EVS30 Symposium
Stuttgart, Germany, October 9 - 11, 2016

Approach to an Agile Development of a Sustainable, Customer-specific Mobility Concept

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Abstract

Electro mobility seems to be of key importance when focusing on sustainable mobility. But today's electric mobility concepts are not able to satisfy the sustainability aspects yet: on one side due to the mid-term unavailability of renewable energy sources and high energy effort during production and recycling processes, on the other side due to an unattractive and customer-unspecific design and missing mobility concepts which combine energy efficiency during production and use instead of integrating the electrification into conventional vehicle architectures.
In this contribution, an approach to an agile development of a sustainable, customer-specific mobility concept is presented.

Keywords: product development process, sustainability, customer-specific, electro mobility, hydrogen storage, mobility concept

1 Introduction

1.1 Problems and Objectives

Energy storage and growing greenhouse emissions are the biggest challenge of the 21st century. The holistic thinking about "energy circle of the future" is based on a closer look onto all energy and environment pollution fields.

Renewable energy is an unlimited primary energy source, like solar or wind power. The problem is, to store the surplus green energy, that are not consumed by customers. So, in times of rising availability of green electricity , new storage systems must develop to use renewable energy, because the source depends on environment influence, like sun or wind intensity. The amount of produced renewable energy is higher as consumed, too. In the future, the hydrogen storage system can be a solution to dissipate the energy as fuel used by mobility, like vehicle or to heat buildings. In addition, energy capacity of batteries are needed to store this are enourmusly high. Therefor the surplus renewable energy has to transformed to a secondary energy carriers, like hydrogen.

The second important aspect is to reduce the steadily increasing greenhouse emissions caused by the growing world population. In order to counteract this negative trend, the governments defined at the Kyoto UN climate summit the maximum allowed greenhouse emission (see Fig.1). Based on the state of the art combustion engine, the future goals can't be reached. A new methodical approach of future mobility is necessary to contribute to the energy revolution. [1], [2].

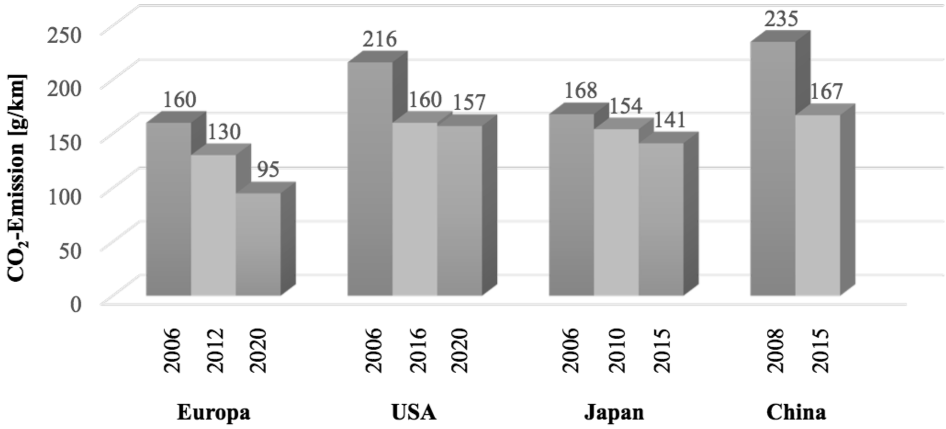

Figure 1: UN climate summit (Kyoto): Maximum allowed greenhouse emission [3]

The consideration of environmental aspects becomes more and more important during product development beside market requirements (development time and cost) and customer requirements (product quality and performance). A view onto energy storage systems shows that the acquisition costs for alternative powertrain vehicles are more expensive in comparison to conventional combustion architecture. By analyses and design of a complete sustainable energy circle - the combination of local and mobile energy systems - the future mobility vehicle can be an energy supply system or buffer tank for renewable energy systems. [4]

Today's vehicle powertrain architectures can be differentiated into 3 types: conventional, electrical and hybrid as a mixture of both aforementioned (see Fig.2). The challenge is to find the best solution for all powertrain types integrated in a platform strategy. The platform architecture provides the basis for further vehicle properties which define the main part of greenhouse gas emissions during driving. [5].

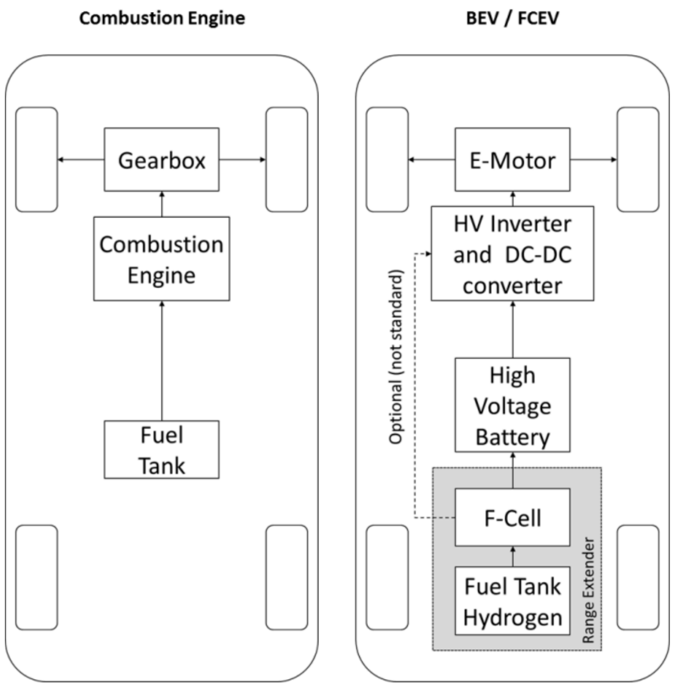

Figure 2: schematic representation of different vehicle architectures

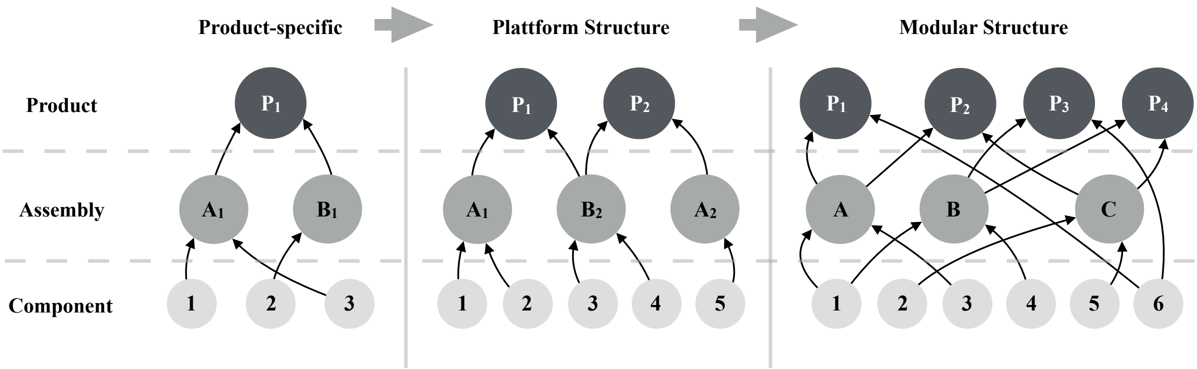

Figure 3: Schematic overview of product-specific, plattform and modular strucuture [6]

1.2 Motivation

Besides the consideration of the tank-to-wheel energy balance (the use phase) it is necessary to take the whole energy balance into account which means well-to-tank, wheel-to-end and cradle-to-cradle. [5]

As a consequence, "real" sustainability in mobility concepts only can be reached if the product life cycle energy balance will be considered and optimized in a holistic and systematic way. Additionally, the CO_2 consumption as a key factor of sustainability has to be considered. With an integrated product and production development [7] in combination with a systematic material generation and recycling strategy it is possible to predict the consumption of carbon dioxide quickly for the whole product life cycle. Thereby, various vehicle architectures have different influences on material, product and production.

Moreover, the use case scenarios for the mobility concepts have to be simulated during concept generation. Thus, it is useful to predict the influences of product weight, usable volume and load capacity on range, energy and CO_2 consumption. Especially the relation between weight as one of the key indicators for sustainability as well as efficiency and range is a vicious cycle. Furthermore, the cradle-to-cradle energy balance changes due to the enlarged energy storage system. As a result today, the tipping point for sustainability at which electric mobility concepts could overcome traditional mobility concepts is late in the use phase.

2 State of the Art

2.1 View of the Product Development Process of a vehicle

According to Pahl/Beitz [8] the product development can be defined into:

- new development,
- adjustment development
- development for building variants.

New development describes a product development started from the first scratch without any carry over or retention of existing components. An example for a new development is the Tesla Model S, because this car was the first product from Tesla. Adjusted design is a small modification of a product in order to satisfy the new boundary conditions, like new legal requirements. Parts and assemblies are varied within certain predefined limits in development for variants building in order to realize a high number of different products. The product structure is nearly the same, whereas some individual components are varied. A example is the simular derivate development of a cabriolet version of a vehicle. [8].

The product development process of a car from the first draft to start of production (SOP) is a complex process [9]. On the base of external boundary conditions, for example the government adopt a new law to limit the permissible greenhouse emission, requires an agile adjustment of the product properties. An other important point is the dynamic of currently and new market from OEMs. For the development of new markets partly niche vehicles are being developed [10].

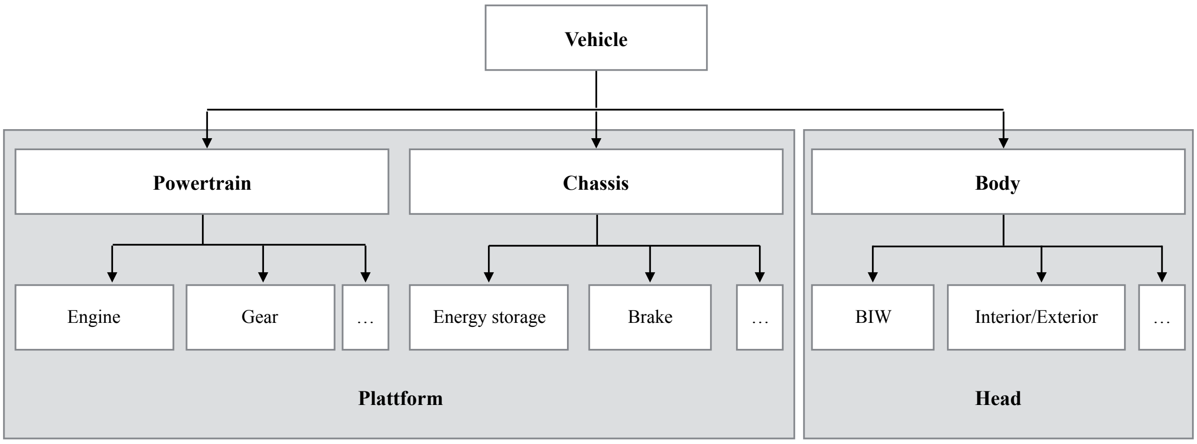

Figure 4: system view of the vehicle (assembly, part,...)

The variety of different vehicle models increases the complexity of the product and the development costs [11] [12]. The steady increasing customer requirements as well as the faster development and innovation cycles of future vehicle models is a major challenge for the automotive industry, too. A measure to reduce the complexity of the product in the automotive industry is the use of common parts [6]. Fig.3 shows that a part can be used for different types of cars. By expansion of the method to create platform or modular strucuture (Fig. 1.3), the cost and development period can be reduced [13].

In order to continue to exist in the established markets and to tap new sales markets, an agile, user-oriented and economic product development is required. Due to the increasing cost pressure and the application of new technologies, it is necassery to adapted the product development process (PEP).

The challenge is a systematic consideration of the influence of assemblies on the common parts characteristics and the derivation of the system properties. Fig.4 shows the modules of a vehicle (assembly, modul, parts,...). To evaluate the effect of a product modifications to the whole system properties, a system modell with the relations between the characteristics and proberties are enormously important.

2.2 Characteristics-Properties Modelling

The Characteristics-Properties Modelling (CPM) approach based on the strict distinction between characteristics and properties of a product as follows[14], [15]:

- Characteristics (Characteristics C_i) describe the structure, shape and quality of a product. and can directly modified.
- Properties (Properties P_j) describe the behavior of a product and can not be directly influenced by the developer. They can only be determined by the developer indirectly via the characteristics. Examples of properties include weight, safety, aesthetics, manufacturing and assembly reliability as well as the cost of a product.

In order to define the modelling approach of products, each property requires a relation which links them to the corresponding characteristics. In CPM, there exist two directions of the relations (Relations R_j, $R_j{}^{-1}$) between characteristics and properties, see Fig.5.

The analysis (R_j) based on already known an clearly determined characteristics or give a prognose for non existing product. The analysis can be done by estimates, experience, calculations, tables/diagrams, simulations or experiments. In the synthesis ($R_j{}^{-1}$), the characteristics of a product are defined. As the main target of synthesis at the product development is to find the best possible combination of characteristics.

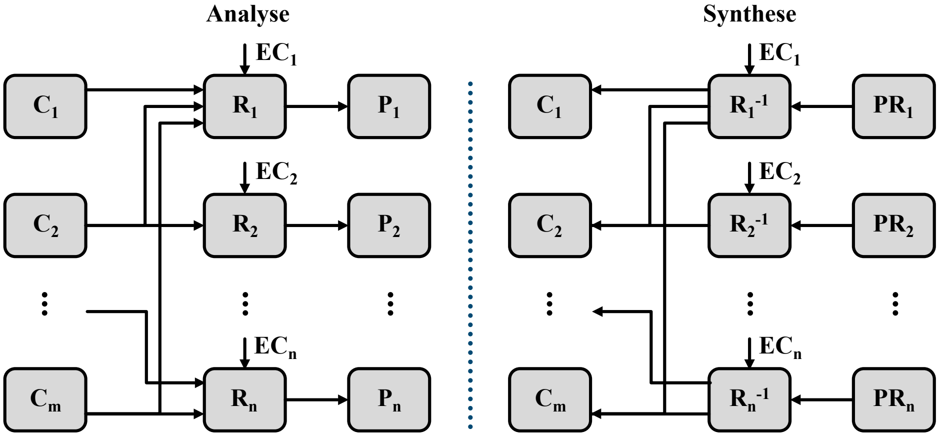

Figure 5: Analysis und Synthesis [16]

The CPM-approach will be discussed in details to the assembly ”powertrain” for the part ”energy storage”.

3 Approach to a Sustainable, Customer-specific Mobility Concept Development

3.1 Sustainable Mobility Concept

To overcome the barriers shown above, an approach to an agile development of a sustainable, customer specific mobility concept is presented. The framework consists of 5 basic elements, shown in Fig.6.

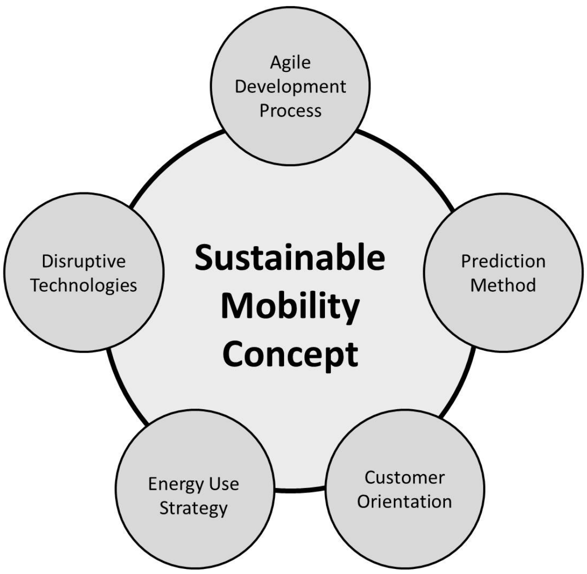

Figure 6: Framework

The conventional development process [8] shows a serial procedure of the development activities. Within the process optimization, loops are conducted after the first concept generation which results in macro iterations and thus, more development time and cost. Supported by a systemic, holistic prediction method for an early estimation of product behavior, performance and properties, it is possible to apply an efficient, simultaneous engineering procedure which leads to micro-iterations and thus, an agile handling of dynamic product changes. [16]

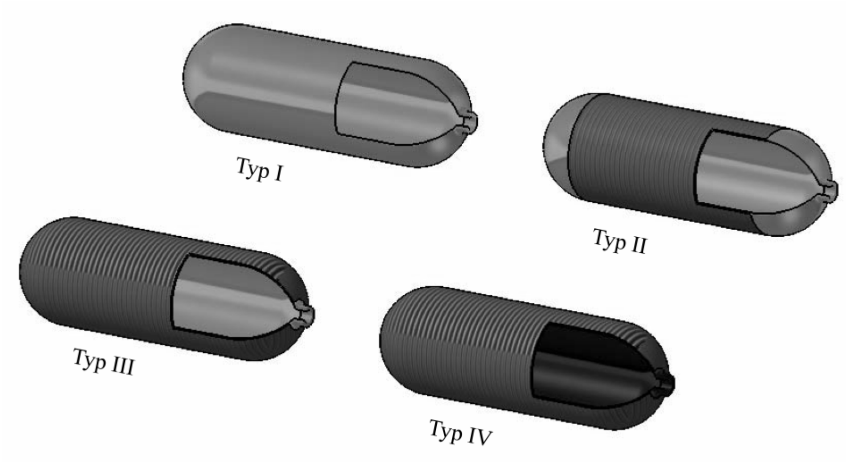

Figure 7: Classification of hydrogen storage systems [19]

The customer orientation (e.g. mobility behavior, customer needs regarding the mobility concept, ...) is transformed into measurable, technical requirements which can be used for the prediction method.

In general, the kind of powertrain of the mobility concept is one point of a sustainable energy concept, but even more important is the handling of energy storage in local and mobile applications, for example using energy storage systems of the vehicle, like fuel-cell systems, as energy delivery for home application. [17], [18]

For an efficient energy circle throughout the whole product life cycle (material generation, production, use, recycling) a combination of new, disruptive and existing technologies is required.

Only a holistic consideration of all the basic elements can lead to a sustainable, customer-oriented mobility concept.

3.2 CPM-Approach of Energy storage systems

The sustainable energy production and storage is a very important aspect for future mobility ceoncepts. The challenge is to integrate the new powertrain technologies in etablished plattform architectures. The dimensions of new energy storage system, like batteries stacks or high pressure tanks (hydrogen), are much higher compared to state of the art fuel tanks. So it is necessary to define new designed space without losing ccomfort for the customers or less range. The approach, based on CPM, will exemplary discussed for hydrogen storage systems.

Commercial high pressure storage systems have a vessel shape with a specific inner diameter and length. The hydrogen pressure storage system types are defined as follows [19]:

- Type I: Seamless metallic cylinder
- Type II: Hoop wrapped cylinder with a seamless metallic liner
- Type III: Fully wrapped cylinder with a seamless or welded metallic liner
- Type IV: Fully wrapped cylinder with a non-metallic liner

The structure based on a metal liner or assembled with composite material, like carbon, by wrapping, see Fig7. The liner is used to barrier coat for hydrogen gas. By using composite fibre, the empty weigth of type I tanks can reduce. The metal container is much heavier as a hybrid structure design. The weight asspect is very important for greenhouse emission, influence total mass, and driving performance of vehicle. Therefore the ratio of metal and the fibre/matrix layers define the potential of lightweight strategy.

Another aspect is the capacity of gaseous hydrogen storage system, because the constructed size is enormously. For example, if the trunk space is used as storage space, the customer losing convenience. The designer has the opportunity to reduce the tank dimension. This leads to a lower storage capacity and therefore a lower range. By rising up working pressure up the empty weight get higher.

The costs of manufacturing are very important, too, because the yearly availability of fibre and matrix define the material costs. The hybrid concept of a high pressure hydrogen storage system depends on:

- lightweigth strategy and construction
- storage capacity
- material and manufacturing costs

A view into the field of high pressure storage technology shows that the type III as well as type IV tank are the commercial products to store gaseous hydrogen. The design is a huge cylinder shape. Usually these tanks consist of an inner diffusion resistant metal or plastic liner and a carbon composite structure outside with the purpose of carrying the pressure loads. Analyzing of hydrogen storage systems show three main facts for the system parameter as follows:

- empty weight of high pressure storage system
- stress caused by internal pressure
- design, material and manufacturing costs

Based on a parameter study and the analysis of the axial and tangential stress, caused by internal pressure, the pipe diameter and length of the cylinder have a enormous influence on the system performance of storage systems.

By modelling the relations of characteristics and the influence of system properties, based on CPM, the optimum of all parameter can calculated. For example, during the product development process of vehicle the total mass increase about 10 percent. The powertrain has to optimize to get the same driving performance as defined. The result of the action is that the engine need more energy and the range get lower. By using a tank with more energy capacity the defined range can reached. But the empty weight of the hydrogen storage system is higher and therefore the total mass of the car. Another very important point is the defined construction space for storage systems. On a later point of the PDP of a new model it is not always possible to change the size. The development process of high pressure storage system is a long term and cost a lot of money. The platform and modular strategy is used to reduce the costs and integrate the new technologies for more different car models. Therefor the variation of system properties have a influence to all vehicles. This is considered in the approach.

4 Conclusion

The sustainable approach is very important future aspect, because the total mass of a vehicle define the energy consumption. At the moment the energy production based on fossil fuels. Therefore the greenhouse emission are steadily rising. The negative trend can reduce by using renewable energy source. To guaranty a comprehensive power supply new energy storage systems and infrastructure are necessary. The Fig.8 show a draft of a sustainable energy circle for mobile and stationary energy scenarios. The combination from both fields is very important for the future.

If the customers buy a hydrogen car, they have a fuel cell with more power as needed for their building. The missing hydrogen infrastructure is a problem. But the car can used as gas delivery system. An sustainable energy circle save money and reduce the greenhouse emission enormously. For the future, batteries are very important, too. Some people need a vehicle with a short range. The mobility service manufacturer can design a customer-specific car based on batteries. After the mobil use case of the batteries they can integrated in stationary energy storage/buffer of buildings or houses.

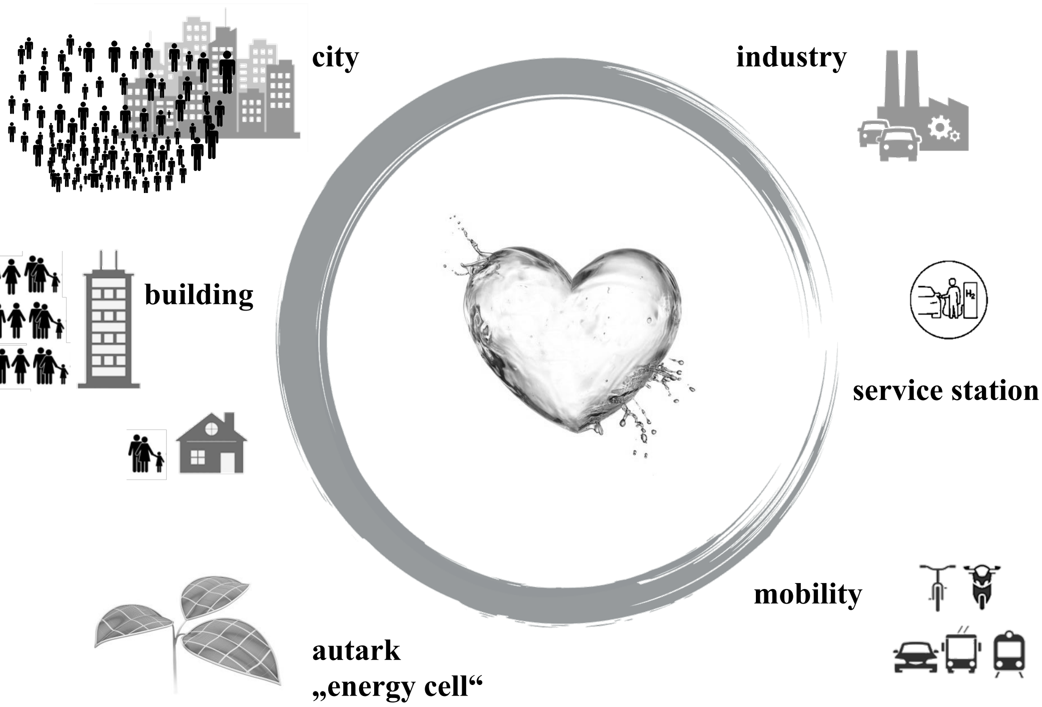

Figure 8: Vision of a mobil and stationary sustainable energy circle

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