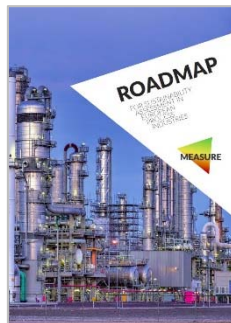


Background document

supplementing the
“Roadmap for
Sustainability Assessment in
European Process Industries”



Sector B: Metal and Automotive

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1 Introduction: overview of assessment tools and methods used in the metal and automotive sector

1.1 Drivers, motivations and applications of sustainability assessment in Sector B

An important factor for material specifiers in a world where sustainable development is a key issue is the environmental and socio-economic performance of material applications, both from a manufacturing and a product performance perspective. An effective sustainability management along the supply chain incorporates the preceding and subsequent businesses, hence the analysis of sector B is focused on both metals and the automotive industries because Improvements achieved within metals production are an advantage for the succeeding car manufacturers.

Environmental protection is now a clear corporate objective and in the current focus of companies. It is an integral component of management tools and it is firmly entrenched in the corporate cultures of companies in the metals and automotive industry. As they are primarily production and manufacturing companies, their environmental performance is directly linked with their production efficiency. Increasingly stringent environmental legislation is another driving factor for environmental improvements.

For raw material intensive industries, the optimization of resource input is a major topic. The Metals industry is an important player in this field as their recyclability enables an effective use of secondary resources. This and other improvements have led to a reduction of 85% waste in automotive production since 1990 (VDA 2014).

Currently, around half of the steel produced in Europe is based on recovered 'secondary' sources (scrap metal). Due to steel's in-use longevity there is not enough scrap to satisfy the demand, so 'primary' raw iron is still an important input into steelmaking (EUROFER 2015). Furthermore the industries work on their raw material efficiency. The example of the German steel industry shows that while the production volume has increased, 10 million tons input materials can be saved due to process optimizations compared to the baseline 20 years ago (STAHLINSTITUT VDEh 2013). Moreover, the steel industry has reduced its energy consumption per ton of steel produced by 60% globally in the last 50 years (Figure 1).

Sustainability assessment and life cycle based evaluations are also very well applied in the so called Design for Environment (DfE) approaches. DfE aims at providing simplified LCA for designers, integrating design constraints and environmental concerns and allowing for single indicators that give weights to different impacts. DfE approaches that are very well applied in the automotive sector (e.g. VW, Daimler, BMW), promote envi-

ronmental improvements and/or resource consumption reduction instead of relying on end-of-the-pipe pollution control.

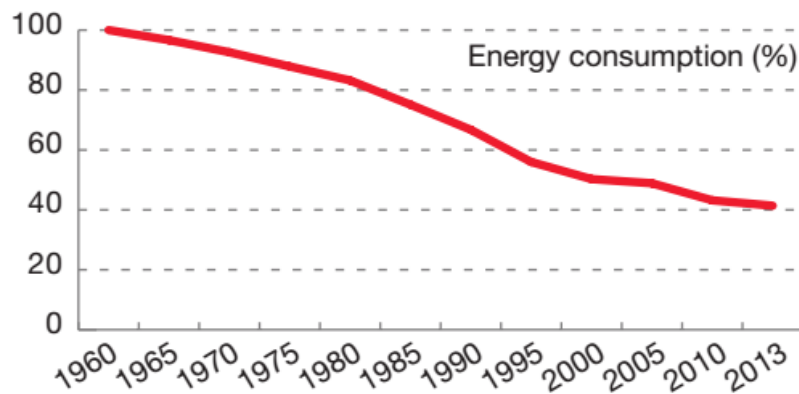


Figure 1: Indexed global energy consumption/ton of crude steel production (worldsteel 2014).

Many metal and automotive companies and associations publish their environmental and socio-economic performance and improvements over time in sustainability reports. Furthermore key figures and their improvement over time are tracked, for example the European aluminium industry (Figure 2) has halved their CO₂-eq. emissions for their primary production since 1997, although the demand is constantly growing (EAA 2012) Reasons are partly due to the optimised production processes and due to increased share of secondary material used.

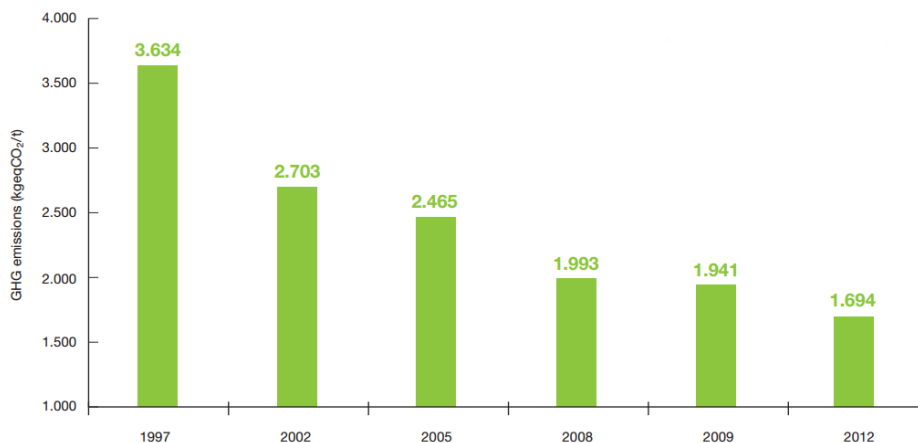


Figure 2: Greenhouse gas emissions of aluminium production in Europe (EAA 2012).

In addition, automotive and metals industries can build on their sustainability and use this advantage to ensure good customer retention. A good environmental performance and socio-economic responsibility is seen as one possibility to differentiate one business from a competitor; it is seen as a unique selling point.

1.2 Important regulatory issues

Most regulations relevant for metal industries are focused on production. There are, in general, no specific targets to be fulfilled by metal products. However, metals are often part of a complex product system and are therefore partly covered by some application cases of the European directive on Ecodesign¹.

In addition, the EC announced that a new strategy will be presented by the end of 2015, calling for a Circular Economy². This package will aim at focusing on possibilities to ensure increased and better recycling for the overall aim of moving from a linear to a finally circular economy. Apart from other measures, this Package will contain legislative proposals for review of the European waste legislation, an important regulation for metals industry. Moreover, the circular economy strategy requires action at all stages of the life cycle of products, linked together, in order to implement improvements in terms of resource and energy efficiency at all stages concurrently.

With regards to the automotive industry and the objectives of the current project, the following main legislative acts are in force in Europe:

1.2.1 Tailpipe Emission Directive³

The Directive sets emission performance standards for new passenger cars as part of the Community's integrated approach to reduce CO₂ emissions from light-duty vehicles. The current regulation focuses solely on what comes out of the tailpipe; these are the emissions produced during the car's driving phase, whereas all other life cycle phases are excluded (worldsteel 2013).

1.2.2 Directive on Type Approval of Motor Vehicles with Respect to Emissions⁴

This Regulation establishes common technical requirements for the type approval of vehicles and replacement parts, such as replacement pollution control devices, with regard to their emissions. It introduces the so called Euro 5 and Euro 6 emission limits that should have been applied from mid-2007 and beginning-2015, respectively. The emission limit values are defined in emissions per kilometre and relate to CO, total and non-methane hydrocarbons, NO_x and particulate matter.

¹ DIRECTIVE 2009/125/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of ecodesign requirements for energy-related products

² ROADMAP: Circular Economy Strategy (<http://goo.gl/7NVggs>)

³ REGULATION (EC) No 443/2009 of the European Parliament and of the Council of 23 April 2009 setting emission performance standards for new passenger cars as part of the Community's integrated approach to reduce CO₂ emissions from light-duty vehicles

⁴ REGULATION (EC) No 715/2007 of the European Parliament and of the Council of 20 June 2007 on type approval of motor vehicles with respect to emissions from light passenger and commercial vehicles (Euro 5 and Euro 6) and on access to vehicle repair and maintenance information

1.2.3 Renewable Energy Directives

This act deals with the inclusion of a share of biofuels into regular fuels, in order to reduce indirectly the Greenhouse Gas (GHG) emissions from fuel combustion. The Directive provides an emission calculation approach, based on the life cycle perspective.

1.2.4 Clean Vehicles Directive⁶

This Directive requires contracting authorities, entities as well as certain operators to take into account the lifetime energy and environmental impacts. This includes energy consumption and CO₂ emissions and other pollutants, when purchasing road transport vehicles. The objective is to promote and stimulate the market for clean and energy-efficient vehicles.

1.2.5 End-of-Life Vehicles (ELV) Directive⁷

The regulation aims at making dismantling and recycling of ELVs more environmentally friendly. It sets clear quantified targets for reuse, recycling and recovery of the ELVs and their components. For example, since 2015 the reuse and recycling shall be increased to a minimum of 85 % by an average weight per vehicle and year. Furthermore reuse and recovery have to make up 95% of vehicle weight. With these targets the Directive follows the waste hierarchy and defines 'recycling' as the reprocessing in a production process of the waste materials for the original purpose or for other purposes, but excluding energy recovery. 'Energy recovery' is the use of combustible waste as a means to generate energy through direct incineration with or without other waste but with heat recovery.

The different target values mean that 85% of the vehicle mass has to be reused or that the material has to be processed for further use. Only for the difference of 10 percentage points between the two targets energy recovery is a suitable treatment at end-of-life.

That is why recyclability is one of the key properties that has to be fulfilled during vehicle design. The recyclability is already checked in the early Research and Development (R&D) phase to allow for the best material selection. The Directive also pushes producers to manufacture new vehicles without hazardous substances (in particular lead, mercury, cadmium and hexavalent chromium).

⁵ DIRECTIVE 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC

⁶ DIRECTIVE 2009/33/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of clean and energy-efficient road transport vehicles

⁷ DIRECTIVE 2000/53/EC of the European Parliament and of the Council of 18 September 2000 on end-of life vehicles

2 Existing agreements and rules in Sector B

Both metals and automotive sectors have experience in applying tools towards decreasing the overall environmental impacts of their activities and increasing transparency along their supply chains. Moreover, representative organizations from both sectors are active stakeholders in organisations which are developing LCA tools and approaches. Herewith, the main LCA-based methodology agreements are described, followed by an overview of the important activities in the metals and automotive sectors.

2.1 Use of LCA

LCA is a widely used tool in evaluating the potential environmental impacts of products. The following table overviews and compares the current practices of LCA in both sectors. Most of the topics are further discussed in the report.

Table 1: Current LCA practices in sector B.

Technical requirement	Metals	Automotive
Methodology	<ul style="list-style-type: none"> ISO 14040/44 	<ul style="list-style-type: none"> ISO 14040/44
Functional unit/declared unit ⁸	<ul style="list-style-type: none"> Mainly kg of product (sometimes m² product for metal sheets) Cradle-to-gate (mostly) 	<ul style="list-style-type: none"> Transportation services of passenger cars of equivalent size, utility, equipment, and power train configuration over their equivalent Lifetime Driving Distance (LTDD)
System boundaries (cut-off rules)	<ul style="list-style-type: none"> Raw materials extraction and manufacturing Exclusion of capital goods 	<ul style="list-style-type: none"> Vehicle life cycle (often only use phase) Exclusion of capital goods
Relevant life cycle stages	<ul style="list-style-type: none"> Mainly production and end-of-life Studies include EoL & recycling and if possible product use phase 	<ul style="list-style-type: none"> Production evaluated, but mainly use-phase relevant with clear tendency to have lower share of environmental burden in future
Allocation	<p>Co-products:</p> <ul style="list-style-type: none"> Follows ISO 14040/44 (can have high relevance) <p>Recycling:</p> <ul style="list-style-type: none"> Avoided burden approach Also in combination with a closed-loop approach 	<p>Co-products:</p> <ul style="list-style-type: none"> Follows ISO 14040/44 <p>Recycling:</p> <ul style="list-style-type: none"> Avoided burden approach and cut-off approach
Data management	<ul style="list-style-type: none"> Primary cradle-to-gate LCI data collected by metal associations; provided as industry average 	<ul style="list-style-type: none"> Country-specific background data preferred for manufacturing Continental data preferred for use-

⁸ As defined by EN 15804 CEN (2012). Sustainability of construction works — Environmental product declarations — Core rules for the product category of construction products (EN 15804), Comité Européen de Normalisation, Brussels, Belgium.

	<p>LCA data</p> <ul style="list-style-type: none"> • Provision of primary data only on B2B level • Use of primary data according to availability and relevance (e.g. iron ore in worldsteel data collection). Secondary data for some upstream processes (e.g. country specific data for electricity) 	<p>phase</p> <ul style="list-style-type: none"> • Country/continental data preferred for EoL • Mix of primary and secondary data to model recycling
Databases	<ul style="list-style-type: none"> • GaBi professional 	<ul style="list-style-type: none"> • GaBi professional
Impact categories	<ul style="list-style-type: none"> • GWP, AP, EP, POCP, ODP • not recommended: ADP, water, land use, toxicity 	<ul style="list-style-type: none"> • Mostly GWP, but also include AP, EP, ODP, POCP, ADP
LCIA methods	<ul style="list-style-type: none"> • CML • Partly consider regional differences, e.g. TRACI in North America and CML (or ReCiPe) in Europe 	<ul style="list-style-type: none"> • Mostly CML, followed by ReCiPe
Communication/reporting	<ul style="list-style-type: none"> • Externally reviewed LCI data provided in a report • B2B (incl. EPDs) 	<ul style="list-style-type: none"> • Environmental certificates, leaflets, brochures • B2B/B2C

Sources: (worldsteel 2011, PE International 2014, Lehmann, Finkbeiner et al. 2015, thinkstep 2015)

2.2 Actions under the PEF Initiative

Several metals companies and associations (representing the aluminium, copper, lead and steel sectors) are taking part in the ongoing Product Environmental Footprint (PEF) pilots phase (EC 2013a) and specifically in the Pilot on “Metal sheets for various applications” (Eurometaux 2015a). The already published screening study (Eurometaux 2015b) aims at testing a harmonized approach leading to defined product category rules for assessing the environmental impact of metal sheet products to encourage improvements and possibly for benchmarking and comparison purposes. Open and conflicting points of the PEF method in general are identified by the working group that conducts the pilot.

The automotive industry does not participate in the pilot phase. The European automotive industry (the European Automobile Manufacturers Association – ACEA) clearly stated in an official statement that they are not supporting the EC’s PEF initiative (ACEA 2013).

2.3 Development of Product Category Rules

Environmental product declarations (EPDs), governed by ISO 14025 (ISO 2006), are type III environmental labels that provide quantified and independently verified environmental information over the life cycle of goods and services (Minkov, Schneider et al. 2015). They are developed according to a set of pre-defined product category rules (PCR) and are mostly applicable in B2B communication.

The metals sector (being a B2B supplier) is involved in the development of EPDs mainly to serve the construction sector, where the type III communication is constantly growing. Several PCRs related to steel or steel products are available and fewer for copper and aluminium products (mostly all of them targeted to the construction sector). However, their development is often triggered by a single company, but not jointly by producers' associations.

Considering the construction sector as being one of the main clients of the metal industries (especially steel, aluminium and copper), the European standard EN 15804 (CEN 2012) is now considered to be a proven standard, developed to ensure harmonization among EPD for all types of building and construction products by providing the so called "Core PCR" (Erlandsson, Ekwall et al. 2013).

In contrast to the metals producers, the demand for verified EPDs and thus, the need for PCR development in the automotive sector is very low. There is currently no valid PCR for vehicles.

2.4 Other initiatives and collaborations

The Metals industry is open towards new sustainability approaches and supports the automotive sector where possible. To ensure a common understanding on LCA and to enable the metals industries to speak with one voice, a joint study on harmonizing the LCA methodology on metals has been conducted (PE International 2014). The white paper, supported by 16 mining and metals industry-related organizations, summarizes common issues and agreement in the metals sector regarding LCA practices.

The World Steel Association (worldsteel), representing around 170 members, develops methodologies to measure CO₂ emissions in steel plants and provides life cycle inventory (LCI) data for key steel products and assists those who use the data, including member companies, customers, universities and LCA consultants, with their analysis. The association is also involved into tracking 8 sustainability indicators (which go beyond the environmental dimension) to demonstrate trends in the steel industry (worldsteel 2014).

The aluminium industry is active in the field of sustainability as well, not only with the International Aluminium Institute (IAI), which represents over 60% of global bauxite, alumina and aluminium production (IAI 2015a), but also with their regional associations. For example the European aluminium industry has been publishing their Sustainable Development Indicators since 2002.

The International Copper Association (ICA) represents 43 member companies and the alliance of national and regional associations. Under their core initiative on Health, Environment & Sustainable Development, the association works, among others, on life cycle based topics including collection of LCI data (for details see section 3.2).

The International Magnesium Association (IMA) is the global voice of the magnesium industry. In recent years, it has worked actively on studies related to life cycle environ-

mental impacts of utilising magnesium components as a promising constituent in light-weighting within transport applications (IMA 2015).

As regards the automotive sector, WorldAutoSteel – the automotive group of worldsteel, is comprised of 20 major global steel producers from around the world. Among other tasks, the association is very active on the topics of sustainability and life cycle based evaluations in order to decrease the negative impacts of the automotive sector.

ACEA represents 15 European-based producers of cars, vans and trucks. It is the voice of car makers on topics regarding among others environmental friendliness, social responsibility and sustainability. As referred to throughout the present report, ACEA has a strong position on using sustainability assessment tools such as LCA, e.g. (ACEA 2012), or the current developments of the PEF initiative (ACEA 2013). In comparison to WorldAutoSteel, ACEA is not publicly engaged in activities to improve the accuracy of LCA and to establish common methodologies and/or datasets.

3 Important topics and open issues in the current sustainability assessment in Sector B

As described in Table 1, LCA practitioners follow ISO 14040/44, but further specification may be needed if LCA is used for specific needs (e.g. communication or comparison, etc.) within the observed industry sectors. Based on such sectorial specifics agreements on related methodological issues can be established including, but not limited to:

3.1 System boundaries in LCA

Metal producers usually focus on cradle-to-gate only when assessing the environmental impacts of their products. The inclusion of use-phase impacts is in general difficult for metal producers due to the semi-product characteristic. Metals can be manufactured to a variety of end-products which can be applied differently. Thus, it is more appropriate and realistic if the end user models the use phase of the metal product, as the purposes of their use it better understood at that point.

Therefore, data on environmental performance published by metals industries usually exclude the use phase and focus on cradle-to-gate, in most cases combined with end of life (EoL) recycling. When considering construction products, the exclusion of a specific life cycle stage, e.g. the use phase, is allowed by EN 15804 (2012). This system boundary option is called “cradle-to-gate with options”. For the case of metals, this is relevant, considering how important EoL processes can be for metals, but assuming an uncertain use phase scenario that does not merit to be considered in the study.

Nevertheless, certain LCA studies show how products perform during the use phase. This is needed to highlight savings and/or improvements of the environmental performance of new material grades. The use and the recycling phases of a metal can help to offset environmental impacts of the production phase relative to competing metal products.

Regarding the automotive sector, the development of new technologies – e.g. lightweight materials, highly efficient combustion engines and electric vehicles in the recent years – determines the need of expanding the boundaries of the LCA studies and considering the complete life cycle of the product instead of only the use phase. Figure 3 represents how the different life cycle stages influence the overall GHG emission profile of four types of vehicles: gasoline (Otto), diesel, plug-in hybrid (PHEV) and battery electric vehicle (BEV).

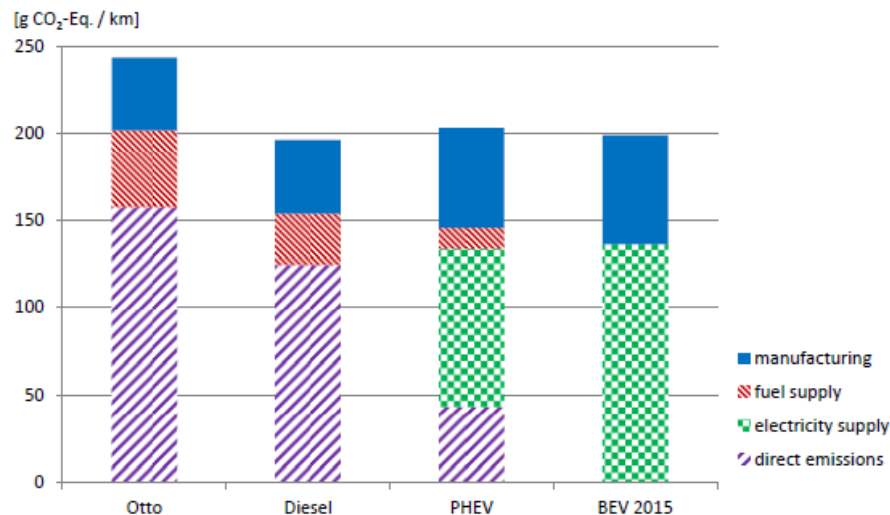


Figure 3: Comparison of four types of vehicle based on Global Warming Potential [g CO₂-eq./km] (Bieman, Dünnebeil et al. 2015).

The figure clearly shows that certain types of vehicles that have been more often introduced on the market recently (e.g. BEV) have very low or no direct impact during the use phase (“direct emissions”, also called “tank-to-wheel”), and also relative low contribution when the fuel and electricity supply is added (called “well-to-wheel”). It is also observed that the lower the use phase emissions, the higher the contribution to the production and EoL phases becomes.

In this regard, an example relevant for the automotive industry is lightweighting. Lighter materials tend to offset the impacts during use phase on the cost of increased impacts during production and EoL. That is why metals used in the automotive sector should not only be compared on a weight basis, but the declared unit should allow for a functional equivalent comparison, that means the same function might be achievable with less material, if the strength of the materials has improved.

There is currently no common approach by the metals industry on how to react on the lightweighting “pressure” in case of sustainability assessments, although the topic is valid and still largely discussed. Raugei et al. (2015) recently published an LCA-based comparison of a range of lightweight options (aluminium, magnesium and carbon fibre composites) and a number of alternative end-of-life scenarios. The authors conclude that only reducing the weight of vehicles is not sufficient to reduce the overall environmental footprint (considering here not only Global Warming Potential (GWP), but other impact categories). Witik et al. (2011) support this by stating that materials offering higher weight savings have been shown to give limited or negative benefits over their life cycle due to increased environmental burdens associated with their production and EoL.

Assumptions on the definition of the goal and scope seem to be the most important issue when developing such comparisons. Expansion of the analysis beyond the use phase is a valid outcome, considering that the potential impacts during the use phase

are not the only important contributor. The overall result turns out to be sensitive to different scenarios on evaluating the impact of the production phase (mainly raw materials extraction).

Summary:

- Due to the connection of the metal and automotive industries along the supply chain, joint research studies are effective means to identify hotspots in the production and use phase and to develop the most promising material choices
- The metal sector should not limit the system boundaries of studies to cradle-to-gate only
- “Cradle-to-gate with options” is a convenient format when metal products are used in the automotive sector
- The automotive sector should not limit the scope only to “tank-to-wheel” or “well-to-wheel”, but complete “cradle-to-grave” scope is necessary

3.2 LCI and data management

Several metal industries collect their own industry data via associations, and provide average LCA datasets of their products. For example, ICA collects timely life cycle data since 2000 for the 3 most important semi-finished copper products – tube, sheet and wire products. The data are provided to interested parties but also used to fulfil the sustainability aims of the copper industry itself (ECI 2015). On a global basis, IAI provides LCI data in detailed reports and also uses them in case studies such as their “Towards sustainable cities“, which investigates the impacts and benefits of building products made of aluminium (IAI 2015b). This is complemented by regional data provided by European Aluminium Association (EAA). Data are provided for primary aluminium ingot and further manufactured products such as aluminium sheet or foil. worldsteel has released its 2010 global steel LCI. The datasets provide data on the environmental profile of 16 key products, representative of the spectrum of steel production.

LCI data are usually provided in two manners:

- Data published on an organization’s webpage or report where the user can get background information of the data compilation process and extract data and convert it to a format for their own purposes
- Data compiled in a dataset with a specific format, ready to be used in a software tool

The automotive industry is a downstream user of LCI data of metals. Following this demand, back in 2003, the German Association of the Automotive Industry (Verband der Automobilindustrie – VDA) developed a Data Collection Format for LCA, serving as a means of collection, processing and documentation of environmentally relevant pro-

cess data along the life cycle of a product (Finkbeiner, Krinke et al. 2003). It is still operational today, but according to industry representatives, this data collection approach is less used. The main reason is considered to be the more detailed data requests and thus, the unavailability of the format to cover the data requirements.

Data management along the supply chain is a key interest for both the metal and automotive sectors. For the automotive industry it focuses on acquiring the most representative upstream data for their products. For the metal industry this is an important aim as well, but furthermore data provision to their business customers (e.g. the automotive sector) can enable a good B2B relation and is, therefore, a tool for customer retention.

In most cases the metals industry provides aggregated data to the automotive sector. The development and use of aggregated data ensures that the data are used in an appropriate manner, whilst confidentiality is respected. Moreover, taking single processes out of the metal production chain can lead to false results.

The metal industry considers that industry averaged datasets are the most accurate and representative of current production and transformation practices, for example, steel is a globally traded commodity and using global average data is appropriate for many studies (worldsteel 2011). These industry averaged datasets are externally reviewed (Eurometaux 2015a).

Furthermore, open communication along the supply chain is gaining importance in general. Knowledge of the supplier and origin of the material that is used in production is seen as a key priority for proving a sustainable supply chain. Therefore, there are first B2B projects in which the representativeness of data is discussed and possibilities for improvement are investigated.

In addition to that, very specific data is a new point of focus. Automotive companies often have the internal aim to show improvements from one model to its successor. Therefore, not only data on company specific production is required, but also data on new grades of materials, that are far more specialized, are assessed. In these cases a general approach to supply data via a well-documented database is not sufficient, because very detailed information is needed. Only the direct contact between the supplier and the producer can ensure that these details can be provided. In this regard, as the demand for the data has developed in the recent years, the earlier mentioned VDA data collection templates are less used.

As in probably every industry sector, one challenge of the automotive industry is the dependence on the availability of representative datasets. It will not always be feasible to provide LCI data for all of the identified materials and manufacturing processes, especially in highly innovative industries such as the automotive sector.

Summary:

- Management of the whole supply chain of a product is becoming a priority; thus,

relevant LCI data is needed

- Development and use of aggregated LCI datasets is recommended when confidentiality has to be respected
- Aggregated LCI datasets from the metals industries are already available; documentation of data sets has to be improved and harmonized
- It is very important that provider and demander of data agree on the best suitable data format
- Industry averaged datasets are the most accurate and representative
- Different levels of data detail are suitable for different types of studies
- Very specific data is becoming a new point of interest to for automotive companies

3.3 Allocation in LCA

3.3.1 Allocation of co-products

When dealing with multiproduct systems, ISO 14044 recommends tackling allocation according to one of the following options, appearing by order of preference:

- 1) when possible, allocation should be avoided by either subdivision or by system expansion;
- 2) when allocation cannot be avoided, partitioning of the inputs and outputs of the system should be applied, based on physical relationships (e.g. mass or energy allocation);
- 3) the last possibility is to allocate the inputs and outputs based on economic value;

Co-production can occur at all stages of a metal production. The treatment of co-products is an especially relevant topic for the metal industry. There is not one common approach, as the characteristic of the joint-production heavily influences the choice of the appropriate method.

In PE's whitepaper (2014) a standardization of the co-product treatment has already been attempted. However, due to the complex situation of having different metals a single approach that fits to all situations has not been found. The report recommends distinguishing between base and precious metals and lists recommended approaches. All in all, a general recommendation is not suitable for specific cases and can therefore not be done on an overarching metals level.

According to worldsteel (2011), system expansion is the preferred method of the steel industry, as it provides the most consistent solution to avoiding many of the problems of other approaches. It closely represents the real interactions of steel production routes with the environment and avoids unsound theoretical scenarios. In contrast,

when metals are considered as input for construction materials, EN 15804 does not consider system expansion as an option to avoid allocation.

Summary

- In order to allow for comparability of results, existing agreements in the respective sectors should be used, but keeping ISO 14044 requirements as a fundament
- A common industry position on the definition on the most appropriate allocation rule depends on the specific co-product and should be defined together with the following or preceding participants along the supply chain. A general approach cannot be recommended.
- Allocation of co-products is an important topic and final results are very sensitive to the approach chosen

3.3.2 Allocation at End of Life

Regarding the EoL phase, ISO 14044 differentiates between the concepts of open and closed loop recycling. Closed loop recycling cannot only be fulfilled when a product is recycled back into the same product, but also when there are no change in the inherent properties of the material.

The allocation of recycling has a huge impact on the sustainability of products. Modelling of the recycling at the EoL phase for materials can be distinguished by two main extreme approaches that are highly discussed lately (also graphically presented on Figure 4):

- 1) Recycled content approach (“cut-off” or 100:0) – the product carries the full environmental burden of the production of its primary material (recycling at EoL does not offset the production of primary material)
- 2) End-of-life recycling approach (“avoided burden” or 0:100) – the product gets a benefit if a recyclable material is produced from the end-of-life product, i.e. it gets a credit

The metal industry sees the end-of-life recycling approach as the only proper approach to consider the recycling impacts of metals (Atherton 2007, worldsteel 2011). This avoided burden approach allows for consideration of recycling rates and the ability to account for quality losses in recycling (PE International 2014).

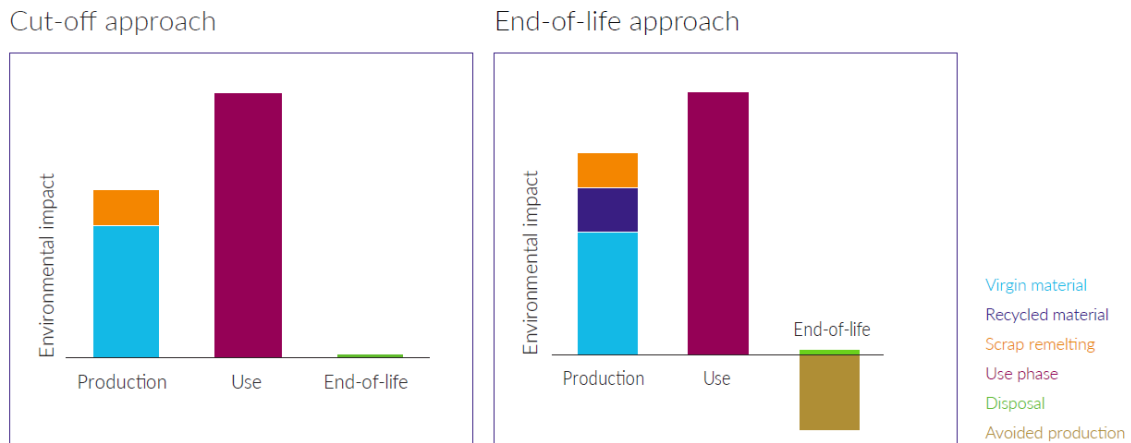


Figure 4: Comparison between cut-off (left) and avoided burden (right) approaches adapted from (worldsteel 2011).

Within the automotive industry both approaches are commonly used, but the avoided burden approach seems to be preferred. However, the majority of LCA studies in the automotive sector agree upon the low EoL importance. Moreover, EoL recycling is seen as uncertain by the automotive companies. Although they ensure via their material choices that the vehicles are recyclable, they cannot know or actually influence that this takes place when the end of the use phase of a car is reached after several years. But prompt scrap (originated during punching process in automotive industry) is considered to be recycled. In this case the car manufacturers can ensure that the recycling actually takes place.

To apply the right credit a fair evaluation has to be done. A suitable methodology determining the so-called “value-of-scrap” is described in worldsteel (2011).

While recycled metals are usually considered equivalent as primary metals in term of quality and properties, special attention needs to be given to some elements or contaminations, which may affect more directly the quality of the recycled ingot/slab etc. This could mean a change in the inherent properties. In addition to that it should be evaluated if the chosen approach reflects the actual recycling reality. Ideally, a methodology based on non-subjective criteria should be used for such evaluation.

Furthermore, McMillan et al. (2012) state in their study that “contrary to the position of the metals industry, metals are not necessarily recycled at high rates, [but] are recycled only a small number of times before final disposal, and are sometimes limited in recycling potential by the economics of contaminant removal”. The analysis concludes that “metal recycled from old scrap largely serves as an imperfect substitute for primary metal” (McMillan, Skerlos et al. 2012). This point of discussion further arose in the “Metal sheets” PEF pilot (2015a).

Probably consensus will never be found in the discussion between the two approaches, due to the involvement of value judgements and preferences in the modelling of EoL. Furthermore, according to Frischknecht (2010), such consensus is not even needed,

but only “clear statements from (public or private) commissioners of LCA study on their preferences with regard to the sustainability concept and risk perceptions to derive the adequate modelling of recycling.” However, the recyclability of metals is considered as one of their essential characteristics and special properties. Metals undergo multiple recycling cycles; therefore, they are already an important part of the European aim of a circular economy. In this sense, based on the cut-off and avoided burden approaches, numerous alternatives for EoL allocation can be found in the literature. Some are described herewith.

The default 50:50 recycling formula proposed in the PEF guide (2013b) tries to combine both cut-off and avoided burden approaches of the recycling chain by considering 50% of the recycled content impacts and 50% of the end-of-life impacts. However, by trying to meet all expectations, this approach does not reflect the recycling reality of many cases, because it is too general. The metal sheets project (Eurometaux 2015a) promotes an alternative by suggesting the so-called “integrated equation” (described in the “Metal sheet” PEFCR (2015a), which theoretically can consider both sides of the recycling chain. By implementing a quality factor in the recycling formula it ensures that the reality of recycling is actually reflected. Alternatively, justifying that no change in the inherent properties of recycled metal occur is possible via a verification scheme as developed in the multi-recycling approach by Neugebauer and Finkbeiner (2013). If a material maintains its inherent properties, and if it can be recycled over and over again, the multi-recycling approach offers the opportunity to map the recycling, which takes place in reality, with an LCA modelling approach. The multi-recycling study analyses the concept of several material and recycling loops. It allows for a product-independent point of view because it focuses on a material pool, meaning all scrap is collected in one pool and then recycled to make any kind of new products. This approach also provides a combined view on primary and secondary production.

Regarding the choice of representative datasets the user has to make informed choices. If a metal product can be produced via primary and secondary production route, a production mix allows for best representativeness. If a specific material grade is technically only producible via either primary or secondary production route, the respective data set should be chosen.

Summary

- It is important to account for recycling at EoL to get the full picture of a product's performance
- When results are reported across sectors along the supply chain, impacts resulting from recycling should be reported separately to allow for best data usage
- Implementation of quality factor to ensure the reflection of the reality is supported: material specific properties such as multi-recyclability should be reflected by the recycling approach

3.4 Impact assessment in LCA

Automotive producers use the most accepted indicators (e.g. GWP, AP, EP, etc.) only, whereas some indicators (e.g. toxicity, water depletion or abiotic depletion potential (ADP)) are still under discussion or considered immature for LCA (Lehmann, Bach et al. 2015). The main Life Cycle Impact Assessment (LCIA) method used is CML (in EU) and TRACI (in USA) (thinkstep 2015). The same applies for the metals industries. There are other methods which lack reliability and are therefore seldom used and published.

One of the indicators being largely discussed in the recent years and being of a great importance for the metals industry, is ADP (also discussed in the **background document** “Current state in resource efficiency evaluation”). For providing a realistic picture of resource depletion Guinée (1995) proposed to use the so called “ultimate reserve” baseline ADP, presented in CML 2001. It represents the quantity of resources that is ultimately available in the earth’s crust. The figure is often criticized as ultimate reserves cannot be extracted completely (Schneider, Berger et al. 2015). Alternatively, the “reserve base” approach has been proposed and implemented in CML 2002. However, the main criticism against the “reserve base” ADP is that the role of exploration is neglected and the total stock of elements is assumed to be fixed (Eurometaux 2015a). The reserve base of most resources has increased over the past, even though the actual depletion problem (referring to the geologic availability of resources) must necessarily have deteriorated. Moreover, the “reserve base” approach has a strong economic link and provides limited information with regard to the availability of geological stocks. Thus, the assessment of reserve base is ephemeral and not a good basis for the assessment of abiotic resource depletion (Schneider, Bach et al. 2015). This leads to false results in CML 2002, proposed as a mandatory impact category by PEF.

In this regard, alternatives have to be used and tested. As described in the **background document** “Current state in resource efficiency evaluation”, a proposal for improvement of ADP is the anthropogenic stock extended abiotic depletion potential (AADP) (Schneider, Berger et al. 2015). It enables a more realistic assessment of depletion of abiotic resources with regard to, e.g. the implementation of new technologies.

Limitations of existing impact assessment methods are especially relevant when it comes to communicating environmental impacts. Within the observed sectors, results to external peers are usually communicated on mid-point level (see section 4.1)

Moreover, the uncertainty increases when impact categories are weighted in order to obtain end-point and single score results. In this regard, ACEA stresses on the exclusion of single score indicators used in any LCAs disclosed to the public. Any weighting leading to single indicators is based on subjectivity and bias. Complexity of environmental impacts cannot be reduced to one single number in a meaningful way and would reduce the transparency of decision making (ACEA 2012).

Summary

- The use of scientifically robust and internationally accepted impact categories and assessment methods is a topic for metals and automotive industries (e.g. “reserve base” ADP provides false results and should not be used)
- Alternatives to ADP to be tested, such as e.g. AADP
- To make sure that all impacts can be evaluated and interpreted correctly a good collaboration of the sectors has to be ensured
- The use of single score indicators for external communication is not supported by the observed industries

3.5 Inclusion of LCA in automotive legislation

Cars are a significant source of GHG and other air emissions. Tailpipe emissions of light duty vehicles alone are estimated to account for 10% of global CO₂ emissions. For a typical gasoline-powered vehicle roughly 85% of GHG emissions come from the fuel cycle with the remaining 15% caused by vehicle production and disposal (WorldAutoSteel 2013). Regulators around the world are addressing this challenge by setting progressive automotive tailpipe GHG emission limits, fuel economy standards or a combination of both.

Due to the direct link with fuel consumption, the tailpipe performance is also relevant to the end-customers. However, during their purchasing decision they are driven by different forces (ADAC 2013). The consumed fuel per kilometre driven is among the top priorities. This can be seen as another motivation for automotive companies to reduce the car’s fuel consumption. Although this is in most cases motivated by monetary savings for the car users, lower fuel consumption results in CO₂-emissions savings during use-phase.

However, “use-phase-only” thinking and the respective legislation is creating an unforeseen problem: the vehicle’s embedded emissions from production and disposal are becoming a greater portion of the life cycle emissions. Current regulatory frameworks do not recognize this (Petterson, Alexander et al. 2011). The current tailpipe directive of the EC excludes the calculation of the overall life cycle impact of a vehicle (worldsteel 2013). Thus, a potential impact reduction in the use phase that leads to an increase of the emissions in other phases (e.g. production) cannot be detected.

In 2013, WorldAutoSteel published a press release where a new study is described. It underscores the need for “a life cycle approach in future automotive emissions regulations as vehicle production phase emission impacts become more significant” (Hickey 2013). It is justified, due to the increasing efficiencies of powertrains and fuels that contribute to lower emissions during the driving phase of a car. The inclusion and accounting for the production and recycling phase is seen as a key point. But the idea of im-

plementing LCA in future regulations is not finally discussed and resolved. In addition to that the best way of starting such an implementation is still an open question.

Furthermore, LCA is on the political agenda and it is already widely used by individual companies in practice. A study by Lehmann et al. (2015) showed that there is a broad range of policy options (including mandatory and voluntary options) for implementing LCA into automotive legislation. Still there is no clear scientific preference of a single option to be implemented.

Contrarily, in their position paper, ACEA underline that LCA can be suitable as a mean of indicating possible answers to environment-policy questions. However, choice of the most suitable instrument is to be made against the background of the question and the investigative framework (ACEA 2012). ACEA recommends that LCA should remain a voluntary tool. Mandatory LCA reporting and mandatory applications of LCA are considered to be not suitable given the developing nature of the LCA techniques and impact assessment indicators.

Summary

- “Use-phase-only” legislation is creating unintended consequences
- Inclusion of complete life cycle perspective in automotive policy is needed
- A range of mandatory and voluntary options for inclusion of LCA in automotive legislation are available

3.6 Inclusion of economic and social aspects

Apart from the environmental aspects, sustainability includes social and socio-economic aspects. Although lacking solid methodological basis (see **background document** “Current state in LCSA”), life cycle based social aspects are becoming more into the focus of the industries, especially for the automotive sector. Lately more effort is being invested in evaluating social and socio-economic impacts of their production and consumption on the workers, the local communities, the consumers, the society and all value chain actors. The BMW Group is one of the founders of the Roundtable for Product Social Metrics and contributor in the development of the Handbook for Product Social Impact Assessment (Fontes 2014). Daimler is also working on social metrics, e.g. (Karlewski 2015). However, due to insufficient maturity of SLCA, social aspects are rarely reported outside of the CSR reporting framework.

A hotspot in terms of social aspects along the supply chain of metals is mining (especially for activities outside EU). However, in this industry, as in the automotive sector, social impacts are reported mostly through CSR initiatives, and very seldom having a life cycle perspective. Furthermore, the Global Reporting Initiative (GRI) have developed individual sustainability reporting guidelines for mining and metals sector (GRI 2013).

Regarding Life cycle costing (LCC), several studies (mostly relating to material alternatives for reduction of weight) also deal with life cycle costs. Often the lightweight material scenarios show increase in materials and manufacturing costs (Witik, Payet et al. 2011). LCC in the production of vehicles is the topic of a book from Bubeck (2002).

No publicly available studies of the metals or automotive sectors are available that report on complete LCSA, considering both social and economic aspects along with environmental LCA; however, results of such are already used internally.

Summary

- Automotive companies are working in the development of methods for the evaluation of life cycle social and socio-economic impacts along their supply chains
- SLCA and LCC are still not used together with environmental LCA in order to have a complete LCSA study

4 Presentation and communication of sustainability results

4.1 Communication of environmental aspects

Although vehicles are end products, the communication of their potential impacts is directed to both business and private consumers (approx. 50:50 share). EPD communication is not common for the automotive sector. B2B communication forms are usually independently developed documents by each manufacturer.

Whereas, e.g. VW exclusively communicates only one impact category (i.e. GWP) in their Environmental Commendations, Daimler discloses several impact categories (PED, GWP, AP, EP, ADP, POCP, etc.) in their LCA studies of Mercedes-Benz through the so called Environmental Certificates. Often producers focus more on the improvements in the operation phase, neglecting to disclose information on other relevant life cycle phases. Obviously, there is no clear standardized communication approach, although these communications are usually based on third-party reviewed LCA studies.

As described above in section 2.3, PCRs on metals and metal products are developed by single entities and a common industry approach is missing. As a result, there are overlapping PCRs that are not comprehensive enough. Moreover, in some cases the rules can be interpreted too generally, which does not allow for comparable EPDs.

4.2 Communication of economic and social aspects

Qualitative and quantitative results on social and economic performance extend only to the coverage of indicators and their communication through (sustainability) reports. Reporting of life cycle based sustainability indicators (other than only environmental) is more a pro-active measure to inform stakeholders. However, companies are more actively engaged in identifying sustainability risks and assessing suppliers along the supply chain. Nevertheless, results on life cycle based social and economic assessments are still not communicated officially to consumers, but rather still kept in the frame of scientific research. Assessment methods for these two sustainability pillars seem to suffer still some lack of maturity in order for the companies to recognize themselves in their official communication and results.

Summary

- PCR development initiatives to be led by industry associations, in order to increase credibility and larger use of the rules; thus, also reducing the number of overlapping PCRs.

- The use of single aspect declarations (e.g. Carbon footprint declarations) in B2B communication should be avoided. Instead, verified Type III declarations, containing full spectrum of impacts to be incentivized.
- Social and economic performance is mostly communicated through CSR reports
- Life cycle based social and economic assessments are still not publicly disclosed

5 Outlook: key areas of further development

Agreements and harmonization activities within the observed industry sectors and along industrial supply chains should be supported. The achievements have to be taken into account for future assessments and regulations.

An improved **data exchange** along the supply chain will enable industries to identify hotspots as working points for improvements:

- Industry averaged data sets are most representative and should be used. Along the supply chain aggregated data sets can be exchanged.
- Documentation on already available data sets should be harmonized.

Agreed scientific **allocation rules** for specific **co-product** and **recycling** cases will allow for better comparability of results:

- Allocation rules should follow ISO 14044 requirements and should represent specificities of the co-products.
- Agreements on allocation rules should be sought and communicated along the supply chain. Recycling phase should be accounted for in an LCA to get the full picture. Results should be reported separately to allow for best data usage.
- Material specific properties should be reflected by the recycling approach.

The correct choice of **system boundaries** will avoid burden shifting between different life-cycle stages:

- The full life cycle perspective should be taken into account and this should be reflected in future automotive policies.

Results focussing on one single aspect can hide hotspots and can therefore only be the first step. Final assessments need to respect complex situations.

The use of relevant **impact categories** will enable further uptake of LCA. Complex results need to be analysed to reveal solutions for improvements:

- Scientifically robust and accepted impact categories and assessment methods should be used.
- Single score indicators should not be used for external communication.

Further research on the practicability of **full sustainability assessment** approaches is needed:

- The use of SLCA and LCC is only starting. Further research for a broader application is recommended.

The improvement and broader uptake of already available **communication** rules will enhance transparency:

- Communication based on standardized rules developed by industry should be increased.
- Communication should not be based on single aspects.

6 Abbreviations

ADP	Abiotic Depletion Potential
B2B	Business-to-Business
B2C	Business-to-Consumer
BEV	Battery electric vehicle
DfE	Design for Environment
EC	European Commission
EoL	End-of-Life
EPD	Environment Product Declaration
EU	European Union
GHG	Greenhouse Gas
GRI	Global Reporting Initiative
GWP	Global Warming Potential
IAI	International Aluminium Institute
ICA	International Copper Association
ISO	International Organization for Standardisation
LCA	Life Cycle Assessment
LCC	Life Cycle Costing
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
LCSA	Life Cycle Sustainability Assessment
PCR	Product Category Rules
PED	Primary Energy Demand
PEF	Product Environmental Footprint
PHEV	Plug-in hybrid
POCP	Photochemical Ozon Creation Potential
R&D	Research and Development
SLCA	Social Life Cycle Assessment
UNEP/SETAC	United Nations Environmental Programme/Society of Environmental Toxicology and Chemistry

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