EVS26
Los Angeles, California, May 6-9, 2012

Integrated Architectures for Third Generation Electric Vehicles – Innovative Concepts to Meet Customer Requirements

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Abstract

The joint European research project ELVA brings in line technology options and customer expectations for third generation electric vehicles. The objective is to develop innovative vehicle architectures fully exploiting freedoms in design that result from the electric drivetrain. This paper summarises the results of the first phase of the project which comprised deep technology and market forecasting as well as an open design contest for future electric vehicles. In the end, an outlook is given for the next phase in which three detailed vehicle concepts will be virtually developed and assessed with regard to several key requirements such as energy efficiency, material application and safety.

Keywords: battery, electric drive, EMC, EU, EV, materials, mobility, powertrain, range, regenerative braking, safety

1 Introduction

In order to fully exploit new freedom in design and to achieve a significant increase of energy efficiency, the third generation of electric vehicles (EVs) requires dedicated architectures. The consortium of the joint European research project ELVA – Advanced Electric Vehicle Architectures is developing until mid-2013 three detailed vehicle concepts which are intended to not only meet all technical requirements, but especially take customer preferences directly into account.

Aiming at series adoption in 2020, a comprehensive forecast of technology options and market requirements is carried out. This includes particularly the in-depth analysis of customer requirements which are investigated based on studies and OEM-internal information, but also on a large-scale public customer survey. In the second phase, these requirements are brought in line with technology options by innovative architectures focussing on urban EVs. To complement the expertise within the consortium a public design contest is organised, allowing designers to present their ideas for future urban mobility. Based on an assessment of all ideas and options, three dedicated vehicle concepts will be developed in detail, enabling optimisation and assessment of all relevant vehicle features (Figure 1).

The first phase of the project offers a wide overview of technology options and customer expectations for 2020 and beyond. Innovative concept ideas and designs will be developed on this basis applying a process for accelerated architecture development. This represents a valuable contribution to the challenges the automotive industry is facing during the development of future electric vehicle generations.

The forecasting of technology options (e.g. batteries and electric motors) as well as customer expectations remains a challenge. On the technology side, substantial improvements especially regarding battery capacity, size and weight are expected. Customer requirements however are very much linked to the use-cases current conventional cars are offering, especially when it comes to the desired range. This has a clear impact on future electric vehicles, but cannot be fully predicted yet.

ELVA is the first European project which is dedicated to specific vehicle architectures for urban EVs. Especially the incorporation of customer requirements based on a pan-European survey and the public design competition must be emphasized in this context. The detailed concepts developed in phase 2 are lead by the involved OEMs and are thus most likely to have a direct influence on future EV architectures with a market introduction from 2020 and beyond.

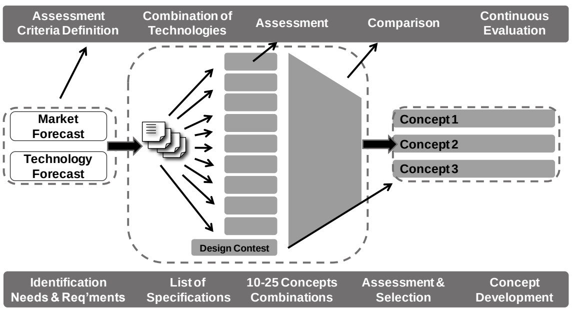

Figure 1: ELVA approach

2 Driving Forces and Societal Scenarios

In order to understand the most important driving forces for future vehicle design about 40 reports have been studied dealing among others with future societal scenarios. Most of these reports are predictions and extrapolations for 2020-2025, based on today's society and technology, while a few reports are descriptions of scenarios for 2030-2050. The main purpose of this analysis was to summarise and structure the material and identify, analyse and define the main driving forces as well as describe basic interactions and some of the relations between these driving forces.

The reports studied are very consistent regarding the driving forces: population and economic growth, demographical changes, urbanisation and the development of mega cities. According to the UN [1], between now and 2025, the world population will increase by 20 % to reach 8 billion inhabitants (6.5 billion today). 97 % of this growth will occur in the developing countries (Asia and Africa), and it is expected that the quantity of goods needed to serve the world's rapidly growing global population will increase over the next 20 years. The increased demand of energy and other resources will follow, especially in China. Almost all reports studied estimate that the energy demand and the CO_2 emissions will continue to increase by 2020. According to IEA [2] in 2025 the world energy demand will have increased by 50 % compared to 2005 and it is estimated that from now to 2030 coal consumption, in particular for power stations in China and India, will increase by more than 50 %.

Several reports emphasise a common concern regarding climate change, congestions, limited resources, and safety and security. In 2009 the EU and G8 leaders agreed that CO_2 emissions must be cut by 80 % by 2050, if atmospheric CO_2 is to stabilise at 450 PPM – and global warming stay below the safe level 2 °C. But 80 % decarbonisation overall by 2050 may (according to McKinsey) require 95 % decarbonisation of the road transport sector [1]. Achieving the 80 % reduction means a transition to a new energy system both in the way energy is used and in the way it is produced. The scenario report [3] concludes that it is possible to fulfil the 80 % reduction by 2050 and provides a roadmap (scenario) for this. For the transport sector, as well as for the power sector, this implies decarbonisation by 95 %, without negative effects on safety.

Important aspects of a sustainable transportation solution are energy efficiency, reduction of limited resources used, a fuel shift and a transition toward renewable energy resources (on a lifecycle basis). To achieve this, three important driving forces are necessary:

1. Technology development (vehicles, batteries, infrastructure and ICT)
2. Political incentives, disincentives and legislations
3. Customer and individuals behaviour, values and attitudes

Most reports argue that the market penetration of electrical vehicles is an important part of the solution, but it can be seen that the penetration of EVs on the market will still be quite modest by 2020. The world market of pure EVs is estimated

in 2020 to be about 5 % (and about 10 % in China) of new vehicles sold. An important technology driving force is the development of reliable, safe, light and affordable batteries. The battery prices are expected to be halved by 2020 [4]. There are several new business model initiatives to compensate for the high prices like Better Place. Information & Communication Technology (ICT) is in many reports regarded as a very important technology enabler, both regarding safety and efficiency e.g. logistic applications and sustainable management systems. ICT is also an enabler of efficient power regulation system and the energy payment system.
The development of the future EV market is expected to be highly dependent on political incentives and regulations that will have a strong impact on customer's choice for transportation solutions. Traditional criteria such as price, reliability and brand are expected to have much less impact in the decision process of the future consumer. Individual values, attitudes and lifestyle will also have a strong influence, not only on the product and services selected, but also on the companies and the business operation itself. According to many reports sustainability, eco-awareness and corporate social responsibility will matter more and more, and it is probably in the emergent areas that changes in demographics and consumer behaviours could have the most significant impact.
Large-scale implementation of road pricing, road tolls and congestion charges are foreseen as well as actions on progressively tightening emission standards, technology development programs and standards development for charging infrastructure. One thing is quite obvious: users and companies should be prepared to pay more for using transport in the future.
Most businesses today have long-term strategies in place which are based on the most likely, foreseeable future developments, but contingency planning based on different scenarios is gaining importance, especially in times where paradigm shifts are likely. Extreme scenarios can help broaden decision makers' awareness of future developments which are not very likely, but which could potentially have a fundamental impact on the industry or on specific companies. For instance, politicians in so-called smart cities might legislate that only zero emission vehicles are permitted to drive in central cities (eco-cities). This would probably have a huge impact on the EV market. Therefore it is not only the scenarios themselves that are important, but also learning about the societal and technology driving forces, and how they relate to each other and by that be prepared for the *non-expected*.
One interesting finding in this study is the gap between the society predicted by 2020 and the explorative society and EU targets by 2050. There is a strong uncertainty in the coming years and the automotive industry will probably have to re-shape their complete business. The automotive inertial transition pace implies that transition activities have to start now in order to ensure a realistic pathway towards achieving the 80 % green house gas reduction by 2050. The four extreme scenarios defined in the SEVS project [5] might be good to use as a reference platform when discussing the timeframe and the actions to take. Although the actions taken, or rather not taken today (year 2011) will effect and shape the future society and the sustainable road transport solutions by 2050.

3 Technology Forecast

Future generations of electric vehicles are offering great opportunities, but are also facing significant challenges. For the development of next generation architectures for urban EVs, a deep understanding of technologies available at the anticipated start of production (SOP) and beyond is crucial.
In order to come to a comprehensive technology forecast for 2020 and beyond, numerous reports and studies have been analysed. They commonly describe the development of reliable, safe, light and affordable batteries being a crucial driving force for EVs. This is in line with common understanding among all experts that has evolved over the past years.
The following sub-chapters briefly describe the technology options as they have been identified. The related project deliverable [11] gives an even deeper insight in the findings.

3.1 Light Weight Design

Materials and design are key technologies in the automotive industry. Besides the advancement in steel body design (short and medium-term), construction methods with fibre- reinforced high performance plastics and multi material design will be able to play an important role in a long term [6].
For electric vehicles, due to the weight and volume of the batteries and the substitution of mechanical drive train the boundary conditions for lightweight architecture have completely

changed. The challenges in lightweight design for innovative vehicle concepts are amplified and the importance of lightweight design increases, due to the significant influence of the battery on the EV's range.
Furthermore the integration of the battery system enables new possibilities for lightweight design [7]. Depending on the number of pieces produced, as seen earlier, an approach consisting of integrating the battery system in a tube-intensive floor panel, combined with a frame load-bearing structure with non-stressed panels could be practicable.
Besides the mechanical properties the choice for light weight materials depends on expected production volume, markets (material availability), vehicle use, customers and performance-cost-balance, Figure 2.

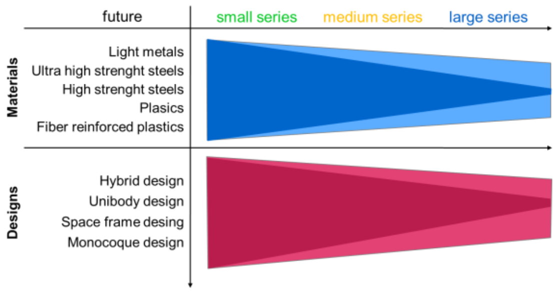

Figure 2: Material strategies depending on volume [6]

Keeping these factors in mind, material opportunities can be summarised as follows:

Body

- Advanced steel (load-carrying structure)
- Advanced aluminium (structure, panels)
- Fibre reinforced plastics (structure, panels)
- Advanced plastic (e.g. batt. cover, glazing)
- Hybrid-structures (functional integration)
  - Aluminium with steel
  - Aluminium with FRP
  - Steel with FRP
- Multi-material design

Chassis

- Advanced steel (levers, arms)
- Advanced aluminium (levers, arms)
- Fibre reinforced plastics (springs)
- Hybrid-structures (functional integration)
  - Aluminium with FRP
  - Steel with FRP

Interior

- Plastics
- Bio-plastics/bio-fibres
- Aluminium, FRP (e.g. seat structures)
- Hybrid-structures (functional integration)
  - Aluminium with FRP
  - Steel with FRP

It must be mentioned that the joining technology of the various parts still is a big challenge which requires significant research efforts, in particular, in the field of joining dissimilar materials.

3.2 EMC

Electromagnetic Compatibility (EMC) and exposure to electromagnetic fields (EMF) are two technology areas that will have increasing importance in the automotive industry. EMC will be affected by several trends: increased number of electronic units, high voltage switching and non-metallic materials in the structure of the vehicle. EMC is a property in a vehicle that normally is unnoticed. The driver only recognises it when there is a problem. However, if there is a problem, it may be costly and time consuming to fix it. It is therefore of high importance to keep EMC in mind from the beginning in a development project.
Methods for virtual assessment can give good information about the general EMC and EMF quality of subsystems and vehicles, and especially at early stages before the systems have been built and to assess limited changes in existing designs, but the final verdict must still come from measurement [8].
There is still no consensus on the risks with long time exposure of electromagnetic fields. But even if the risk is low, there is still a public concern that needs to be addressed. Reducing the field levels for the occupants in the vehicles is hence important.

3.3 Electric Storage and Drive Train Technology

Future EVs will be different from today's cars in several ways. This requests an overall optimisation of efficiency and reliability of the drive train with regard to:

- Battery technology that must be affordable, lightweight and reliable
- Charging that has to be standardised and easy to handle
- Selected power train arrangement that has to be optimised and matched with the brake
- Intelligent thermal management that keeps the efficiency of the EV on a high level

These topics are responsible for a successful introduction of EVs in near future and they open up new opportunities and degrees of design freedom, which enable and require new vehicle concepts.
In a holistic approach the intelligent interaction between the domains power train, brake and navigation is absolutely necessary. Future EV concepts must respect such an approach and presume the availability of the technologies and their interaction.
With current vehicle body (not isolated) it is not sufficient to develop a heating system only based on a thermal management. Thermal comfort and efficiency can only be provided by an effective solution with a good thermal protection of vehicle, motor, components and passenger compartment.

3.4 Brake Technology

The brake system must be able to recuperate energy. By pure friction braking, normally a high amount of energy is dissipated into heat and cannot be used within the vehicle anymore. By an intelligent solution part of this energy can be recycled, using the electric motor(s) as generator(s). By these means, a longitudinal motion control for optimized energy consumption in an EV is feasible.
The brake force generation has to provide a management between friction and electrical regenerative braking, depending on the individual situation (like soft stop, emergency braking). Also a smooth transfer between friction and regenerative braking is to be guaranteed. This is achieved by optimal blending of electrical and mechanical brake torques. A big challenge is the perfect handling of the basic brake function by recuperating energy out of the movement (deceleration) of the fully electric vehicle and to use the friction brake only for “hard stops” or emergency situations. The switch from one (recuperation) to the other (friction) mode must be taken by the system itself, within shortest time and without error, e.g. without any negative impact on safety (stopping distance, vehicle stability) and driver’s perception or influence (no heavy pedal implications).
As an alternative to the central motor concept, a new cooperative motion control management of individual electric motors is achievable: this may be the case during anti-lock conditions, due to the possibility of wheel-selective distribution of torques by controlling individual electric hub motors (in-wheel motors).
Also torque vectoring including vehicle stability control can thus be influenced in a positive kind and manner.
Additionally, by the electrification of the brake system including the active control of electrical drive motors, solutions summarized by “brake-by-wire” systems may open further options towards active safety in terms of advanced driver assistant system, e.g. adaptive cruise control, stop & go/traffic jam assist, parking aid [9] .

3.5 Vehicle Safety

Considering recent research developments it can be expected that for 2020 for a number of important active safety systems formal assessment methods will become available. Due to this consumer testing programs [10] and also legal requirements are expected to adopt such assessment methods. The implication for ELVA is that for EV vehicles 2020+ active safety systems including (intervening) advanced driver assistance systems will be an important part of the requirements but further progress in passive safety will also be necessary. Both for active and passive safety systems the EV concepts should get the highest ratings in 2020 Euro NCAP type of standards.
Active safety systems expected for market penetration in 2020 and beyond, and thus to take on board in the ELVA concepts include:

- Autonomous braking for rear-end impacts based on pre-crash sensing. For other accident situations the technology is probably not mature enough yet.
- Automatic braking based on pre-crash sensing to avoid or to mitigate the severity of impacts with vulnerable road users (pedestrians and bicyclist).
- New ESC systems in case electric motors would drive wheels independently which offers new and advanced possibilities for vehicle control in case a crash would be expected.
- Driver monitoring system. Driver distraction and inattention is a growing problem in particular due to the increase of devices in the car that distract the driver. Various methods are under development or already have been introduced to monitor the fitness state of the driver and for a 2020+ EV such system should be part of the requirements.
- Lane keeping system. Such systems can be effective in particular on 2-lane roads with opposing traffic.

Passive safety protection requirements in an EV should include:

- A vehicle structure that retains survivable space for the occupant in various crash modes. Particular if the vehicle is small and light this becomes a challenge. This aspect relates directly to the compatibility with other vehicles in a crash.
- Adaptive restraint systems (seatbelts, airbags, head restraints). Based on pre-crash sensing information for the most important accident conditions the occupant should be offered an optimal protection.
- Vulnerable road user protection in case a crash cannot be avoided. Some systems to reduce the severity of the crash are already on the market based on pre-crash sensing. But further mitigation of the consequences of the crash is needed using passive safety measures (pedestrian friendly front).
- Fulfilling the highest requirements concerning battery safety.

4 Market Forecast

The market success of electric vehicles s is largely influenced by the acceptance of customers. However, the behaviour of customers in 2020 and beyond, i.e. the potential SOP of vehicles based on ELVA ideas is difficult to predict. This concerns all stakeholders and is of particular importance for the OEMs.

In order to define a future vehicle, it is hence essential to project the future vehicle market. Possible changes in customer behaviour and customer requirements need to be taken into account as well as environmental and societal changes (cf. chapter 2). Accordingly, numerous studies have been performed with the intention to generate a market forecast for electric vehicles. Besides the analysis of these studies within ELVA a dedicated customer survey is performed (cf. chapter 4.2).

4.1 Review of Studies

As a first step towards an appropriate conclusion for the targeted market about 20 selected publications regarding the future of mobility are analysed. The publications consider automotive mobility in particular as well as mobility in general. Current and future developments in environment, society and resources are the foundation for most of the predictions. Respondents to customer surveys are also taken into consideration.

The research identifies four major topics: current mega trends, mobility specific requirements, vehicle specific requirements and vehicle buying criteria. Mega trends in transport (Figure 2), as mentioned already in chapter 2, are presented in several publications [12],[13],[14]. Mobility and vehicle specific requirements are derived from these mega trends.

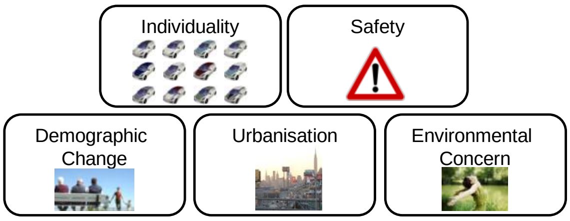

Figure 2: Five mega trends for transport

The mega trends are not EV specific, but rather are valid for the entire future of (personal) transport.

The same applies for customer patterns such as changes in mobility models [15] or the decreasing commitment of customers for a specific model or brand [14]. The influences of rising energy cost and the ageing society are discussed for several years already and have a likewise influence on all future vehicles [16].

More vehicle specific are maintaining expectations for high safety standards and reliability. An increase in connectivity seems to be obvious, what might include communication between cars or cars to infrastructure [17].

Several studies have investigated user expectations for EVs. In general, customers show an interest in purchasing EVs. However, the accepted extra that buyers are willing to pay is as low as 10 % for the majority [18].

Another major aspect is the significantly different process for recharging the batteries compared to conventional refuelling. Here, studies show a large difference depending on the type of user. Figure 3 sums up three different user types and their demand for public charging infrastructure.

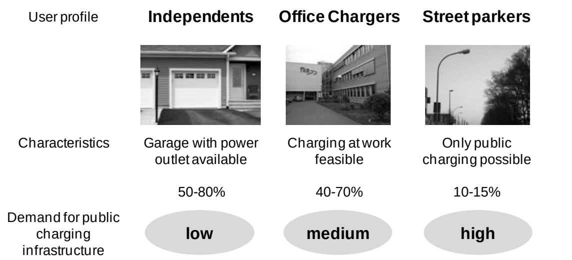

Figure 3: Public charging infrastructure demand [19]

The most widely discussed aspect of fully EVs is their autonomous driving range. Especially the difference between actual daily ranges (5-70 km) [20] and the expected offered range of the vehicle (>300 km) [21] differ widely. This has a large influence on the vehicle concept definition and the battery as the most expensive component.

4.2 Customer Survey

In parallel to the above described analysis of studies, a public customer survey is performed from April to June 2011. The goal is to receive direct input for the concept definition. Therefor, general questions about mobility are posed, but also very specific ones regarding acceptance of and requirements for electric vehicles.

The majority of answers is received via the project's website on which three different language versions of the questionnaire are available. Paper questionnaires are furthermore used in some European cities (Figure 4).

In total, about 1,100 persons answered the questionnaire. However the results cannot be regarded as representative as for instance about 88 % of the respondents are male, and 78 % hold a university degree. Nevertheless the replies of this selection of the population show that there is only little willingness for compromises e.g. in the autonomous range, the number of seats in the car or cost extra. This particular holds for the first car of the person/family.

Figure 4: ELVA customer survey

Uncompromised as well is the importance of a car for life (Figure 5). Personal mobility remains a major demand and offers potential for EVs e.g. in densely populated areas such as mega cities.

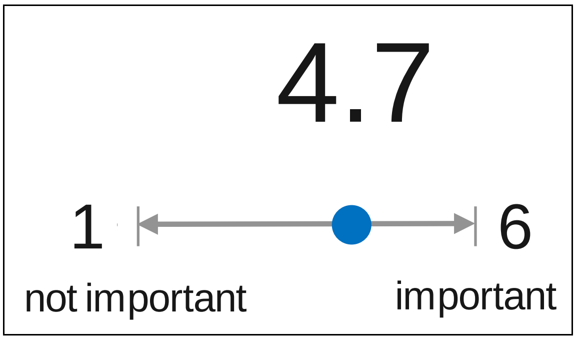

Figure 5: Importance of a car in life

When asking about expected changes with regard to mobility and transport, a slight majority expects new drive concepts to be introduced (Figure 6). It is however unclear if this expectation is a neutral customer expectation or already influenced by the promotion of such new concepts (like hybrid and fully electric vehicles) over the past years.

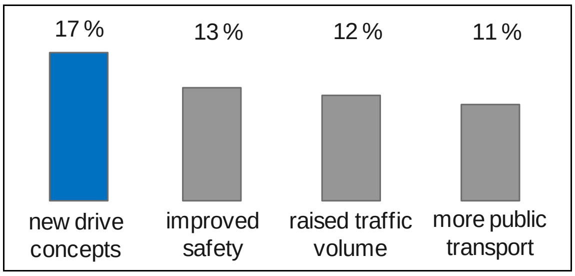

Figure 6: Expected change

The same holds true when asking about advantages and disadvantages of EVs. These questions are posed open, i.e. without suggesting specific replies. The replies are nevertheless very similar and represent the topics which are widely discussed also in the general public. Figure 7 and Figure 8 show the clouds of given answers to these questions.

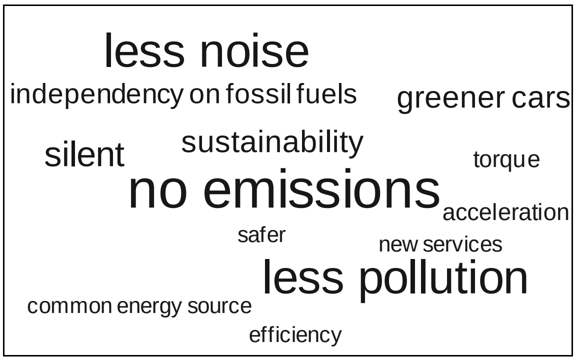

Figure 7: Expected advantages of electric vehicles

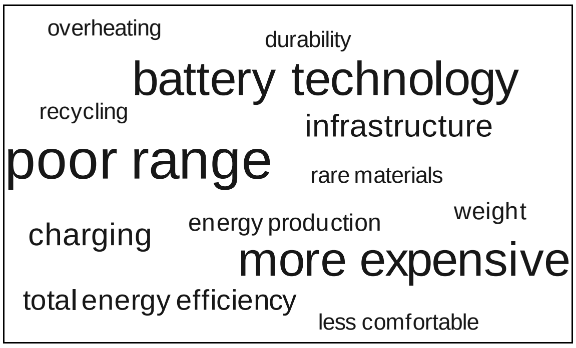

Figure 8: Expected disadvantages of electric vehicles

For the participants of the survey the average car size is a mid-size car, and is thus in line with the number of 4-5 seats that are expected (Figure 9). As stated in the previous chapter, this is a major deviation from actual car occupancy rates.

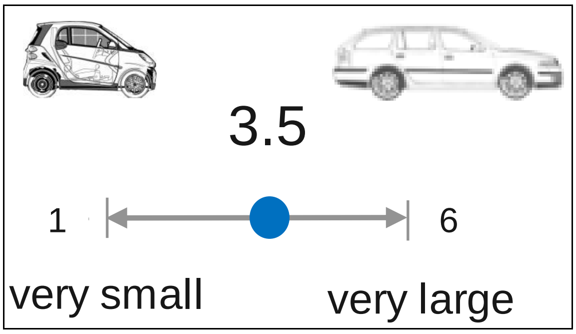

Figure 9: Vehicle size

Also the expected range of the main car of the person/family is with 400 km or more way above what current battery technology reasonably offers today and potentially in 2020 and beyond.
This is closely related to the question of recharging. Here, two different scenarios can be interpreted from the replies. About one third of the user group expects a charging time of not more than 30 minutes. Half of the users would also be accepting charging times of 2-5 hours (Figure 10). Currently presented concepts with quick charges (e.g. up to 80 % state of charge) and over-night charges seem to be addressing these expectations fairly well.

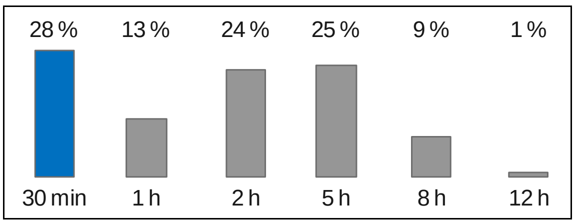

Figure 10: Acceptable recharge duration

With the current limitations given by battery, but also the electric drive train technology, it is of special interest what compromises the customer would accept. Figure 11 gives an example of trade-offs between range and some key features of the vehicle. There is limited willingness to compromise the autonomous range with safety, interior space or cost. For climate comfort and performance, certain compromises seem to be possible.
For cost, the replies to the ELVA customer survey support the outcome of the study research that was described in the previous chapter. More than 50 % of customers would be accepting no to maximum 10 % additional cost. The average value of accepted additional cost is 163 €.

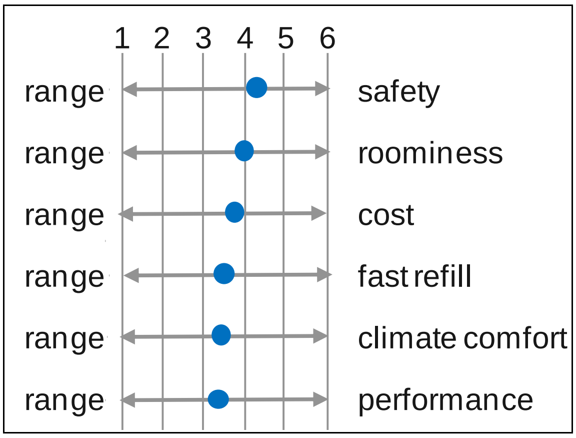

Figure 11: Trade-offs

4.3 Conclusions

In general, customers expect electric vehicles to provide the same values as conventional cars these days. This concerns the transport function as such including the autonomous range, number of seats and space for luggage. In addition it is expected that electric cars are more efficient, more quiet and easier to handle. Requirements such as safety and comfort cannot be compromised at all or only to a little extent. Study results, OEM-internal information and the ELVA customer survey all confirm these trends.
It is still very difficult to predict in how far aspects such as use cases, business case or intermodality in transport will be changing over time. Within the horizon of the ELVA project, these changes may be rather small, but are at the same time depending very much on external factors such as political decisions. One of the often cited examples is limitations for entering urban environments with vehicles that produce

local emissions (cf. e.g. congestion charge in London).
The autonomous range of the vehicle is the most influencing factor in terms of concept definition. It affects the size of the battery being the most expensive single component that needs to be integrated in the vehicle. The range which is expected by the customer and the actual daily range which is driven in reality differ widely. As a consequence, different concepts may be developed in the later stage of the project offering significantly different autonomous ranges.
As for all vehicles it can be stated that only when the requirements and expectations of the customer are met in most, if not all cases, the model can be a success. The sales price of the electric vehicle may be slightly higher compared to a conventional car. The EV must then however offer a clear benefit for the customer by reduced usage cost or other advantages such as inner city access. The most important buying criteria can be summed up to fuel-efficiency, eco-friendliness, safety, cost effectiveness and driving experience.

5 Design Contest

In addition to the above described aspects, successful vehicle models must also offer an attractive design. Especially full EVs of coming generations offer the possibility to combine an innovative architecture with an outstanding design that accommodates the freedom given by a different layout compared to conventional cars.
The ELVA partners have agreed from the beginning of the project that external parties should be invited to share their ideas about the future of EV design. Thus a public two-stage design contest was organised between June 2011 and January 2012. Design schools and institutes, but also freelance designers and other interested person were invited to hand in their ideas. In total, a prize of 10,000 euro is drawn for the most promising design ideas.
For the first of two phases, only few requirements for the designs were given. These were:

- Urban commuting as use case
- 4 wheels
- Space for 4-5 passengers incl. driver
- 75-125 litre volume for the battery system

An additional motivational movie and a design brief which were intended to transport the context and motivation for the designers are still available on the project's website [22]. There, also all stage 1 entries are at display. Out of these entries, a jury consisting of experts from the project partner organisations as well as external design experts selected six most promising ideas and invited them to participate in the second stage of the contest (Figures 12-17).

Figure 12: "Kabuki" by Enrico Gatto [23]

Figure 13: "Bugaboo" by László Fogarasi-Benkő [24]

Figure 14: "Elva" by Pete Clarke [25]

Figure 15: "MOD3" by Joost Roes [26]

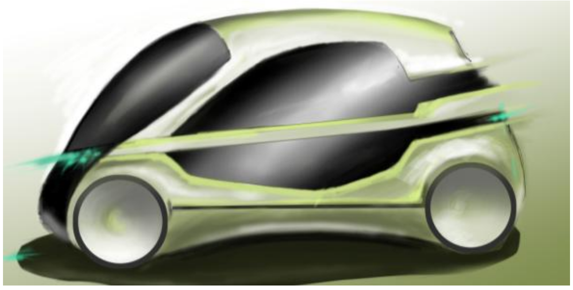

Figure 16: “Firefly” by Ádám Csicsmán

Figure 17: “worm-e” by Jorge Biosca [27]

In that second stage, much stricter requirements had to be incorporated by the designers. To two different designers per OEM, a rough technical package was handed over. The designers were required to incorporate this package in a more detailed design that had to be provided as a virtual 3D model.

At the end of the second phase, all six designs [22] were again evaluated by the jury, which selected three winning designs in the end (Figures 18-20). The leaders of the detailed concept development are willing to take the designs further in the project, i.e. use them as outer skin for the technical solutions that are to meet both customer requirements as well as technical options.

Figure 18: Winning design “worm-e”
by Jorge Biosca [27]

Figure 19: Runner-up “Kabuki”
by Enrico Gatto [23]

Figure 20: Runner-up “Bugaboo”
by László Fogarasi-Benkő [24]

6 Summary & Outlook

The development of new concepts for electric vehicles is one of the most challenging tasks for future transport. The European project ELVA is currently developing Advanced Electric Vehicle Architectures. The goal is to exploit new freedoms in design and to realize effective lightweight measures. A prerequisite for a target-oriented concept development is a comprehensive understanding of technology options at the anticipated SOP. A forecast for all relevant technologies was developed by the project partners and summed up in this paper.

Besides the full exploitation of technology options, a convincing design is crucial for the success of a vehicle model. Consequently, a design contest has been drawn by the project and is still under way at the publication of this paper. Designers are invited to share their ideas about future EV design and have the chance to see them incorporated in the ELVA concepts which will be developed from January 2012 and until the end of the project in May 2013.

Three different vehicle concepts intend to best meet customer requirements while at the same time fully exploiting the technology options. As it is still very difficult to describe customer requirements for 2020 and beyond, the concepts may be addressing different user needs. The development process will be accompanied by a continuous assessment of the concepts in all relevant functions as well as resource demand.

Acknowledgments

The ELVA project is coordinated by the Institute for Automotive Engineering (ika) of RWTH Aachen University. Furthermore, four of the largest European automobile manufacturers and suppliers, namely Fiat, Renault and Volkswagen as well as Continental participate in the project. The consortium is supplemented by the Swedish Vehicle and Traffic Safety Centre SAFER in addition to IDIADA Automotive Technology.

The research leading to these results receives funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement no. 265898.

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