Implementing Life Cycle Engineering efficiently into Automotive Industry Processes

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Abstract

Life cycle assessment (LCA) is a powerful tool which supports life cycle engineering. It can be used as an environmental management instrument within the product development. For successful life cycle engineering the formal incorporation of life cycle thinking into the company policy is a necessary pre-requisite. Additional success factors which have to be met are the transformation of LCA results into measurable targets for engineers. Based on given environmental targets, such as a certain target value for greenhouse gas emissions, LCA can be used to calculate a specific technical target such as the weight of a component, the fuel consumption of a vehicle or the minimum amount of recycled content in a product. The transformation of pure LCA results into measurable target values, which can be understood by engineers, will clearly show the added value which LCA can give in terms of life cycle engineering.Even for very complex products with a huge variety of different materials and a complex value chain life cycle assessment can be performed with a reasonable time demand, with good quality and integrated efficiently into business processes.

Keywords

Design for Environment; Automotive; LCA; Life Cycle Engineering

1 INTRODUCTION

The automotive industry is since decades one of the industrial focus areas for environmental technologies and environmental protection.

But how can the environmental performance of a complex product such as an automobile be measured? The aspects which directly or indirectly influence the environment are manifold:

Starting with the production of raw materials and going along the value chain the entire production affects the environment. Especially the automotive industry is one of the industry sectors with a very complex value chain, including nearly all kind of materials such as metals, polymers, glass and ceramics. The usage phase of the vehicle also effects the environment due to the combustion of fuel and the herewith linked emissions such as CO2, contributing to climate change. Other tailpipe emissions such as carbon monoxide, nitrogen oxides and hydrocarbons contribute to local air quality (e.g. summer smog). The quantity of these impacts depends on the fuel consumption and the emission standard of the vehicle. And last but not least the driving behavior of the customer, which influences the fuel consumption, has an impact on the environment. During the end-of-life phase materials are recovered or recycled from the end-of-life vehicle and can be used as secondary (raw) materials in other applications.

Therefore the environmental assessment of a vehicle has to cover the entire life cycle. One of the most suitable instruments to measure the potential environmental impact of a product is life cycle assessment [1, 2]. Volkswagen started in 1991 with a research study for the life cycle inventory (LCI) of the Golf III which was published as first automotive LCI of a complete vehicle worldwide in 1996 [3]. In the following years LCIs of different vehicles of the Volkswagen Group were published [4, 5, 6, 7].

Today the Volkswagen Group has incorporated life cycle thinking as a main principle of the product development. The advantages of this approach are:

- Environmental management based on figures and facts
- Identification of hot spots for product optimization along the entire value chain
- LCA is an internationally accepted method and a firm basis for a dialogue with stakeholders
- LCA is part of company ratings which directly influences the interest rate and financial power of the company

In the following chapters the environmental strategy of the Volkswagen group and the implementation of life cycle engineering into the environmental management will be explained.

2 ENVIRONMENTAL STRATEGY

The key element of the Volkswagen group strategy 2018 is to position the Volkswagen group as a global economic and environmental leader among automobile manufacturers. We intend to set new environmental standards in vehicles, powertrains and lightweight construction.

2.1 Environmental challenges

The main environmental challenges for the automotive industry today and in future are climate protection, health and local air quality and resource protection. Therefore these three items are incorporated into the environmental principles product of the Volkswagen Group. This standard is the basis for the product related environmental strategy.

2.2 Environmental strategy of the Volkswagen Group

The environmental strategy of the Volkswagen group has two main pillars: The environmental standard production and the environmental principles product. The latter addresses the three main environmental challenges (climate protection, health and local air quality and resource protection) and incorporates the life cycle engineering as a main principle in product development.

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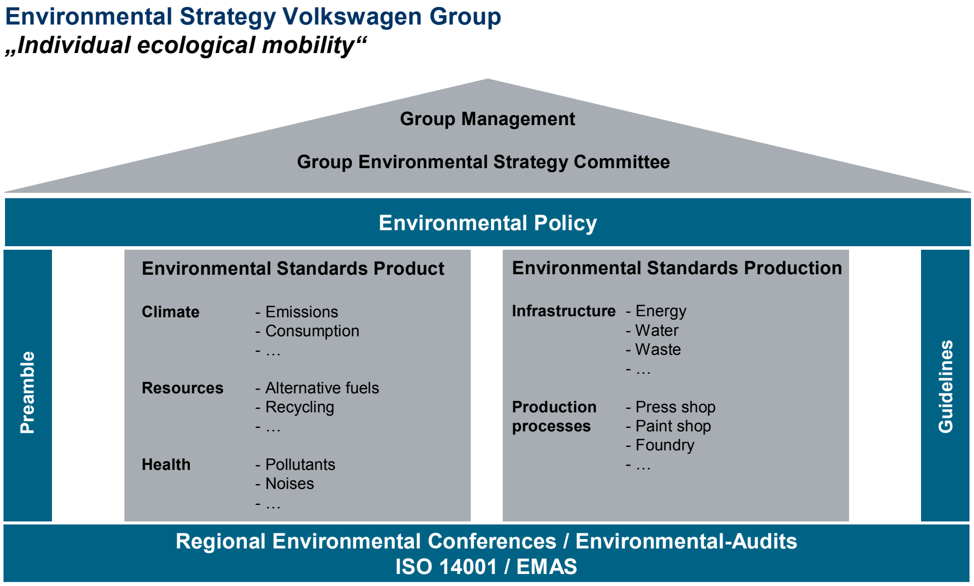


Figure 1: Environmental strategy Volkswagen Group.

The Volkswagen group is committed to developing vehicles and components in such a way that they have better environmental properties than their predecessors over the entire life cycle. Life cycle assessments are used to analyze and document the environmental performance of vehicles, technologies and processes.

3 SUCCESS FACTORS FOR LIFE CYCLE ENGINEERING

Whereas the first ideas of life cycle based analysis were developed 30 years ago, it still remains a challenge to implement life cycle assessment successfully as environmental management tool into business processes. In this chapter we describe the key success factors for such an implementation.

The success factors are:

- Integration into company policy and processes
- Reasonable time demand
- Reliable, meaningful and measurable targets for product development
- Communication strategy

3.1 Integration into company policy and processes

The commitment of the top management is crucial for the success of any environmental policy and strategy.

For the Volkswagen group the environmental standards production and product are the basis for the environmental strategy. But for a successful environmental management system this is only the starting point.

For the Volkswagen brand we developed an environmental management scheme according to Figure 2. Responsible for the implementation of environmental aspects into the product development is the environmental officer product.

Figure 2: Environmental management at Volkswagen.

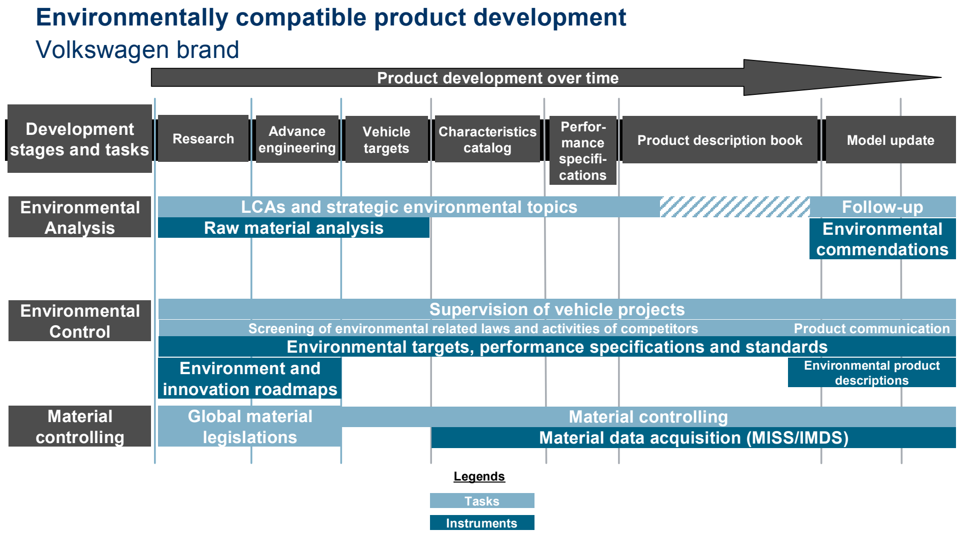


Figure 3: Environmentally compatible product development for the Volkswagen brand.

Figure 3 shows an overview of different tasks and instruments along the product development which usually takes around 48 months until the start of production.

Different teams act along the product development. The team environmental analysis has the task to perform LCA and strategic raw material analysis for different components and technologies. The focus of this work is the early phase of the product development including research.

Strategic raw material analysis focuses on long term risk assessment [8] such as

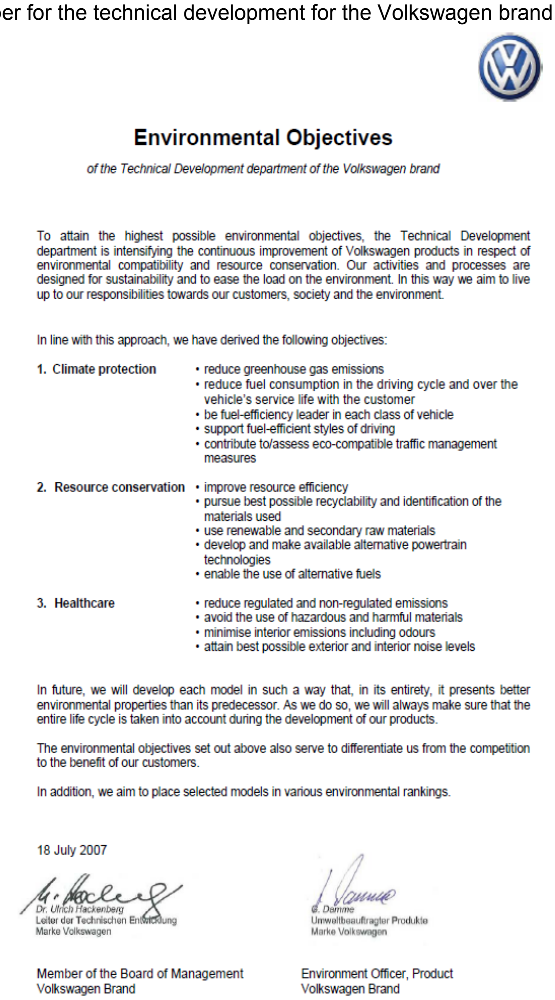
- Supply and demand today and in future
- Production costs
- Geostrategic risks
- Market power of the raw material suppliers

Life cycle inventory data and the herewith linked bill of materials is a powerful basis for raw material risk assessment which can not be performed without that information.

The task of the LCA is to compare different technologies in the early phase of product development. The challenge of this task is that the information required for the LCA is often not fully available in the early phase of the product development. E.g. the body-in-white concept is known from the material perspective, but the exact weights of the different components are unknown. Here LCA should be applied in such a way that the unknown variables are calculated as measurable target values. In our example where we do not know the exact weight of all components the sum of the component weight can be calculated as target, which has not to be exceeded in order to achieve an environmental goal such as a maximum greenhouse gas emission potential.

Another important aspect for the implementation of life cycle engineering is the formal inclusion of the suppliers. Volkswagen included in its supplier conditions that on request the supplier has to deliver life cycle inventory data for his parts and components [9]. Additionally the IMDS system (www.mdsystem.de) is a reliable data basis for information about the material composition and the bill of materials of a certain part.

The most important aspect is that the Volkswagen brand included in its environmental objectives "that we will develop each model in such a way that, in its entirety, it presents better environmental properties than its predecessor. As we do so, we will always make sure that the entire life cycle is taken into account during the development of our products." This target is signed by the board member for the technical development for the Volkswagen brand.



Environmental Objectives

of the Technical Development department of the Volkswagen brand

To attain the highest possible environmental objectives, the Technical Development department is intensifying the continuous improvement of Volkswagen products in respect of environmental compatibility and resource conservation. Our activities and processes are designed for sustainability and to ease the load on the environment. In this way we aim to live up to our responsibilities towards our customers, society and the environment.

In line with this approach, we have derived the following objectives:

1. **Climate protection**
   - reduce greenhouse gas emissions
   - reduce fuel consumption in the driving cycle and over the vehicle's service life with the customer
   - be fuel-efficiency leader in each class of vehicle
   - support fuel-efficient styles of driving
   - contribute to/assess eco-compatible traffic management measures
2. **Resource conservation**
   - improve resource efficiency
   - pursue best possible recyclability and identification of the materials used
   - use renewable and secondary raw materials
   - develop and make available alternative powertrain technologies
   - enable the use of alternative fuels
3. **Healthcare**
   - reduce regulated and non-regulated emissions
   - avoid the use of hazardous and harmful materials
   - minimise interior emissions including odours
   - attain best possible exterior and interior noise levels

In future, we will develop each model in such a way that, in its entirety, it presents better environmental properties than its predecessor. As we do so, we will always make sure that the entire life cycle is taken into account during the development of our products.

The environmental objectives set out above also serve to differentiate us from the competition to the benefit of our customers.

In addition, we aim to place selected models in various environmental rankings.

18 July 2007

Dr. Ulrich Hackenberg
Leiter der Technischen Entwicklung
Marke Volkswagen

G. Demme
Umweltbeauftragter Produkte
Marke Volkswagen

Member of the Board of Management
Volkswagen Brand

Environment Officer, Product
Volkswagen Brand

Figure 4: Environmental objectives of the Volkswagen brand.

3.2 Reasonable time demand

LCA is a very comprehensive tool which offers a detailed insight in the environmental profile of a product.

Performing an LCA of a complex product can be divided into two steps: The first is the data collection of the product. Here the part list of the product is required. For every single component the material composition must be quantified and the herewith linked production process chain must be defined. This step can be improved in terms of time efficiency via the implementation of IMDS data for the components and the linkage to other internal IS-systems of the company. Anyhow this still remains a time consuming step and can take even today up to 30 days. The final result of step 1 is a so called transfer file, which describes for a vehicle every single component by its bill of material and the respective production chains (see Figure 5).

The second step is the transfer of this information into a LCA model. Within Volkswagen we developed an in-house solution which automatically builds up the LCA model based on the information of the transfer file and the so called correlation list [10]. The correlation list correlates each material and each production process to a respective LCI data set. The advantage of this approach is not only a huge reduction in time demand but also huge increase in consistency and quality of the LCA results.

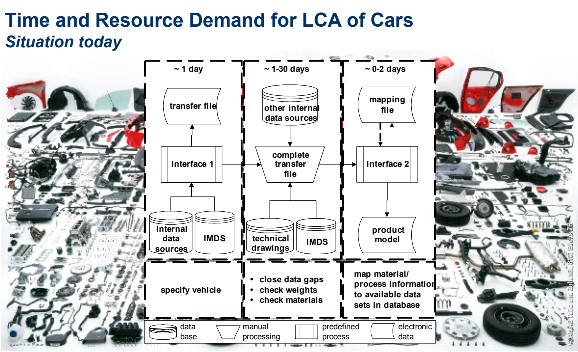


Figure 5: Time and resource demand for LCA of vehicles.

Therefore life cycle assessments, even for complex products with a huge variety of different parts and materials, can be performed with a reasonable time demand.

3.3 Reliable and measurable targets for the product development

Life cycle assessment is an environmental management tool that delivers scientific sound results, not less but also not more. A good environmental management system is therefore characterized by the capability to transform LCA results e.g. in terms of a greenhouse gas profile of different technologies into a technical target which can be understood, measured and monitored by an engineer. These targets can be fuel consumption, electric power consumption or the weight of a certain component. The real challenge of life cycle engineering is to bring together two different worlds: The world of the LCA expert, who models the product in terms of environmental impacts versus the world of the engineer who develops the product and takes technical measure that influence the environment.

In order to derive reliable, meaningful and measurable targets the following aspects should be considered.

Stable and reliable results

As LCA is a model outcome every LCA result should be tested by sensitivity analysis in order to prove whether the result, or much more important, a derived technical recommendation, is stable while varying certain model parameters or assumptions.

Data quality

Foreground data, such as the bill of materials, information about production processes or energy consumption in the use phase, describes the characteristics of the product. From our experience this foreground data is of major relevance and has a strong influence on the overall LCA results.

For commodities generic data sets can be used as a first approach.

For the modeling of special materials, which are new on the market or based on new technologies, a data acquisition in cooperation with the respective supplier is strongly recommended. At that point a formal requirement for data acquisition of life cycle inventory data in the supplier contracts is very helpful.

For highly innovative industries, such as the automotive industry, it is of utmost importance to use high-quality inventory data in order to assess the environmental profile of new materials and new technologies. This is a challenge because the knowledge of new technologies and new materials is of course limited. But this does not mean that LCA can not be applied. Also in this case the area of unknown knowledge can be transformed by LCA into a measurable target value. If, for instance, the energy consumption of a new production process is still unknown, an LCA can be used to calculate the acceptable maximum energy consumption in order to achieve a certain environmental target.

Anyhow there is a parallel between the automotive industry and life cycle assessment: High-tech powertrains need high-quality fuels – high-tech LCA need high-quality inventory data. Therefore today and in the future the provision of high-quality inventory data will remain an important and necessary task, especially for science and consultancy.

3.4 Communication strategy

It is most important that products with special environmental features or technological improvements are also communicated as such. A company which invests in environmental performance and technology leadership should also use these characteristics in the communication and marketing. Therefore the challenge in that area is to translate LCA results into a communication that will be understood by the respective target groups. It is notable that economical and environmental optimization oftentimes are in line, especially with regard to the fuel consumption. In the case of the automobile industry we have to differentiate between private customers and fleet customers as two different kinds of target groups. Whereas private customers mostly focus on fuel consumption and emission levels in terms of costs, they do not reflect what we call total cost of ownership (TCO). While TCO means that higher purchase prices can be amortized over life time at the customer, the private customer has in many cases a limited willingness to pay for additional environmental features, even if they offer the opportunity to get the economical break-even within a time scale of 2-3 year. In contrast to that, fleet customers base their decisions often on TCO calculations. For an OEM this means that fleet customers have a willingness to pay for environmental technologies such as BlueMotion, if the economical break even will be reached within a few years. But also other environmental aspects might be important for fleet customers, e.g. a company can improve their sustainability ranking by improving the company fleet cars.

For the Volkswagen brand we developed the so-called environmental commendations (www.environmental-commendation.com). Environmental commendations for new vehicle models and technologies highlight ecological progress compared with predecessor models and previous technologies. We use environmental commendations to inform our customers, our shareholders and other stakeholders how we are making our products and production processes more environmentally compatible and what we have achieved in this respect. The underlying LCA not only covers the time when the vehicle is on the road but its entire life cycle from production through to use and disposal. This reflects the fact that we assume responsibility for the entire supply chain, including the production of raw materials and parts for our vehicles. We engage in dialogue with our suppliers to identify environmental measures that can be taken. The information of environmental commendations is based on an LCA, which has been verified and certified by the technical inspection organization TÜV NORD. The TÜV certificate confirms that the LCA is based on reliable data and that the methods used to compile it comply with the requirements of the ISO standards 14040 and 14044.

4 INTELLIGENT LIGHTWEIGHT DESIGN OVER LIFE CYCLE

In this chapter we show how an LCA can be applied as environmental management tool within the product development. Lightweight design measures are chosen for this example.

Modern lightweight design is one of the key technologies for an efficient future mobility, because it contributes to reduce the fuel consumption and the herewith linked CO2-emissions. Based on the Volkswagen's environmental standard for products this means that any lightweight design measure should also have an environmental benefit over the entire life cycle. Approximately one third of the fuel consumption in the NEDC (New European Driving Cycle) depends on the mass of the vehicle. Lightweight materials such as aluminum or magnesium are energy intensive in the production as shown in Figure 6.

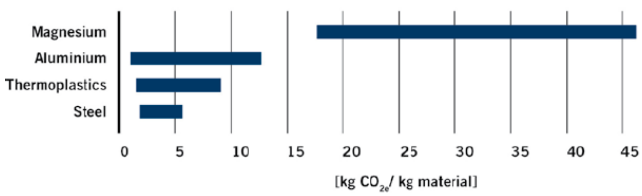


Figure 6: Greenhouse gas emission for the production of different materials.

Figure 6 also shows the range of greenhouse gas emissions for the production of different metals. The reasons for this range are manifold: The amount of recycled material, the CO2-intensity of the used energy mix, different kinds of protecting agents and their impact on climate change are only a few aspects which influence the greenhouse gas balance of such a material. It is also important to note that a comparison of materials can not be done based on Figure 6. A comparison can be done by including the entire life cycle and by assessing products which fulfill the same functions. E.g. a body-in-white with the same crash performance will have different weights depending on the material-mix applied and the design of parts.

For lightweight concepts the herewith linked CO2-emissions in the production phase are often, but not always, higher than those ones for conventional construction. These additional CO2-emissions which occur in the production phase should be compensated as fast as possible during the use phase due to lower fuel consumption of the lightweight design. Only when we achieve the ecological break-even, we speak of an “intelligent“ lightweight design as shown in Figure 7.

Volkswagen has different strategies to reduce the weight of a vehicle. Besides different material concepts the integration of different functionalities contributes to reduce the number of parts. For the body-in-white construction, which accounts for up to 35% of the overall vehicle weight in the series production of passenger vehicles steel- and aluminum lightweight are established technologies.

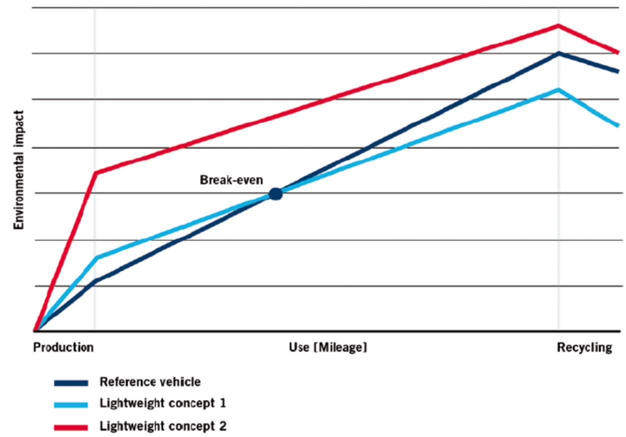


Figure 7: Lightweight design and environmental break-even.

The question whether a specific lightweight concept has a better greenhouse gas balance than a competing concept, can be answered only by assessing the entire vehicle. An important question is whether a lightweight measure will lead to a smaller engine or not. Of course any lightweight measure reduces the fuel consumption. But this reduction is low (0,15 l/100km*100kg for gasoline engines) compared with a fuel reduction of 0,35 l/100km * 100kg which can be achieved by additional measure of the engine.

What is clear from the above examples is, that it is not possible to make general claims along the lines that „material A is always better or always worse than material B“. Whether a lightweight design measure reduces life cycle greenhouse gas emissions or not will primarily depend on the following factors: the extent of the weight savings by material and material-adopted design, whether powertrain modifications can be implemented and the quality of secondary (recycled) materials derived from the end-of-life vehicle. In practice, one and the same lightweight design measure might allow powertrain modifications to be made on vehicle A but might not, by itself, be sufficient to warrant such modifications on vehicle B. Saying this, it is often the case in practice that components or assemblies are optimized and assessed in isolation from each other, so that the significance of each measure in the causality chain that leads ultimately to powertrain modifications cannot always be clearly determined. Therefore lightweight measures should always be assessed from the perspective of the entire vehicle and not from the part perspective.

As can be seen in Figure 8, the potential benefits of the various lightweight materials extend even further. The table shows the main actors – and potential actions – at the different life cycle stages. For example the material manufacturing stage offers the opportunity to significantly reduce specific CO2-emissions per kg of material produced by reducing specific energy consumption and/or through the use of renewable, low-carbon energy sources. The use of secondary (recycled) materials can likewise help to reduce environmental impacts – for example some cast alloys already use up to 90 % recycled content. On the process side, too, measures such as use of climate-friendly shielding gases as a replacement for SF6, or the reduction of offcuts and scrap, all have a part to play. In the vehicle use phase meanwhile, fuel-efficient vehicle design measures by the OEM must be complemented and maximized through the optimal use of this potential by customers e.g. by eco-driving trainings. Finally, at the recycling stage, reprocessing of lightweight materials into high-quality secondary materials will influence the range of potential applications of such materials and thus the associated positive environmental impacts.

LIFE CYCLE STAGE AND MAIN ACTORS	ASPECT	MEASURE
PRODUCTION (SUPPLIERS, OEM)	: Energy demand : Energy mix : Secondary resources : Process-specific aspects	: Reduced energy consumption : CO_2-reduced energy mix : Increased use of secondary resources : Optimized consumables
USE STAGE (OEM, CUSTOMER)	: Lightweight effect (massinduced, secondary measures, e.g. downsizing) : Customer behaviour	: Strict design in favour of fuel efficiency : Avoidance of unnecessary ballast, optimal tyre pressure, etc.
END-OF-LIFE (RECYCLING-INDUSTRY)	: Recovery of materials : Availability : Scrap quality : Secondary material quality	: Installation of collection systems : Development of separation technologies : Enhancement of yield/quality

Figure 8: Environmentally friendly lightweight design, aspects and measures.

Seen from this overall perspective therefore, it is clear that environmentally friendly lightweight product development offers a wide range of different measures. In addition to the engineers in the automotive industry, the other stakeholders in the value chain (materials manufacturers, suppliers, recycling companies) likewise have their part to play in further improving their products and enhancing the life cycle environmental impact of vehicle concepts of the future.

5 CONCLUSIONS

As demonstrated above, life cycle assessment is a powerful tool which can be used as an environmental management instrument within the product development.

For successful life cycle engineering the formal incorporation of life cycle thinking into the company policy is a necessary pre-requisite. Additional success factors which have to be met are the transformation of LCA results into measurable targets for engineers. Based on given environmental targets, such as a certain target value for greenhouse gas emissions, LCA can be used to calculate a specific technical target such as the weight of a component, the fuel consumption of a vehicle or the minimum amount of recycled content in a product. The transformation of pure LCA results into measurable target values, which can be understood by engineers, will clearly show the added value which LCA can give in terms of life cycle engineering.

Even for very complex products with a huge variety of different materials and a complex value chain life cycle assessment can be performed with a reasonable time demand, with good quality and integrated efficiently into business processes.

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