project duration: 3 – 4 years
- the **industrial dimension**, e.g. sufficient combination of technical aspects and economic/business prospects, as well as inter-industry partnership (e.g. full supply chain plus research/business partners)
- the **global perspective**; e.g. specific automotive industry aspects need to be included in global context.

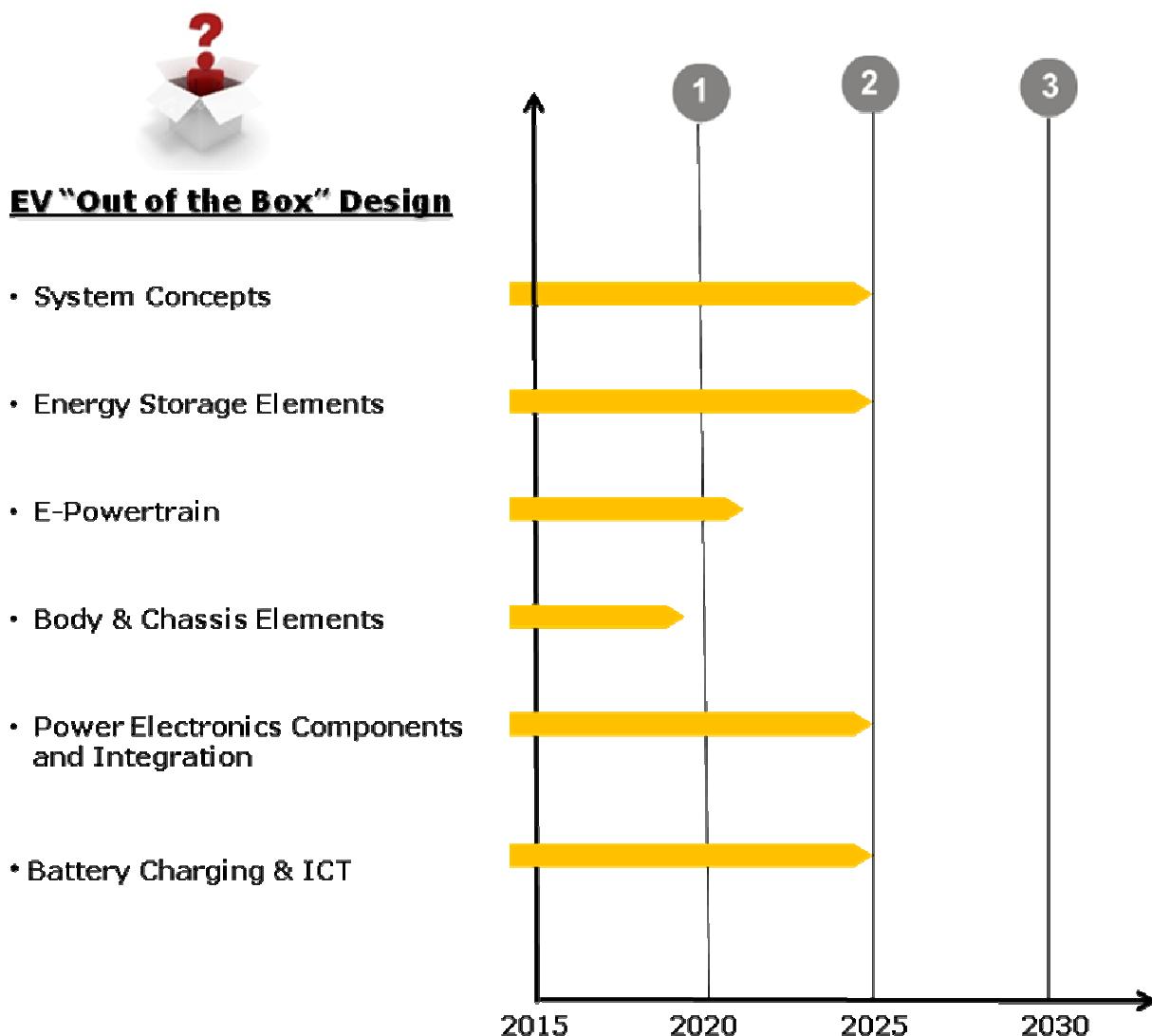
In parallel, similar criteria were defined for the efficiency enhancers, as well as for the social and educative factors. This process has not been exhaustive and will be continued repeatedly in order to refine the content of the roadmap and update it as appropriate.

5. Roadmaps

With regard to the EU Commission's fresh approach to industrial policy and the respective new orientation of the next Framework Program, all items identified for future research, development and demonstration, which will increase the competitiveness of the European automotive industry, are assigned to the following areas:



5.1: The Incubator*

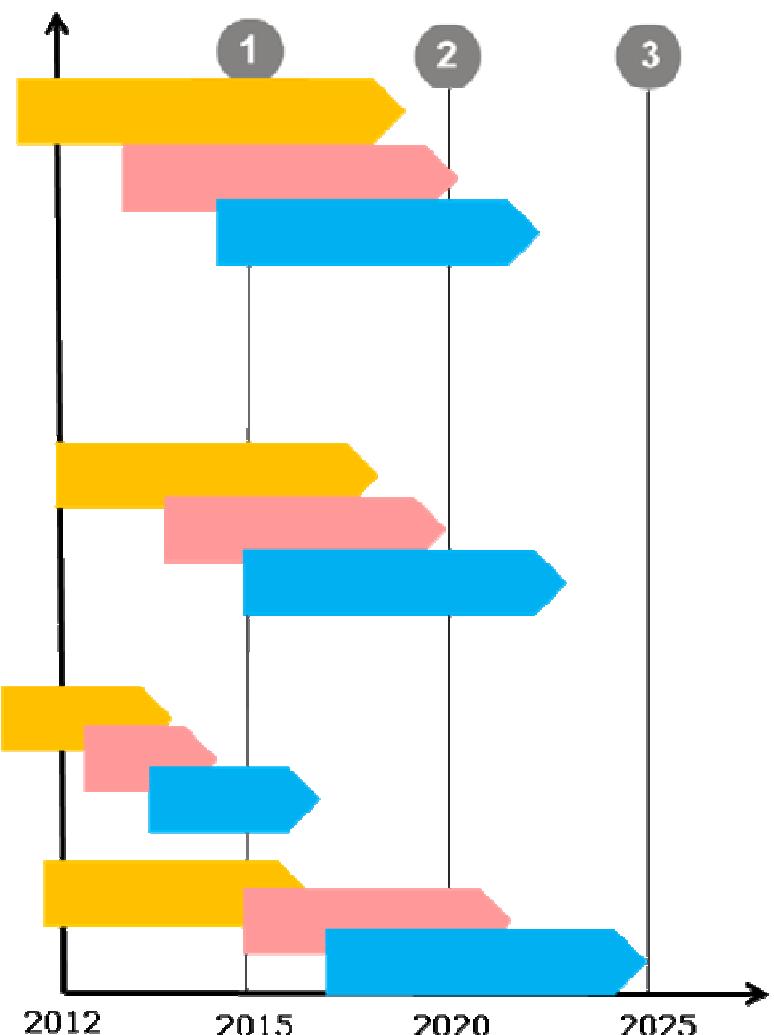


* Since it is the purpose of the “Out of the Box Design for Electric Vehicles in their environment” to collect ideas about the future vehicle technology needs and to stimulate novel ideas, no development, demonstration let alone market introduction will be supported.

5.2: Global Automotive PHEV & EV Production



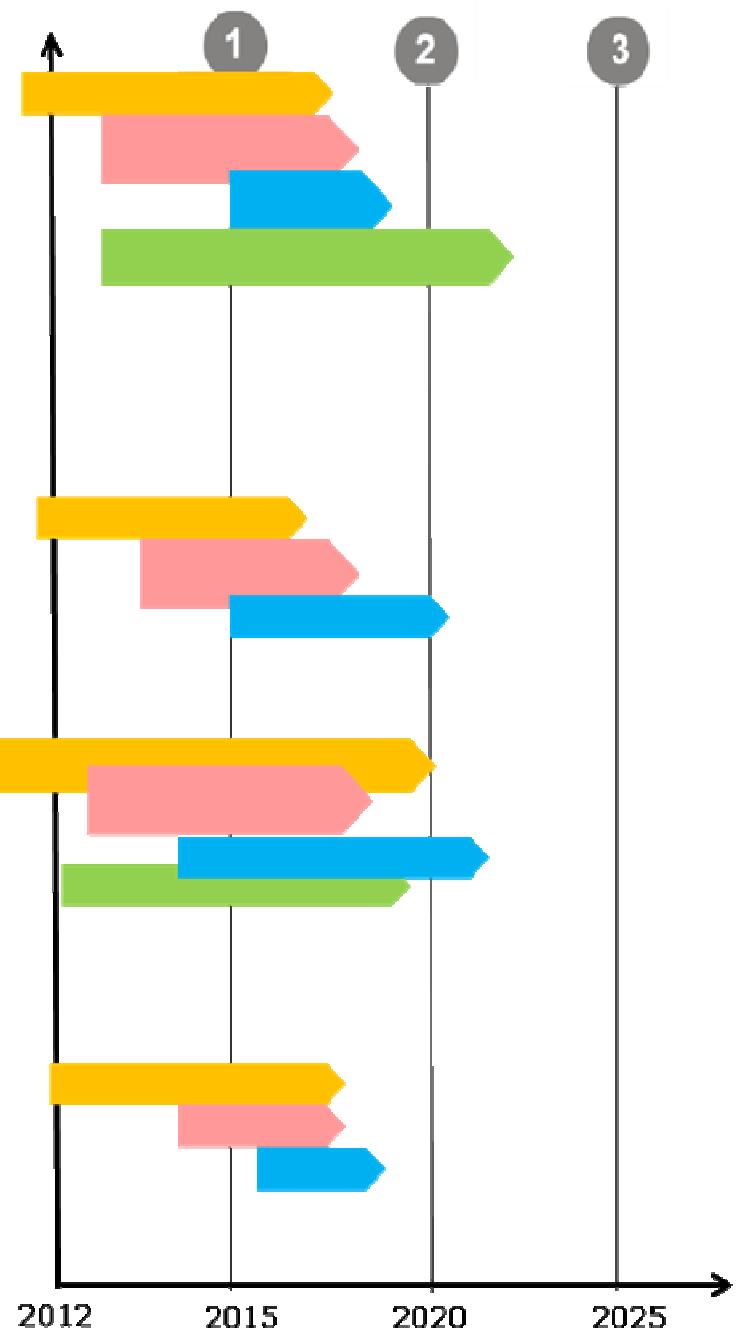
- **The EV Factory"**
 - variability, modularization & flexibility in EV production for HVs, PHEVs and EVs
 - handling of high-voltage components in production, assembly & repair
 - production forecast system for EV-components
 - novel joining concepts in EV production
 - new high volume production concepts for high quality F-Motors and batteries
 - affordability in EV manufacturing (batteries, power electronics, quality control)
 - step-change in variants; "brand+system=EV2.0"
 - collaborative planning & responsiveness
 - global ICT production concepts
- **The Just-in-Place EV Factory"**
 - rapid factory adaptation & novel global location in decentralized EV sites
 - global micro-factory management
 - real-time shop-floor control systems & product planning in global EV component production
 - sequencing on plant, grid & industry level
- **Industrial Interdependence**
 - synchronizing the highly volatile EV sector and the longer term driver semi conductor industry
 - cross industry resource planning and control
- **Eco-Modelling & Impact Assessment**
 - Emission & energy aware production of EVs
 - sustainability driven EV production & decision support system
 - global CO₂ production footprint in EV manufacturing
 - assessment tools for designing CO₂ neutral EV production plants



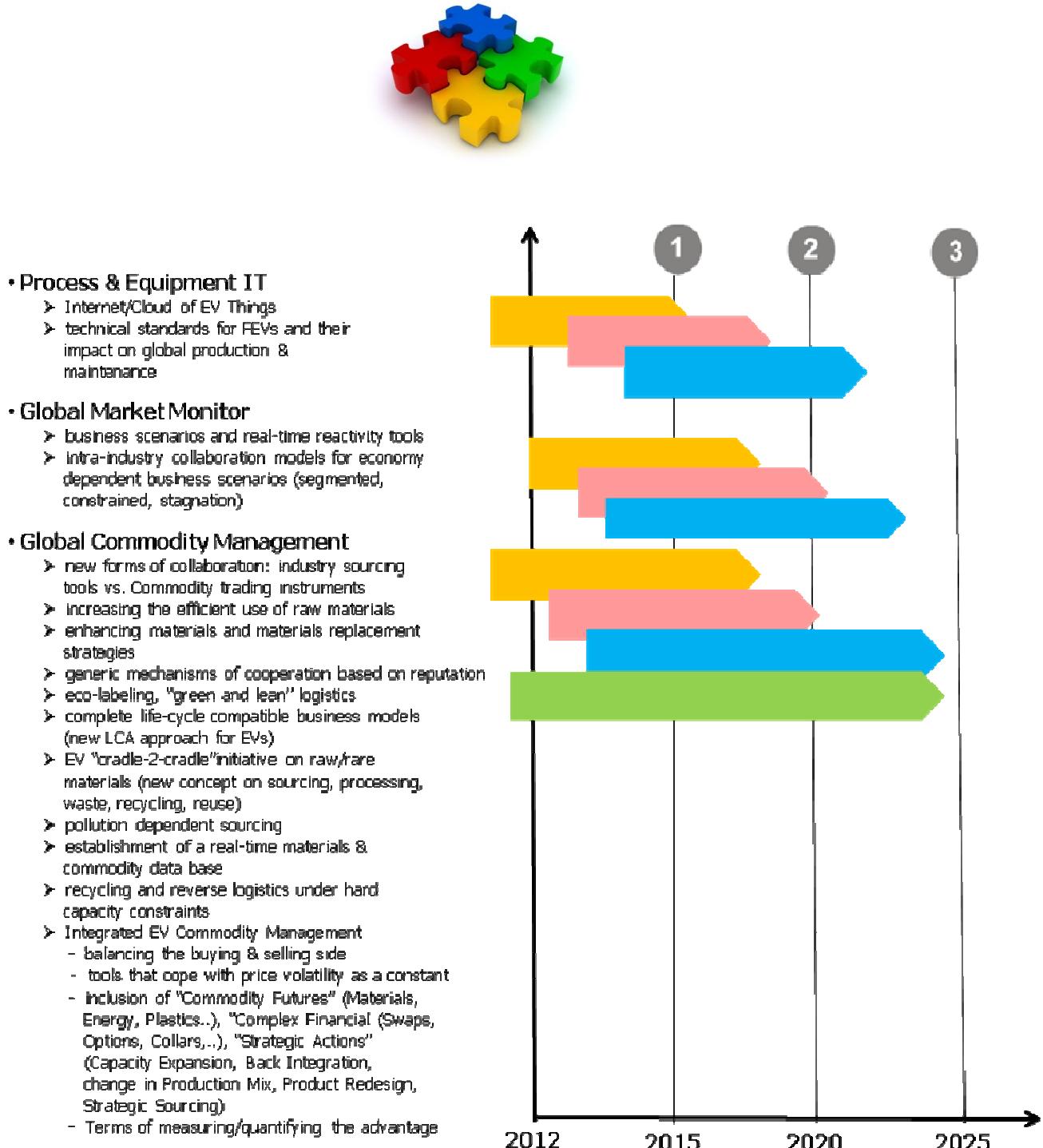
5.3: Global Supply Chain Management & Logistics for EVs



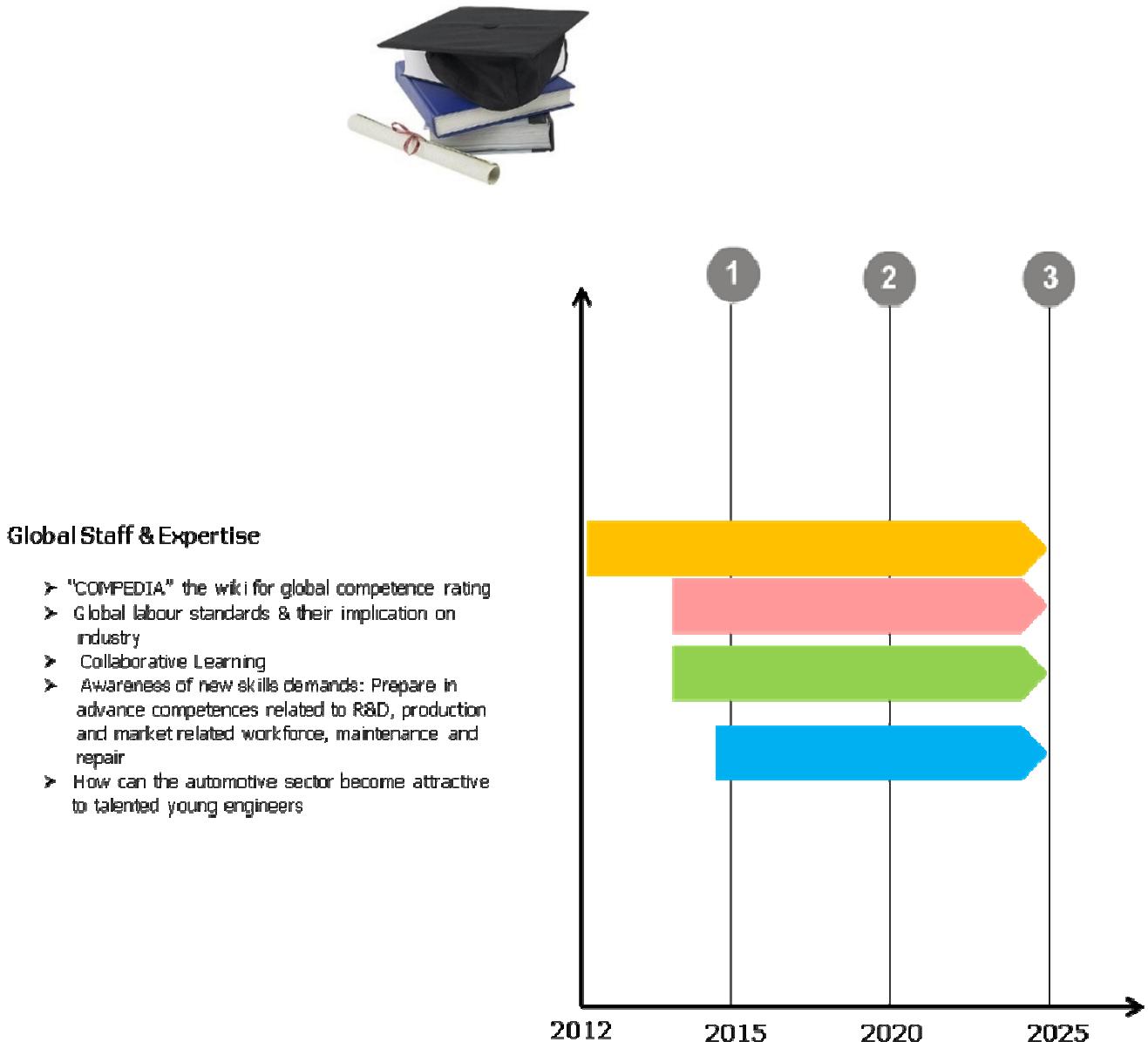
- **"Connecting Decentralized global Production Grids"**
 - global responsiveness by decentralized/downsized sites
 - automated SC & planning transparency
 - Trust/Security & Partners awareness
 - Real-time (RT) demand planning & RT Supply Chain adaptation
 - Business processes & communication security
 - the global FEV battery/chassis/powertrain Supply Chain
 - Ontology mapping/merging
 - Business models facilitation cooperation
- **Systems Network beyond nodes**
 - Supply Chain Re-design (e.g. micro production sites)
 - Adaptive logistics for flexible plant in global parts production
 - new ways of FEV-SC cost-benefit sharing
 - Self-organization
 - Production as service type models
- **Global Dynamic Supply Loops**
 - Advanced IT Systems for global application
 - open exchange interfaces to incorporate SMEs
 - intra-network capacity communication
 - "Optimized Transport Flow" under various biz conditions
 - Global Forecast Inclusion for FEV supply
 - Competence management to balance local & global suppliers to FEV production
 - Material & Commodity Supply Chain
 - Overall connectedness and computing, tracking and tracing
 - Advanced, robust local planning
- **Energy/Emission optimized global logistics approach**
 - Tools to determine the specific CO2 Footprint for FEV logistics
 - FEV supply network simulation instruments
 - green logistics 4 FEVs
 - 2030 Packaging



5.4: Global Business Processes

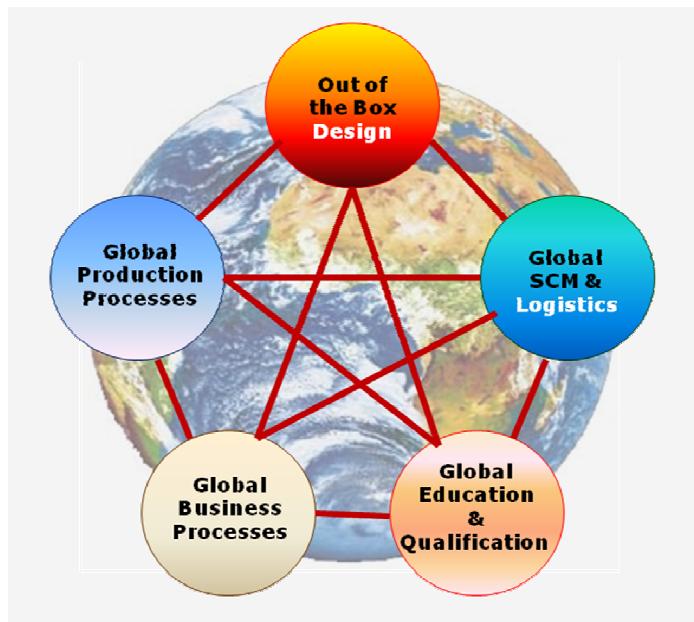


5.5: Global Education & Qualification



5.6: Milestones

It is important to register that none of the 5 major domains is of self-standing character and all are inter-related with the “Out-of-the-Box Design” making an intelligent guess on all future technologies of relevance and the respective production, SCM and business process domains, as well as the social part, following suit.



	Milestones 2020	Milestones 2025	Milestones 2030
Out of the Box Design	Updated short list of EV concepts and related technologies	Global component tool kit	
Global PHEV & EV Production	Global production concepts for 2 nd Gen EVs operational	Roll-out of global production concepts for 3 rd Gen EVs	
Global SCM & Logistics for EVs	Demonstration of advanced collaboration schemes on global scale; Implementation of tools to assess the CO ₂ Footprint	Implementation of concentric global collaboration, planning and real-time event management	
Global Business Processes	New IT processes implemented; Harmonization of engineering and Business IT accomplished; 1 st Tools for PHEV/EV Commodity Management in service	Implementation of real-time materials data base; Next Generation Commodity Management instruments tested and implemented	
Global Staff & Expertise	MeChemTronic Engineers education & Training implemented, Global Competence & Social Standard Wiki adopted	Establishment of novel educational degrees	

6. Recommendations

Tackling the affordability is crucial for advancing from niche products of PHEVs and particularly EVs towards a sufficient market penetration of electric vehicles. Since the affordability is directly related with reaching the respective economies of scale and high volume production a roadmap on the Technology and Production Concept for Electric Vehicles is of high value for the European automotive industry partnership. Specific features of the automobile sector regarding the products, the customers, the industrial network and the challenge of the novel technologies justify a separate approach to secure and enhance the global competitiveness within the framework of ERTRAC and its related Green Cars Initiative. The roadmap on the ***“European Technology and Production Concept for Electric Vehicles”*** will collaborate closely with all other ERTRAC roadmaps and is also ready to cooperate, as appropriate, with other related Technology Platforms and their PPPs, e.g. the “European Factory of the Future Association” (EFFRA).

ERTRAC's Global Competitiveness Working Group (GC-WG) has addressed its needs for RD&D in various submissions against the ERTRAC Steering Committee. The principles that the industry recommends are:

1. That competitive performance in global markets should be the primary reason for investing in RD&D – especially for the European industry that needs to secure market shares in other parts of the world.
2. That Community funding should also recognize the dimensions of the industry and the ways it takes part in the global market, directly with prime products and indirectly through the supply of systems and components for hybrid and fully electric vehicles.
3. Funding should be applied to programs that as near to market as the conventions of international trade and the collaborative ability of European firms permit.
4. That funds should only be applied to submissions of high quality which hold out the prospect of tangible gains from the work. The industry strongly confirms its own commitment to the criteria of technical excellence and high quality in any submission intended to attract Community funding.
5. That a pilot RD&D initiative is launched within the current Framework Programme in order to allow achieving the objectives of affordable PHEVs and EVs already during the market ramp-up phase securing the profitability of European companies in global competition.

7. References

- 1 Schumpeter 1942; Solow 1956; and Swan 1956
- 2 Technology Roadmap, Electric and plug-in hybrid electric vehicles, IAE, 2009
- 3 European Roadmap, Electrification of Road Transport, ERTRAC, EPOS, SMARTGRIDS, 2009
- 4 European Factories of the Future PPP, Strategic Multi-annual Roadmap, Brussels, 2010
- 5 United Nations Development Program, Human Development Report Office, Oxford 2004
- 6 A portfolio of power-trains for Europe: a fact-based analysis, McKinsey & Company 2010
- 7 La Civilization du Risque, Patrick Lagadec (1981)
- 8 The Raw Materials Initiative – Meeting our Critical Needs for Growth and Jobs in Europe; Commission Staff Working Document, Brussels SEC (2008), 2008
- 9 Commodity Management: Profiting from Volatility Deloitte, 2006
- 10 The Global Competitiveness Report 2009 – 2010, World Economic Forum, 2010
- 11 Supply Chain Decarbonization, World Economic Forum, 2009
- 12 brand eins – Die Problemlöser: Schwerpunkt Logistik; Heft 03, März 2010
- 13 Human Development Report 2009; United Nations Development Programme 2009
- 14 Zukunft der Mobilität; Szenarien für das Jahr 2030; ifmo, 2010
- 15 EU Sectoral Competitiveness Indicators; European Commission, DG ENTR, 2005
- 16 Elektroautos schaffen Jobs Wachstum und Jobs in Europa; McKinsey&Company, 2011
- 17 Communication from the Commission to the EU Parliament, the EU Council, the EU Social Committee and the Committee of the Regions: An integrated industrial policy for the globalization era putting competitiveness and sustainability at centre stage Brussels, COM (2010) 614
- 18 Global Manufacturing Competitiveness Index, Deloitte Touche Tomatsu, June 2010
- 19 Paving the way for electric vehicles: a trajectory for a 50% cost reduction by 2020, PRTM Management Consultants, Brussels 2010

- 20 The Raw Materials Initiative – Meeting our critical needs for growth and jobs in Europe, Commission Staff Working Document, Brussels, 2008
- 21 European Industry in a changing world – updated sectoral overview 2009, Brussels SEC (1111 final)
- 22 Roadmap to a Single Transport Area - Towards a competitive and resource efficient transport system; White Paper 2011, Brussels COM(2011) 144
- 23 White Paper: European transport policy for 2010: time to decide; Brussels, DG MOVE (2011)

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 involved European Technology Platforms, e.g. for ERTRAC at www.ertrac.org.

Rapporteur:

Gloria Pellischek
Global Competitiveness Working Group
on behalf of ContinentalAutomotive
Tel.: +49 8192 7538
g.pellischek@erpc-gmbh.com