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Best Environmental Management Practice for the Car Manufacturing Sector

Learning from frontrunners

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Title: Best Environmental Management Practice for the Car Manufacturing Sector

Abstract: The European automotive industry is one of the EU's largest manufacturing sectors, and the automotive value chain covers many activities largely carried out within the EU, such as design and engineering, manufacturing, maintenance and repair, and end-of-life vehicle (ELV) handling. This Best Practice report describes Best Environmental Management Practices (BEMPs), i.e. techniques, measures or actions that are implemented by the organisations within the sector which are most advanced in terms of environmental performance in areas such as energy and resource efficiency, emissions, or supply chain management. The BEMPs provide inspirational examples for any organisation within the sector to improve its environmental performance.
The report firstly outlines technical information on the contribution of car manufacturing and end-of-life vehicle (ELV) handling to key environmental burdens in the EU, alongside data on the economic relevance of the sector. The second chapter presents best environmental management practice of interest primarily for manufacturing companies (car manufacturers and associated manufacturers in the supply chain) covering cross-cutting issues related to key environmental impacts (such as energy, waste, water management, or biodiversity) before exploring best practice linked to specific topics, such as supply chain management.
Subsequently, specific information concerning actors in the treatment of end-of-life vehicles is presented in the third chapter, focussing in particular on best practice applicable to processers of ELVs.
This Best Practice Report was developed with support from a Technical Working Group of experts from the car manufacturing and ELV sector and associated fields.
The report gives a wide range of information (environmental benefits, economics, indicators, benchmarks, references, etc.) for each of the proposed best practices in order to be a source of inspiration and guidance for any company of the sector wishing to improve environmental performance. In addition, it will be the technical basis for a Sectoral Reference Document on the car manufacturing sector, to be produced by the European Commission according to the EMAS Regulation.

Contents

Acknowledgements

This **Best Practice Report** was prepared by the European Commission's Joint Research Centre in the framework of supporting the development of an EMAS Sectoral Reference Document for the car manufacturing sector. This document is based on a preparatory study (Background Report) carried out by Ricardo-AEA (UK), currently trading as Ricardo Energy and Environment.

In the course of preparing that background report, and this present best practice report, numerous experts from companies active in the target sector provided invaluable information which greatly enriched the technical content described; their contribution is highlighted in the body of the report for each individual Best Practice section.

Moreover, a technical working group, comprising a broad spectrum of experts in the manufacture of cars and automotive components, and the handling of ELVs, supported the development of the document by providing input and feedback. Technical summaries from the meetings of the technical working group are available on the Joint Research Centre's website[1].

The authors also wish to acknowledge the editorial support of Carmen Ramírez and Soledad Doñaque of the Joint Research Centre.

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[1] http://susproc.jrc.ec.europa.eu/activities/emas/car.html

Executive summary

Policy context

EMAS is a management tool for companies and other organisations to evaluate, report and improve their environmental performance. The latest revision of the EMAS Regulation (EC No. 1221/2009) introduced a particular focus on promoting best environmental management practices. To support this aim, the European Commission is producing Sectoral Reference Documents to provide information and guidance on BEMPs in eleven priority sectors, including the Car Manufacturing sector.

The present Best Practice Report provides the technical basis for the development of the EMAS Sectoral Reference Document for the Car Manufacturing Sector according to article 46 of the EMAS Regulation.

Main findings

The European **automotive industry** makes an important contribution to many of the EU's national economies and is one of the EU's largest manufacturing sectors.

Around 2.3 million people are directly employed in the manufacture of motor vehicles in the EU (including commercial vehicles), and around 12.2 million people indirectly employed along the whole value chain – about 5% of the EU's employed population. The sector itself represents around 4% of the EU's GDP.

The automotive value chain covers many activities largely carried out within the EU, such as design and engineering, manufacturing, maintenance and repair, and end-of-life vehicle (ELV) handling. These in turn exert a range of **environmental impacts** such as energy consumption, climate change, resource use, waste production, water consumption, emissions to air, soil and water, and impacts on ecosystems.

The present Best Practice Report provides an overview of techniques that may be considered **Best Environmental Management Practices (BEMPs)** in the car manufacturing sector, with a focus on the **manufacturing** and **end-of-life vehicle handling** stages. BEMPs are techniques, measures or actions that are implemented by the organisations within the sector which are most advanced in terms of environmental performance in areas such as energy and resource efficiency, emissions, or supply chain management. The BEMPs provide inspirational examples for any organisation within the sector to improve its environmental performance.

The report was developed by the European Commission's Joint Research Centre in the framework of supporting the development of an EMAS Sectoral Reference Document for the sector[2]. It is based on an extensive background study carried out by Ricardo-AEA (UK)[3]. Additionally, a technical working group, comprising a broad spectrum of experts in the automotive sector, supported the development of the document throughout this process by providing inputs and feedbacks.

The main target groups of this report are **manufacturing companies** (car manufacturers and associated manufacturers in the supply chain) and **ELV handling** companies. The selected BEMPs are practices already implemented by some companies in the sector, leading to very high levels of environmental performance and with large potential to be adopted more broadly.

The report covers core business activities of companies belonging to the car manufacturing sector. It specifically targets companies that belong to NACE code 29, as well as some companies belonging to NACE code 38.3.1.

The report encloses BEMPs for the following two areas:

[2] Further information on the development of the EMAS Sectoral reference Documents is available online at: http://susproc.jrc.ec.europa.eu/activities/emas/documents/DevelopmentSRD.pdf

[3] currently trading as Ricardo Energy and Environment.

- Car manufacturing processes;
- End-of-life vehicle treatment.

These areas are briefly presented below.

A. Manufacturing

The BEMPs in this area offer guidance on some of the core manufacturing activities of the production of automotive bodies, powertrains and components, as well as some more general supporting processes, such as plant utilities. The BEMPs identified in this area are briefly listed below:

- A BEMP on the implementation of an advanced *environmental management system*;
- A BEMP on the implementation of detailed *energy monitoring and management* systems;
- A BEMP on increasing the efficiency of *energy-using processes* ;
- A BEMP on *renewable and alternative energy* use;
- A BEMP on optimising *lighting* in automotive manufacturing plants;
- A BEMP on the rational and efficient use of *compressed air*;
- A BEMP on optimising *electric motor* usage;
- A BEMP on preventing and managing *waste*;
- Three BEMPs on *water management*, i.e. on water use strategy and management, water-saving opportunities in automotive plants, and water recycling and rainwater harvesting;
- A BEMP on *green roofs* for stormwater management;
- Two BEMPs on *biodiversity management*, i.e. on the review and strategy of ecosystems and biodiversity management throughout the *value chain*, and on biodiversity management at *site level*
- A BEMP on promoting environmental improvements along the *supply chain*;
- A BEMP on collaboration with suppliers and customers to reduce *packaging*;
- A BEMP on designing for sustainability using Life Cycle Assessment (LCA); and
- A BEMP presenting general best practices for *remanufacturing* components.

B. End-of-life vehicles

The BEMPs in this area offer guidance on some of the core activities carried out by processers of end-of-life vehicles, principally authorised treatment facilities. The BEMPs identified in this area are briefly listed below:

- A BEMP on component and material *take-back networks* ;
- A BEMP on *depollution* of vehicles;
- General best practices for *plastic and composite parts*; and
- Best practices for *other automotive components* and materials.

Most of the BEMPs are broadly applicable to companies of the sector of any size. When specific technological, economical or geographical limitations exist for the implementation of each identified BEMP, these are described in the relevant sections and summarised in the conclusions[4].

Related and future JRC work

This best practice report is part of a series of related documents, each supporting a Sectoral Reference Document for a priority sector identified under EMAS.

The present report will be usefully complemented by the forthcoming report on the Fabricated Metal Products manufacturing sector, which covers many process steps which are present in car manufacturing but also used more broadly. Some aspects of the report concerning the Electrical and Electronic Equipment manufacturing sector may also be relevant to the readership of the present report.

[4] The table in Chapter 5, summarises the key environmental performance indicators and benchmarks of excellence (where available) for each identified BEMP.

Quick guide

This document is not primarily intended to be read from beginning to end, but as a working tool for professionals willing to improve the environmental performance of their organisation and who seek reliable and proven information in order to do so. As such, different parts of the document will be of interest and will apply to different professionals and at different stages:

- A rapid way to start using this document is by reading section 2.2 about its structure to understand the areas for which BEMPs have been described and how these BEMPs have been grouped.

- Then, Chapter 1 would be a good starting point for readers looking for a general understanding of the sector and its environmental aspects.

- For readers looking for practical information on how to improve their environmental performance in a specific area, it is recommended to start directly at the concrete description of the BEMPs on that topic, which can be easily found through the table of contents (at the very beginning of the document). Chapter 2 covers BEMPs related to manufacturing activities while Chapter 3 deals with ELV-related topics.

Preface

Context and overview

This **Best Practice Report**[5] provides an overview of techniques that are **Best Environmental Management Practices** (BEMPs) in the car manufacturing sector. The document was developed by the European Commission's Joint Research Centre (JRC) on the basis of desk research (including a Background Report produced by Ricardo Energy and Environment on behalf of the JRC), interviews with experts, site visits and in close cooperation with a Technical Working Group (TWG) comprising experts from the sector. This Best Practice Report provides the basis for the development of the EMAS Sectoral Reference Document (SRD) for the car manufacturing sector. The structured process for the development of best practice reports is outlined in the guidelines on the ***"Development of the EMAS Sectoral Reference Documents on Best Environmental Management Practice"*** (European Commission, 2014), which are available online[6].

EMAS (the EU Eco-Management and Audit Scheme) is a management tool for companies and other organisations to evaluate, report and improve their environmental performance. To support this aim and according to the provisions of Art. 46 of the EMAS Regulation (EC No. 1221/2009), the European Commission produces SRDs to provide information and guidance on BEMPs in several priority sectors, including the car manufacturing sector.

Nevertheless, it is important to note that the guidance on BEMP is not only for EMAS participants, but rather, it is intended to be a useful reference document for any relevant company that wishes to improve its environmental performance or any actor involved in promoting best environmental performance.

Key stakeholders who may benefit from this guidance include practitioners in the following sectors:

- **Car manufacturing processes**: including a broad range of stakeholders involved at all stages of the supply chain, such as:
    - Car manufacturers and suppliers to car manufacturers (incl. remanufacturers),
    - Equipment suppliers,
    - Researchers and NGOs.
- **End-of-life vehicle (ELV) handling**: effective implementation of BEMPs often involves collaboration between several stakeholder groups:
    - Remanufacturers of used automotive components,
    - ELV collection networks,
    - ELV depollution, dismantling and treatment facilities,
    - Recycling and waste management firms.

Representatives from these stakeholder groups were involved in the preparation of this document either on an individual basis or through their involvement in the Technical Working Group (TWG) which reviewed and provided feedback on the current Report, as described above.

[5] This report is part of a series of 'Best Practice reports' published by the European Commission's Joint Research Centre covering a number of sectors for which the Commission is developing SRDs on Best Environmental Management Practice. More information on the overall work and copies of the 'best practice reports' available so far can be found at: http://susproc.jrc.ec.europa.eu/activities/emas/

[6] http://susproc.jrc.ec.europa.eu/activities/emas/documents/DevelopmentSRD.pdf

Section 2.2 (**Structure**) below provides more information on the indicative applicability of best practices for various stakeholders.

BEMPs encompass techniques, measures or actions that can be taken to minimise environmental impacts. These can include technologies (such as more efficient machinery) and organisational practices (such as staff training).

An important aspect of the BEMPs proposed in this document is that they are proven and practical, i.e.:

- they have been implemented at full scale by several companies (or by at least one company if replicable/applicable for others);
- they are technically feasible and economically viable.

In other words, BEMPs are demonstrated practices that have the potential to be adopted on a wide scale in the automotive manufacturing sector, yet which at the same time are expected to result in an exceptional environmental performance compared to current mainstream practices.

A standard structure is used to outline the information concerning each BEMP, as shown in Table 1.

Table 1: Information gathered for each BEMP

Category	Type of information included
Description	Brief technical description of the BEMP including some background and details on how it is implemented.
Achieved environmental benefits	Main potential environmental *benefits* to be gained by implementing the BEMP.
Appropriate environmental indicators	Indicators and/or metrics used to monitor the implementation of the BEMP and its environmental benefits.
Cross-media effects	Potential *negative* impacts on other environmental pressures arising as side effects of implementing the BEMP.
Operational data	Operational data that can help understand the implementation of a BEMP, including any issues experienced. This includes actual and plant-specific performance data where possible.
Applicability	Indication of the type of plants or processes in which the technique may or may not be applied, as well as constraints to implementation in certain cases.
Economics	Information on costs (investment and operating) and any possible savings (e.g. reduced raw material or energy consumption, waste charges, etc.).
Driving force for implementation	Factors that have driven or stimulated the implementation of the technique to date.
Reference organisations	Examples of companies that have successfully implemented the BEMP.
Reference literature	Literature or other reference material cited in the information for each BEMP.

Sector-specific Environmental Performance Indicators and Benchmarks of Excellence are also derived from the BEMPs. These aim to provide organisations with guidance on appropriate metrics and levels of ambition when implementing the BEMPs described:

- **Environmental Performance Indicators** represent the metrics that are employed by organisations in the sector to monitor either the implementation of the BEMPs described or, when possible, their environmental performance directly.

It is important to stress that in most cases, indicators are designed to be used for continuous improvement through time, or possibly for comparing sites between them ensuring that they use the same methodology and nomenclature. However, they are not developed to enable direct comparisons between organisations.

- **Benchmarks of Excellence** represent the highest environmental standards that have been achieved by companies implementing each related BEMP. These aim to allow all actors in the sector to understand the potential for environmental improvement at the process level. Benchmarks of excellence are **not** targets for all organisations to reach but rather a measure of what can be achieved (under stated conditions) that companies can use to set priorities for action in the framework of continuous improvement of environmental performance.

The sector-specific Environmental Performance Indicators and Benchmarks of Excellence presented in this report were agreed by the TWG at the end of its interaction with the JRC.

Box 1

Environmental performance indicators and functional units

The EMAS environmental management system stresses the importance of environmental performance indicators to monitor improvement. In particular, the EMAS Regulation introduces the use of core indicators as well as specific indicators for suggested use by organisations, according to the specific priorities and areas of major environmental relevance of each organisation.

The **Environmental Performance Indicators** presented here with each of the BEMPs are proposals of metrics which can be used to monitor, directly or indirectly, progress achieved through the implementation of the BEMPs. These will be tailored to the specific needs and priorities of each organisation in order to be as relevant as possible under its own circumstances.

As such, many indicators can be normalised to allow for a comparison through time or even between different sites. **Annex IV.C.2.c of the EMAS regulation** offers a detailed discussion of the characteristics of the normalisation factors to be considered. These **'functional units'** will be chosen by each organisation to reflect a unit of output, of activity or resource use which is relevant for its specific case (and can be adapted depending on the site, environmental aspect considered, etc…). Typical metrics (usually counted over a reference period, e.g. 1 year) in use through industry as functional units could include:

- number of units (vehicles, engines, gearboxes, parts…) produced
- turnover in €
- added value in €
- output measured in kg
- full time equivalent (FTE) employees
- man-hours worked
- …

Role and purpose of this document

This document is intended to support the environmental improvement efforts of all companies in the car manufacturing and ELV handling sectors by providing guidance on best practices.

Companies from the car manufacturing and ELV handling sectors can use this document to identify the most relevant areas for action, find detailed information on best practices to address the main environmental aspects, as well as company-level environmental performance indicators and related benchmarks of excellence to track sustainability improvements.

This Best Practice Report provides the technical basis for the development of the EMAS Sectoral Reference Document (SRD) for the Car Manufacturing Sector according to Article 46 of the EMAS Regulation.

How to use this document – what this document is and is not

- This document is not primarily intended to be read from beginning to end, but as a working tool for professionals willing to improve the environmental performance of their organisation and who seek reliable and proven information in order to do so. As such, different parts of the document will be of interest and will apply to different professionals and at different stages.
    - A rapid way to start using this document is by reading section 2.2 about its structure to understand the content of the different chapters and, in particular, the areas for which BEMPs have been described and how these BEMPs have been grouped.
    - Then, the rest of Chapter 1 would be a good starting point for readers looking for a general understanding of the sector and its environmental aspects.
    - For readers looking for practical information on how to improve their environmental performance in a specific area, it is recommended to start directly at the concrete description of the BEMPs on that topic, which can be easily found through the table of contents (at the very beginning of the document). Chapter 2 covers BEMPs related to manufacturing activities while Chapter 3 deals with ELV related topics.
- This document is intended to support the environmental improvement efforts of all companies in the car manufacturing and ELV handling sectors by providing guidance on best practices. While some BEMPs might be of use to all companies within the sector and beyond, most are more directly applicable and useful to specific stakeholders. Section 2.2 provides a table highlighting the most relevant groups of stakeholders for the different BEMPs.
- BEMPs (and, more generally, the EMAS approach) are designed in reference to the *activities and processes* of an organisation, rather than *products*. In the present case, the focus of the document, is on car manufacturing (M1 category vehicles), as set out in the Commission Communication (2011/C 358/02), which identified a list of priority sectors for the adoption of SRDs. Since car manufacturing can be done in conjunction with, or at least present extensive similarities to, manufacturing of other types of vehicles (in particular vans but also larger vehicle categories), many BEMPs and techniques will be directly applicable or of interest to the manufacture of these vehicles. However, they have been developed primarily based on practice in the car manufacturing sector.

- The implementation of techniques contained in these documents is on a voluntary basis; these best practices are therefore supposed to complement and go beyond existing regulation which already covers the environmental impact of the sector, aimed both at the product- and activity/process-levels; in particular, major relevant texts include:
    - Regulations (EC) regarding the use phase, at product level such as Euro 5 and 6 (No. 715/2007 and 692/2008) or manufacturer level regulation e.g. on CO_2 (No. 443/2009). The use phase of vehicles is explicitly out of the scope defined for this work (see Scope section 2.1 below).
    - Best Available Technique (BAT) Reference Documents (or BREFs) formulated under the Industrial Emissions Directive, which set out references for setting Industrial Emissions Directive (IED) permit conditions (of a binding nature). Many of these apply to some activities in the car manufacturing value chain, e.g. on Treatment of Surfaces with Organic Solvents or for Waste Treatment (see section 0).
    - Directives relating to used cars such as the End-of-Life Vehicle directive (2000/53/EC) or "RRR" (Reusability, Recyclability, Recoverability) Directive (2005/64/EC).

More extensive references are provided in each section. The BEMP descriptions contained here, and which will form the basis of the forthcoming SRD, are therefore designed to cover additional practices that go beyond both the regulatory minimum, as well as common practices applied in the sector.

1 Introduction

General background information on the car manufacturing industry

Europe is currently the second-largest producer of passenger cars in the world, accounting for 24% of global production in 2015 (16.3 million units), second only to China (21.1 million units in 2015) (OICA, 2015). The industry makes an important contribution to many of the EU's national economies. Around 2.3 million people are directly employed in the manufacture of motor vehicles in the EU (including commercial vehicles), and indirect employment along the whole value chain brings the total employment to around 12.2 million people – approximately 5% of the EU employed population (ACEA, 2016).

The car industry in Europe suffered heavily following the economic crisis, and production still has not recovered to its peak levels seen in 2007 (OICA, 2015). Nevertheless, the sector continues to play a major role in EU international trade. Motor car exports were worth €139.4 billion in 2011 (around 7.5% of total value of all extra-EU exports), while imports were worth around €39.1 billion (less than 2.5% of the total value of all extra-EU imports) (ACEA, 2016; Eurostat, 2015). The majority of these exports (based on 2012 figures) were from Germany (around 60% of the total) and the UK (around 13%) (Eurostat, 2012).

In addition to the manufacture of cars, some environmental aspects of the treatment of End-of-life vehicles (ELVs) are also considered in this report. Since the average lifespan of a car in Europe is around 12 years (although this varies depending on the Member State), ELVs that are being treated today are (for the most part) cars that were manufactured many years ago. Official statistics report that around seven million units arise each year in the EU (Eurostat, 2013).

Composition of the sector

Table 2 provides an overview of the automotive industry sub-sectors according to the statistical classification of economic activities in the EU (NACE). The NACE code is the European standard industry classification system[7]. The total turnover of the automotive industry[8] - including manufacture of vehicles, bodies and components – was around €865 billion in 2010, and total value added was €217 billion (Eurostat, 2015).

Table 2: Overview of automotive industry sub-sectors (data for 2013)

Sub-sector	Turnover (€ billion)	Value added (€ billion)	Number of enterprises	Employment (thousands)
Motor vehicle manufacture NACE 29.1	620	158	2190	1040
Manufacture of bodies for motor vehicles NACE 29.2	27	7	7078	154
Manufacture of parts and accessories for motor vehicles NACE 29.3	218	52	10100	1100

Source: (Eurostat, 2015)

Notes: NACE codes referenced above are indicative of the scope of activities relevant to the car manufacturing sector, but may also include other sectors. Data from Eurostat refer to individual enterprises, rather than business groups of manufacturers. Figures include manufacture of passenger cars and commercial vehicles.

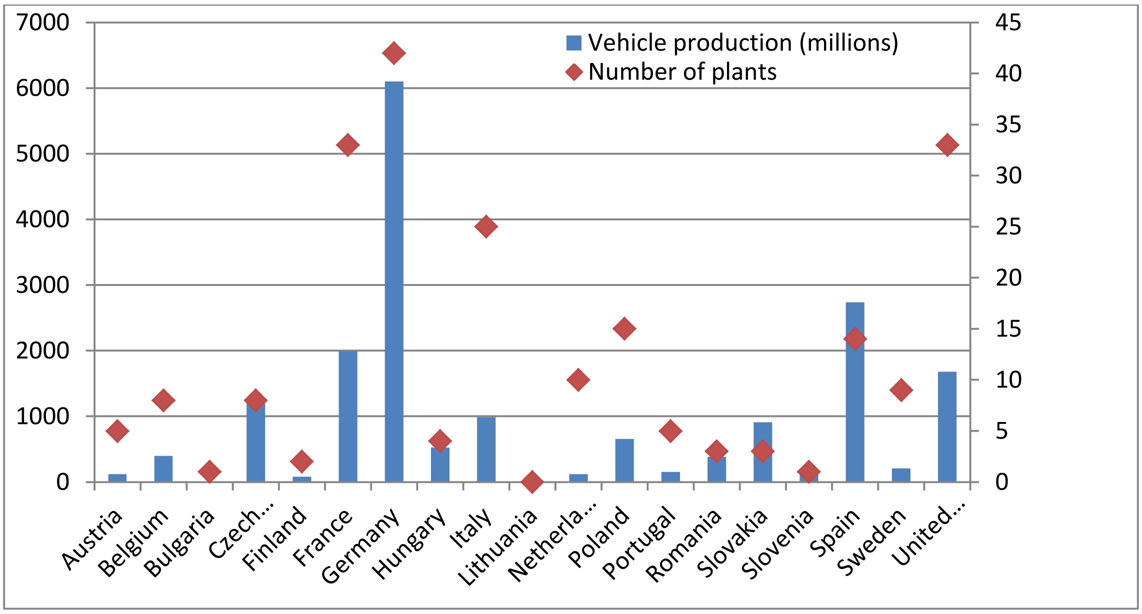
[7] See http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-RA-07-015/EN/KS-RA-07-015-EN.PDF
[8] Including passenger cars and commercial vehicles (vans, trucks and buses)

Precise figures for employment in the ELV sector are not available, as the activities involved are subsets of three wider areas: *Dismantling of wrecks* (NACE 38.31, including dismantling of ELVs for materials recovery), *Recovery of sorted materials* (NACE 38.32, including ELV shredding) and *Wholesale of waste and scrap* (NACE 46.77, including dismantling of ELV for obtaining and re-selling usable parts). ELVs are only a part of total shredder input, accounting for around 10% to 40% in many countries (Schneider et al, 2010).

Geographical distribution

Car production in Europe is concentrated in a small number of Member States. Figure 1 shows the volume of vehicle production and the number of production plants in each Member State. Germany is a clear leader (33% of total production in 2015). Other important producers include Spain (15%), France (11%), and the UK (9%), as well as the Czech Republic, Poland and Italy. The same countries are also the main producers of parts and components, although Central and Eastern European Member States such as Slovakia, Slovenia, Hungary and Romania are gradually gaining a higher share of total production, particularly with respect to parts and components.

Figure 1: Vehicle production and number of production plants per Member State in 2015



Source: (ACEA, 2016)

In total, there are around 220 vehicle production plants in Europe in 18 Member States (ACEA, 2016). Certain manufacturers have opened new manufacturing sites in Europe (mainly in Central and Eastern Europe) to take advantage of the lower production costs and the proximity to the Western European markets. While the majority of sites belong to European OEMs, others have also invested in new plants – for example, in the Czech Republic (Hyundai), Hungary (Suzuki) and Poland (Toyota) (Kawecka-Wyrzykowska, 2009).

Turnover and employment is also concentrated in a few Member States. Around 40% of total EU vehicle manufacturing turnover comes from Germany, and around 10% from France, while all other countries each account for less than 10% (Eurostat, 2013). Of the 2.2 million jobs in direct vehicle manufacturing, around 840,000 are based in Germany, 250,000 in France and between 100,000 and 200,000 each in the UK, Italy, Spain, Czech Republic and Poland (Eurostat, 2013).

Regarding the activities related to the processing of end-of-life vehicles (ELVs), those involve several stages that may take place at different facilities. In general, ELVs may be received by various types of Authorised Treatment Facilities (ATFs) for depollution (removal of liquids, airbags, batteries and other hazardous materials) and dismantling prior to shredding. These facilities include scrap yards, dismantling businesses, salvage operators and secondary metal businesses. The ELVs are typically passed on to shredding facilities once they have been depolluted and dismantled. Since shredding facilities involve large, capital intensive operations, they tend to be far fewer in number compared to ATFs. Indications of the number of ATFs and shredders in each Member State are provided in **Table 3**.

Table 3: Number of Authorised ELV Treatment Facilities (ATFs) and shredders in European countries

Member State	No. ATFs (incl. shredders)	Year of data source
Austria	216 (6 shredders)	2008
Belgium	120 (12 shredders)	2010
Cyprus	2	2008
Czech Republic	80-100	2005
Germany	1261 (36 shredders)	2008
Denmark	210	2005
Spain	540	2005
Estonia	32 (1 shredder)	2010
Greece	56	2008
France	1,000	2005
Finland	235	2010
Hungary	150	2005
Italy	1,800	2005
Ireland	85	2008
Luxembourg	4	2005
Latvia	261	2005
Lithuania	43	2005
Malta	ND	-
Netherlands	418	2008
Portugal	45	2008
Poland	557 dismantlers	2007
Sweden	365	2008
Slovenia	20	2005
Slovakia	30	2005
UK	1,750	2010

Source: (Schneider et al, 2010)

Refurbishment and remanufacturing activities account for over 32,000 jobs in Europe (with the automotive sector representing the largest part of this activity) (Optimat, 2013).

A large number of used cars are exported from the EU each year, which reduces the number of ELVs that require treatment. It is estimated that in 2013 between 3.4 and 4.6 million used vehicles were missing from national statistics ('unknown whereabouts' in ELV reporting, mostly resulting from non-harmonised data collection methodology, scrapped unofficially in the EU or exported unofficially) and about one and a half million used vehicles were exported to non-EU countries (Öko-Institut, 2016). According to Eurostat statistics (Eurostat, 2013), the countries with the highest number of 'actual' ELVs (registered) are the UK and France (about 20% of the total in Europe each).

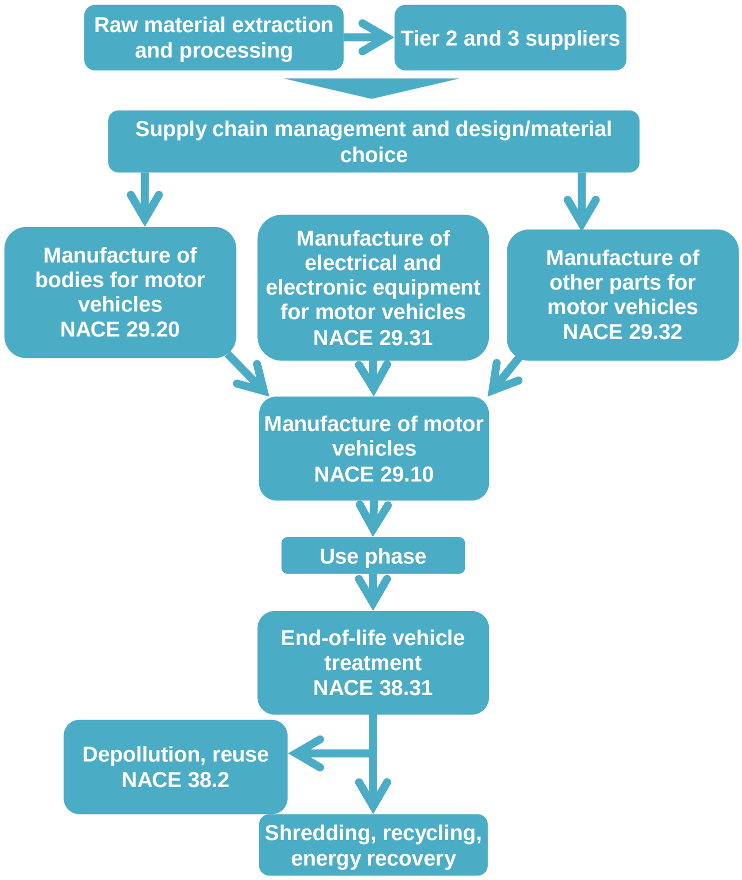
Overview of the automotive value chain

Vehicle manufacturers are known as Original Equipment Manufacturers (OEMs). There are a small number of major OEMs in the European market, although they typically manufacture and market a number of different brands. More broadly, the value chain of the car manufacturing industry, from materials supply to end-of-life treatment, incorporates the following main elements:

- **Supply chain:** Automotive suppliers are generally categorised in 'tiers'. Tier 1 describes suppliers delivering directly to OEMs, Tier 1 suppliers tend to supply some of the largest components or sub-assemblies (including powertrain, transmission and steering systems), and work in close collaboration with the OEMs. Tier 2 suppliers provide components to Tier 1 suppliers (e.g. pump units, bearing assemblies etc.). Finally, Tier 3 suppliers provide smaller components and raw materials to upper Tier suppliers or in some case the OEMs.
- **Engineering and design:** Most OEMs carry out design and engineering of the vehicles and all the major components in-house (while outsourcing some or all of the manufacturing as described above). Key decisions impacting all lifecycle stages are made during this pivotal activity.
- **Manufacturing and assembly stages,** including production of components, subassemblies and other equipment that is assembled in the final vehicle, as well as the manufacture of the vehicle body, engine etc. and final assembly. This includes operations typically carried out in-house by OEMs as well as externally by suppliers. Whilst a higher emphasis is placed on activities that take place within Europe, it is recognised that many important environmental impacts are generated along the supply chain in regions outside of Europe.
- **Use phase** including retail, maintenance, and repair. This is a key part of the vehicle lifecycle, but focussed on customer behaviour and product specification, and only indirectly linked to the automotive manufacturing activity per se.
- **End-of-life**: Treatment of the vehicle at the end of its life, including dismantling and depollution of the vehicle before shredding or general recycling.

A high level overview of the scope of activities covered in this report is shown in **Figure 2**. A distinction between suppliers and OEMs is not made in this figure, as the division of activities carried out varies depending on the organisations involved and their business models and may even differ for different products from the same organisations. In general, it can be said that the OEMs often (but not always) retain production of body panels and powertrain in-house, along with assembly and painting of the bodyshell, and attachment of assemblies and components to the painted bodyshell to produce the final vehicles. The majority of components and assemblies fitted to the vehicle (aside from the powertrain and body panels) are usually produced by suppliers. Likewise, the majority of the Best Practice described in this report can apply to OEMs or Tier 1 suppliers indistinctively, when activities carried out by each are similar or overlap. Aspects where this may not apply are highlighted in the relevant BEMPs.

Figure 2: High-level overview of sector-level scope for this report according to NACE (Rev.2)



The NACE code is the European standard industry classification system[9]. NACE codes referenced above are indicative of the scope of activities relevant to the car manufacturing and ELV sectors, but may also include other sectors.

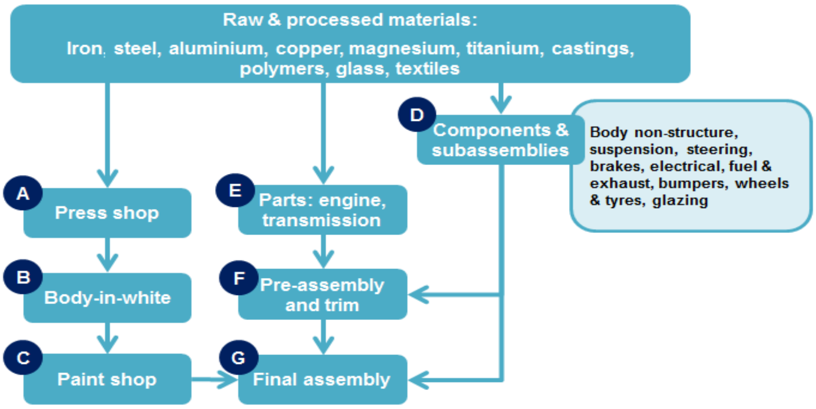
Key activities within car/component manufacturing

Passenger vehicles are very complex, with up to 180,000 parts (Schmidt, 2007), and typically around 75% of a vehicle's value is derived from automotive suppliers (CLEPA, 2013). As such, it is necessary to prioritise the scope of the investigated BEMPs for this report in terms of their importance, i.e. processes that: contribute to a significant proportion of environmental impacts in one or more categories, and over which the actors in the car manufacturing industry could have significant influence.

A high level overview of the stages of manufacturing a car is shown in **Figure 3** with a description of the processing stages, which correspond by and large to key areas or 'maintenance groups' within plants.

[9] See http://ec.europa.eu/eurostat/documents/3859598/5902521/KS-RA-07-015-EN.PDF

Figure 3: High-level overview of car manufacturing stages



The stages include:

Press shop: The vehicle body is typically made out of stamped steel, although other materials are increasingly used to reduce weight (such as aluminium, plastics and carbon fibre).

Body-in-white: Production of vehicle body structure including closures. The separate panels are assembled by welding or other joining methods.

Paint shop: Application of interior and exterior paint and finish. The body is usually painted with several layers to protect it from corrosion

Component and subassembly manufacturing (excluding powertrain and chassis): There are a large number of components and subassemblies in a vehicle. These include the exterior trim (e.g. wheels, bumpers, trim, glazing), interior trim (e.g. seats, dashboards, trim, fascia/dashboard, carpets, steering wheel), and electrical and electronic components (e.g. engine control units, safety systems, battery control systems, entertainment systems).

Manufacturing of powertrain and chassis: The chassis of the vehicle is the main structure, and is usually made out of a pressed steel frame on which other components can be mounted – such as wheels, steering gear, power train (engine, transmission, drive shaft), brakes and exhaust system.

Pre-assembly and trim: Certain parts may be assembled separately before being joined with the car body in the final vehicle assembly

Final assembly: Assembly of finished vehicle.

Vertical integration of automotive manufacturing plants

The automotive industry has been adapting manufacturing capabilities to respond to market constraints throughout the years, and as a result there is a very broad diversity in which key stages of automotive manufacturing (described above) are carried out in automotive plants. Whether greenfield sites or historical facilities, many different stages can be included, from almost completely integrated plants from foundry to finish, to 'CKD' (completely knocked-down) assembly-only plants, as well as intermediate configurations where suppliers are located near site.

It is therefore difficult to directly compare the environmental performance of plants with such broadly varying scopes. In the present document, while BEMPs have been developed to be as broadly applicable as possible, the applicability and relevance of the best practices (as well as indicators and benchmarks) will have to be tailored to the characteristics of each facility.

Key activities within end of life vehicle (ELV) handling

At the end of life stage, there are two main steps that can be considered:

Depollution: At the end-of-life, fluids are drained and hazardous materials (such as batteries and airbags) are removed.

Salvage and reuse: Spare and core parts that can be reused or recycled are removed. The remaining body is fed into a shredder.

Main environmental pressures and aspects in the sector and environmental requirements in force

Main environmental pressures

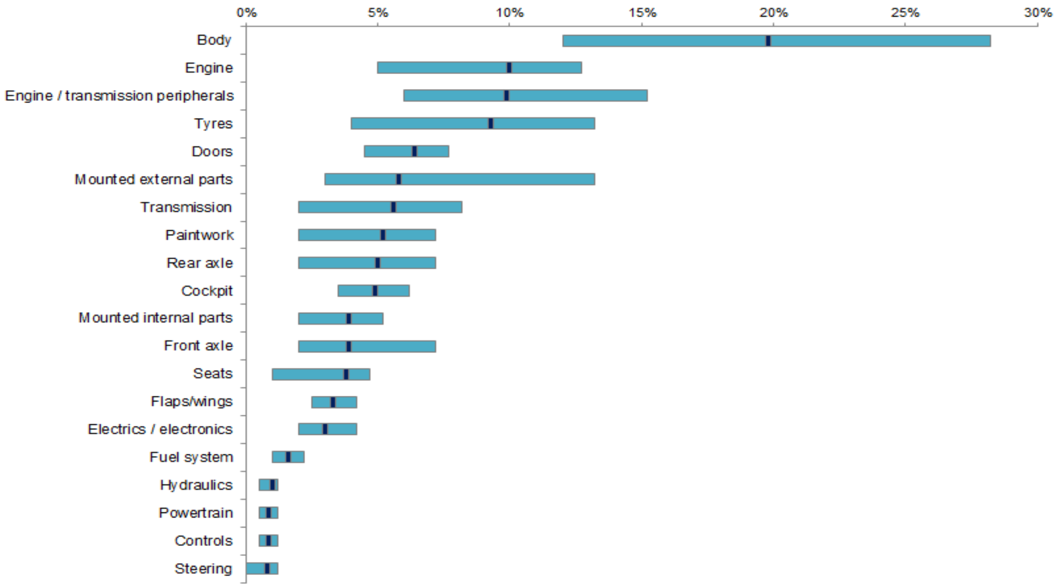
The guidance in this document aims to provide practical advice on how to reduce environmental impacts or pressures at the *organisational level*, rather than at the product level. It therefore focusses on best practices for specific manufacturing or organisational processes regardless of the chosen technologies included in the vehicle (such as the type of powertrain or the vehicle segment). However, it is worth noting that the in-use phase accounts for a significant proportion of overall environmental impacts in most categories.

The main environmental impacts related to car manufacturing and ELV treatment include:

- **Energy consumption and climate change:** Energy is used throughout the processes involved in vehicle production and ELV treatment. Energy consumption is often associated with emissions of greenhouse gases (GHGs), which lead to global warming and climate change. GHGs primarily consist of carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4).

Figure 4 shows an illustration of the range of CO_2 emissions from production of various parts. In terms of the specific components involved, in general most large components made primarily of metal account for a significant share of CO_2 emissions (which are closely correlated with energy use) – including the vehicle body, engine and transmission (Mercedes, 2009). Other metallic components may also account for a significant proportion of energy consumption (e.g. exhaust, axles, transmission).

Figure 4: Range (light blue) and average (dark blue) share of production CO_2 emissions from different components



Source: Values taken from life cycle studies across five different Mercedes models (E-class, C-class, SL-class, M-class and GLK-class) (Mercedes, 2009).

- **Resource use and waste production**: Higher levels of waste imply that more resources are consumed. Finite resources, security of supply and the environmental burdens of resource consumption are increasing concerns for many organisations, but of particular concern for the automotive industry is the need to balance the need to improve fuel efficiency while using materials that are recyclable at the ELV stage.
- **Water consumption**: The difference between the amount of liquid water input and waste water is the consumption. This accounts for freshwater withdrawals that are evaporated or incorporated in products and waste i.e. the water that is not available in liquid form for reuse immediately after it is consumed.

A breakdown of water consumption due to different processes is shown in Table 4**:** Water consumption through a car's life cycle (excluding use phase), litres per vehicle. Most of the water consumption occurs in producing iron and aluminium (Bras et al, 2012). The casting of metal components has a high water consumption value because the high temperatures involved in treating the materials requires more water for cooling (Bras et al, 2012).

Table 4: Water consumption through a car's life cycle (excluding use phase), litres per vehicle

Lifecycle phase	Water use	%	Water consumption	%
Material production	169,212	80%	5,570	68%
Parts production	34,956	17%	894	11%
OEM assembly/production	4,550	2%	1,490	18%
Recycling	3,039	1%	259	3%
Total (excluding use phase)	211,757		8,213	

Source: (Bras et al, 2012), based on literature values

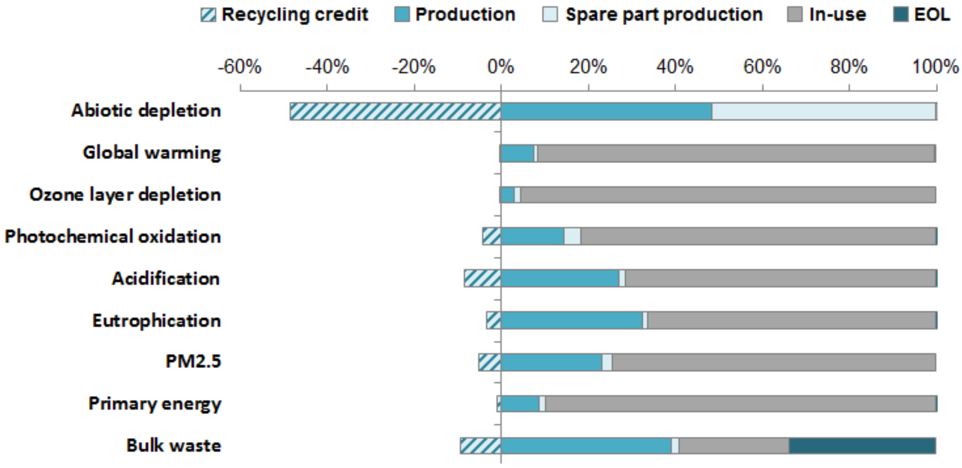
- **Emissions to air, soil and water**: includes any pollutants that could be released during car manufacturing and/or at the ELV stage – as such it encompasses a very broad range of possible issues. Specific aspects include:
    - Acidification potential (AP): SO_2 and NO_x emissions are the main causes of acid deposition, which leads to changes in soil and water quality and damage to vegetation, buildings and aquatic life.
    - Eutrophication potential (EP): Eutrophication is a process whereby water bodies, such as lakes or rivers, receive excess chemical nutrients — typically compounds containing nitrogen or phosphorus — that stimulate excessive plant growth (e.g. algae).
    - Photochemical pollution (PCOP): The increased potential of photochemical smog events due to the chemical reaction between sunlight and specific gases released into the atmosphere. These gases include nitrogen oxides (Nox), volatile organic compounds (VOCs), peroxyacyl nitrates (PANs), aldehydes and ozone.
    - Particulate matter ($PM_{2.5}$): Inhaling particulate matter has been linked to asthma, lung cancer, cardiovascular problems, birth defects and premature death.

Most of these substances are subject to regulatory limits (discussed below), and therefore the scope of the study will focus on instances where manufacturers have voluntarily exceeded their regulatory obligations.

- **Impacts on ecosystems and biodiversity:** Ecosystems refer to plant, animal, and microorganism communities and the non-living environment interacting as a functional unit. Biodiversity refers to the variety of animal and plant life within a region, which is crucial for the functioning of ecosystems.

Figure 5 shows the distribution of life cycle impacts for a typical petrol car during different phases. Total life cycle primary energy consumption, greenhouse gas (GHG) emissions and ozone depletion impacts are dominated by the in-use phase. In general, the share of impacts is similar for Diesel vehicles, although there are some differences that are mainly due to the different fuel production and combustion processes (Nemry et al, 2008). Highly fuel-efficient vehicles such as plug-in hybrid electric vehicles and battery electric vehicles have the potential to reduce environmental impacts in most categories; however current studies indicate that the local electricity generation mix has a significant impact on this potential (Nemry et al, 2008). Thus, as the automotive industry moves toward more highly fuel-efficient vehicles, the relative environmental impacts in the production and end-of-life stages will become more important.

Figure 5: Share of life cycle impacts for a typical petrol car (percentage attributable to different life cycle stages)



Notes: Based on average characteristics derived from statistics of new cars sold in Europe. The main characteristics are: Euro 4 standard petrol car with an average lifespan of 12.5 years and annual mileage of 16,900km, vehicle weight 1,240kg (mid-size category). Source: (Nemry et al, 2008)

Given that the use phase accounts for a significant proportion of overall life cycle impacts, it is worth emphasising the importance of adopting a life cycle approach to decision-making to ensure that environmental impacts are reduced overall. This is especially important when considering trade-offs between different life cycle phases, as well as between different impact categories. Therefore, while the in-use phase is not explicitly covered within this report, the "cross-media impacts" section of each BEMP includes a review of possible benefits and trade-offs in other areas.

Main environmental aspects

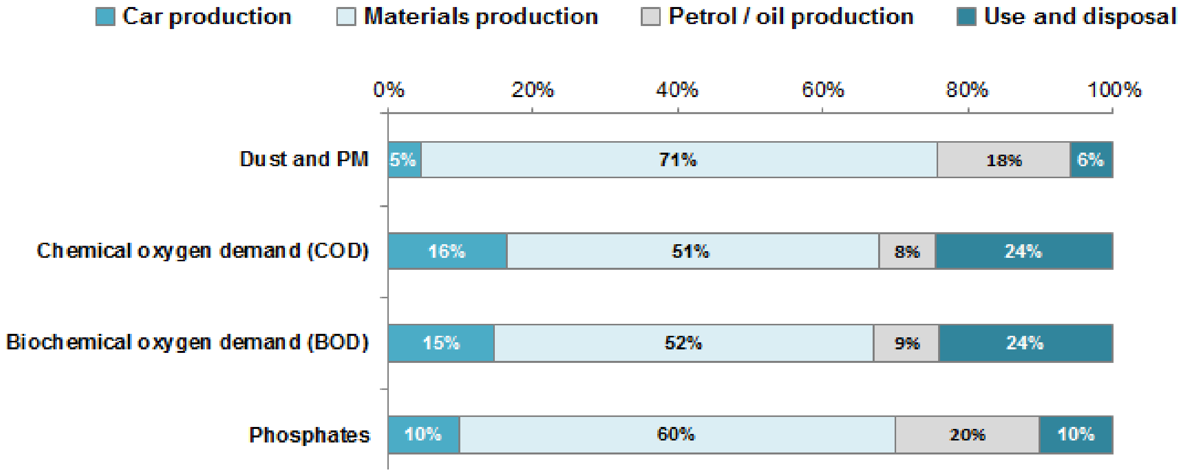
According to EMAS terminology, *'environmental aspect'* means 'an element of an organisation's activities, products or services that has or can have an impact on the environment'. This section examines key aspects in the manufacturing activities at large to be considered as potential environmental aspects.

Foundry processes and fabrication of metal products; fabrication of other materials

These processes, which cover metals but also other elements such as plastics, textiles, leather and other materials, are highly significant in terms of energy consumption, waste production and water consumption (see ***Figure 4*** and **Table 4** above for an illustration).

Figure 6 shows the life cycle emissions from a Golf A4 (petrol version), calculated using data from 1999. Although it is likely that treatment of these emissions has improved in Europe since the publication of that study, it still gives an indication of the relative importance of materials production in the generation of particulate matter (PM), chemical oxygen demand, biochemical oxygen demand and phosphates.

Figure 6: Emissions from a Golf A4 with 55 kW petrol engine



Source: (Schweimer, 2000)

Paint shop operations

The paint shop is one of the most significant processes in terms of environmental impacts in a car assembly plant. Environmental impacts include:

- Significant contribution to total energy consumption (Sullivan, 2010). Depending on the processes involved, painting systems can account for up to half of total electricity consumption (Galitsky & Worrell, 2008), or if infra-red drying is not used then natural gas can be consumed (Schweimer, 2000);
- Specific figures with respect to the proportion of total waste arising from the paint shop were not available, but the painting process has been specifically mentioned as a significant source of waste in several publications including (Ai Group, no date), (Environment Australia, 2002) and (Volkswagen, 2012);
- Water consumption from paint operations can account for 60-70% of water use in a plant (Toyota, 2012a);
- VOC emissions from painting have relatively high impacts (Renault, 2011).

Electrical and electronic equipment

The increasing levels of electrical and electronic equipment in modern vehicles mean that the environmental impacts of these components are growing. For example, electronics were identified as having >10% impact on SO_2 emissions in some Mercedes vehicles, due to the use of non-ferrous metals (Mercedes, 2009).

Potential releases of hazardous or polluting fluids

During production, new vehicles are filled with various fluids (including fuels, lubricants, refrigerants etc.), some of which could be harmful to the environment. In addition, various production processes require fluids for operation – including the use of lubricants and cooling fluids.

Primarily, measures to minimise the use of hazardous fluids will be investigated. Potential options in the automotive sector include:

- **Introduction of processes requiring lower levels of emulsions or cooling lubricants.** However, the integrity of production processes must be maintained when considering options to reduce or change lubricants. For example, inadequate damping of press machinery can lead to damage to buildings due to excessive vibration (Volkswagen Group, 2007);
- **Biodegradable hydraulic oils** may be used wherever possible or economically reasonable.

Where the relevant substances cannot be avoided, measures must be implemented to ensure that storage, handling and transfer of these fluids is managed to prevent releases to the environment. For example, Volkswagen has mandated the "2-barrier" principle at all plant and storage facilities housing fluids that are potentially harmful to the environment, as well as monitoring of leak tightness (Volkswagen Group, 2007). The choice of refrigerants used in mobile air conditioning devices is the subject of separate regulations, but proper storage and transfer of the refrigerant is required to avoid emissions.

End of life

Every year, end-of-life vehicles (ELVs) generate between 7 and 8 million tonnes of waste in the European Union which need to be managed correctly. This includes hazardous waste such as the fluids contained in the vehicles and the substances in certain components such as batteries; in addition, older vehicles may contain specific hazardous substances such as lead, mercury, cadmium and hexavalent chromium. Appropriate management at end of life to minimise those impacts is therefore paramount.

Environmental requirements and other sources of best practice and references

The automotive sector is one of the most tightly regulated in Europe; on environmental issues alone, the sector is subject to a range of EU, national and regional requirements related in particular to product specifications, emissions during use, requirements on the supply chain and materials used, or aspects related to the end of life of the vehicle. Automotive manufacturing activities are also covered by generic legislation applicable to manufacturing in general.

In addition, a number of guidance or recommendation documents already exist to support the industry in improving its environmental performance. The section below explores some of the key mandatory and optional reference texts which are of relevance to the industry, according to key processes and lifecycle stages and following the environmental aspects described in the above section.

Foundry processes and metal fabrication

General best practices as well as minimum requirements are covered in the Best Available Techniques Reference Document (BREF) for two relevant sectors:

-Smitheries and Foundries Industry (SF), which includes pattern making; raw materials storage and handling; melting and metal treatment; mould and core production; casting or pouring and cooling; shake-out; finishing; and heat treatment.

- Ferrous Metals Processing industry (FMP), which includes techniques related to hot and cold forming (pickling, rolling, annealing, tempering, finishing etc..

For the latest available versions of the BREFs, please refer to the online repository[10].

In addition, a forthcoming Sectoral Reference Document on *Best Environmental Management Practices for Fabricated Metal Products*[11] will cover many generic processes relevant to metallic components. This will provide guidance on how to minimise the environmental impacts of most generic processes that are used in the production of metallic vehicle components.

This document will be available on the JRC's website[12].

Manufacturing of other key components and materials

Guidance and requirements for the manufacturing of trim, glazing, plastics, textiles and other relevant materials is included in **Best Available Techniques Reference Documents (BREFs)** for the following sectors (in addition to the ones mentioned above and below on SF, FMP, STS and STM):

- TAN Tanning of hides and skins;
- GLS Manufacture of glass;
- CER Ceramics manufacturing industry;
- ICS Industrial cooling systems (cross-cutting);
- IS Iron and steel production;
- NFM Non-ferrous metals industries;
- POL Production of polymers;
- TXT Textiles industry;
- WI Waste incineration.

For the latest documents, please refer to the online repository[13].

Paint shop operations

Due to the importance of the paint processes, dedicated guidance has been developed in a separate document. Guidance on Best Available Techniques and minimum requirements are available in the Reference Document (BREF) for Surface Treatment Using Organic Solvents (STS-BREF), which covers the painting of car bodies and components, including:

  - Selection/substitution of paint types including low-solvent paints;

[10] http://eippcb.jrc.ec.europa.eu/reference/

[11] During the elaboration of the present Report, the contributing Technical Working Group (TWG) (on the Automotive sector) also recommended some Best Practices for consideration under the workstream led on the Fabricated Metal Product sector, as those techniques seemed of broader relevance to the latter rather than strictly for automotive manufacturing.

[12] http://susproc.jrc.ec.europa.eu/activities/emas/fab_metal_prod.html

[13] http://eippcb.jrc.ec.europa.eu/reference/

- Pre-treatment techniques;
- Paint application techniques and equipment to reduce emissions and energy consumption;
- Drying techniques;
- Waste gas and water treatment.

At the time of writing, the existing document is currently undergoing revision. For the latest available version, please refer to the online repository[14].

A separate BREF on the Surface Treatment of Metals and Plastics (STM-BREF) is also relevant to paint shop operations.

EEE (Electrical and electronic equipment)

Manufacturers can usefully consider the

guidance outlined below, which covers general issues relating to best practice in electronics and electrical equipment manufacturing. The forthcoming Sectoral Reference document on *Best Environmental Management Practices for the manufacture of electrical and electronic equipment* will cover processes that are applicable to many automotive electronic systems.

This document will be available on the JRC's website[15].

Minimising releases of hazardous or polluting fluids

The guidance on Best Available Techniques Reference Document (BREF) for Emissions from Storage (EFS-BREF) provides detailed information on the storage, transfer and handling of liquids, liquefied gases and solids (regardless of the sector or industry). It addresses emissions to air, soil and water.

This document is available online[16].

Although proper storage, transfer and handling minimises releases, they may not be entirely preventable – in which case, the hazardous or polluting substances must be captured and treated. The guidance on Best Available Techniques Reference Document (BREF) for Waste Treatment Industries (WT-BREF) provides guidance on treatment, filtration and management of wastes in gases, water and soil.

This document is available online[17].

End of life of the vehicle and associated waste streams

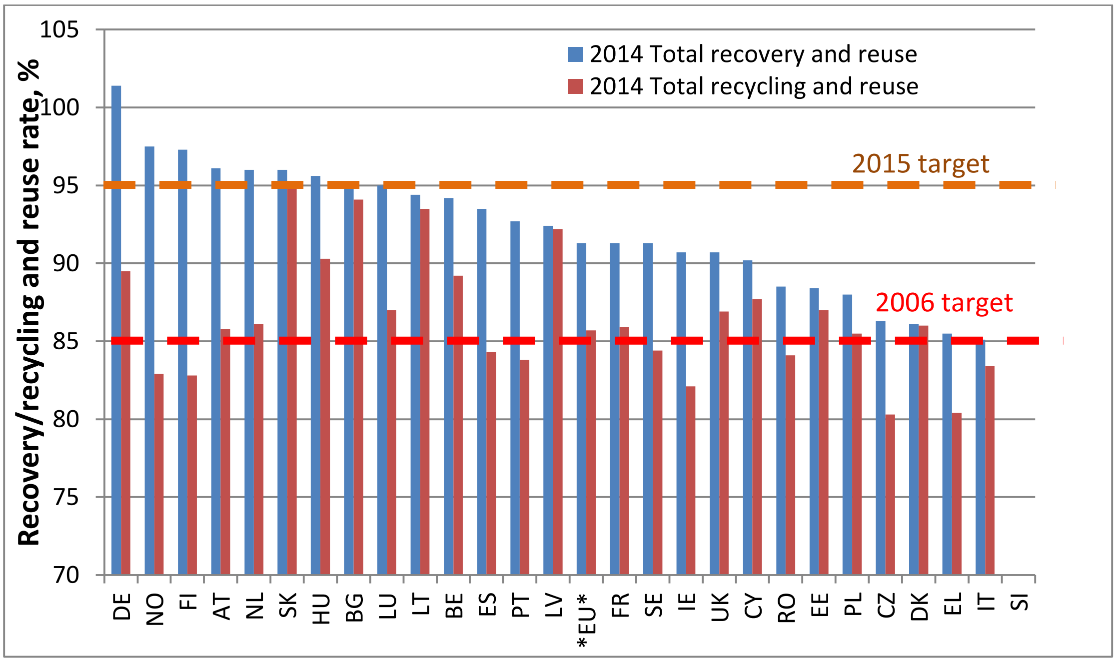
Regarding the end-of-life stage, the End-of-Life Vehicles (ELV), Directive 2000/53/EC (Directive 2000/53/EC - the "ELV Directive") on end-of life vehicles aims at making dismantling and recycling of ELVs more environmentally friendly. It sets clear quantified targets for reuse, recycling and recovery of the ELVs and their components. It also pushes producers to manufacture new vehicles without hazardous substances (in particular lead, mercury, cadmium and hexavalent chromium), thus promoting the reuse, recyclability and recovery of waste vehicles (see also Directive 2005/64/EC on the type-approval of motor-vehicles with regards to their reusability, recyclability and recoverability – "RRR Directive"). The remaining specific exemptions to the prohibition of the use of hazardous substances in vehicles are listed in Annex II to the ELV Directive and are subject to regular reviews according to technical and scientific progress.

[14] http://eippcb.jrc.ec.europa.eu/reference/
[15] http://susproc.jrc.ec.europa.eu/activities/emas/eeem.html
[16] http://eippcb.jrc.ec.europa.eu/reference/BREF/esb_bref_0706.pdf
[17] http://eippcb.jrc.ec.europa.eu/reference/BREF/wt_bref_0806.pdf

Directive (2000/53/EC) initially required that in each Member State an average of at least 80% of the mass of an ELV be reused or recycled and another 5% or more of its mass be energetically recovered. In 2015 the rates were increased to 85% and 10%, respectively. Even before the implementation of the ELV Directive, most Member States had recycling rates for ELVs of around 75%. This is largely because around 75% of a vehicle's weight is metal, for which recycling is usually economically attractive. Increasing the overall reuse and recycling rate further therefore requires a higher recycling rate of non-metallic fractions, which is typically less economically attractive and/or more technically challenging.

The most recent Eurostat data (for 2014, see **Figure 7**) show that all countries exceed the 2006 requirement in the ELV Directive for reuse and recycling plus energy recovery, although many had not yet reached the 2015 target. However, earlier analysis by Eurostat revealed considerable differences regarding the data collection and evaluation by the Member States that suggest these aggregated figures are not entirely comparable (Schneider et al, 2010).

Figure 7: ELV recovery and reuse rate in the EU-27 in 2014



Source: (Eurostat, 2016)

Notes: Germany's rate temporarily exceeded 100% as the remaining ELV stocks which arose due to scrappage schemes were processed.

European legislation in other areas is also relevant, such as:

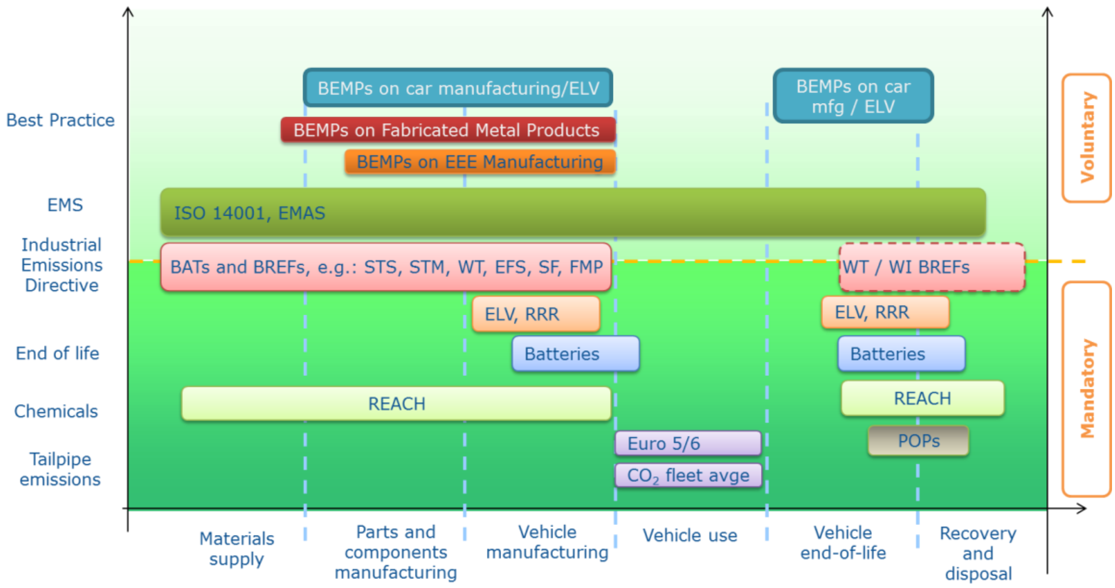
- EU Directive 2006/66/CE on batteries requires a recycling rate of 50% for electric vehicle Lithium-Ion batteries. It also requires the recycling of 65% by average weight of lead-acid batteries and accumulators, including the recycling of the lead content to the highest degree that is technically feasible while avoiding excessive costs. The Directive does not specifically address nickel-metal hydride batteries that are sometimes used in hybrid cars.
- The Waste Oil Directive 75/439/EEC as amended by Directive 2000/76/EC is designed to create a system for collection, recovery and disposal of waste oils (including lubricant oils for vehicles, gearboxes and engines, hydraulic oils etc.).

- The REACH (Registration, Evaluation, Authorisation and Restriction of Chemical substances) Regulation, (EC) No 1907/2006, which was enacted in June of 2007, includes regulations pertaining to substances of very high concern (SVHC). It addresses chromium, lead, mercury, brominated flame retardants, and phthalates, which are present in many polymers.
- The POPs (persistent organic pollutants) Regulation, (EC) No 850/2004, according to which producers and holders of waste shall undertake all reasonable efforts to avoid, where feasible, contaminating recyclable waste with POPs substances.

Other general EU legislation on waste can affect relevant activities in the automotive sector. These include (amongst others): Directive 1999/31/EC on the landfill of waste, Directive 2000/76/EC on the incineration of waste and Directive 94/62/EC on packaging and packaging waste. The WT-BREF is also of potential relevance here.

The chart below (which is not intended to be exhaustive) illustrates the articulation of some key requirements and guidance detailed in this section which are relevant for the sector considered:

Figure 8: landscape of reference texts applying to the value chain



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2 Scope and structure

2.1 Definition of the scope for this report

The scope for this sector is defined taking into account the above considerations regarding the initial definition of the *target sector*, the *structure* of the industry, the key *environmental aspects* and *pressures* of the sector as well as the existing *legislation and guidance* already in place affecting the sector.

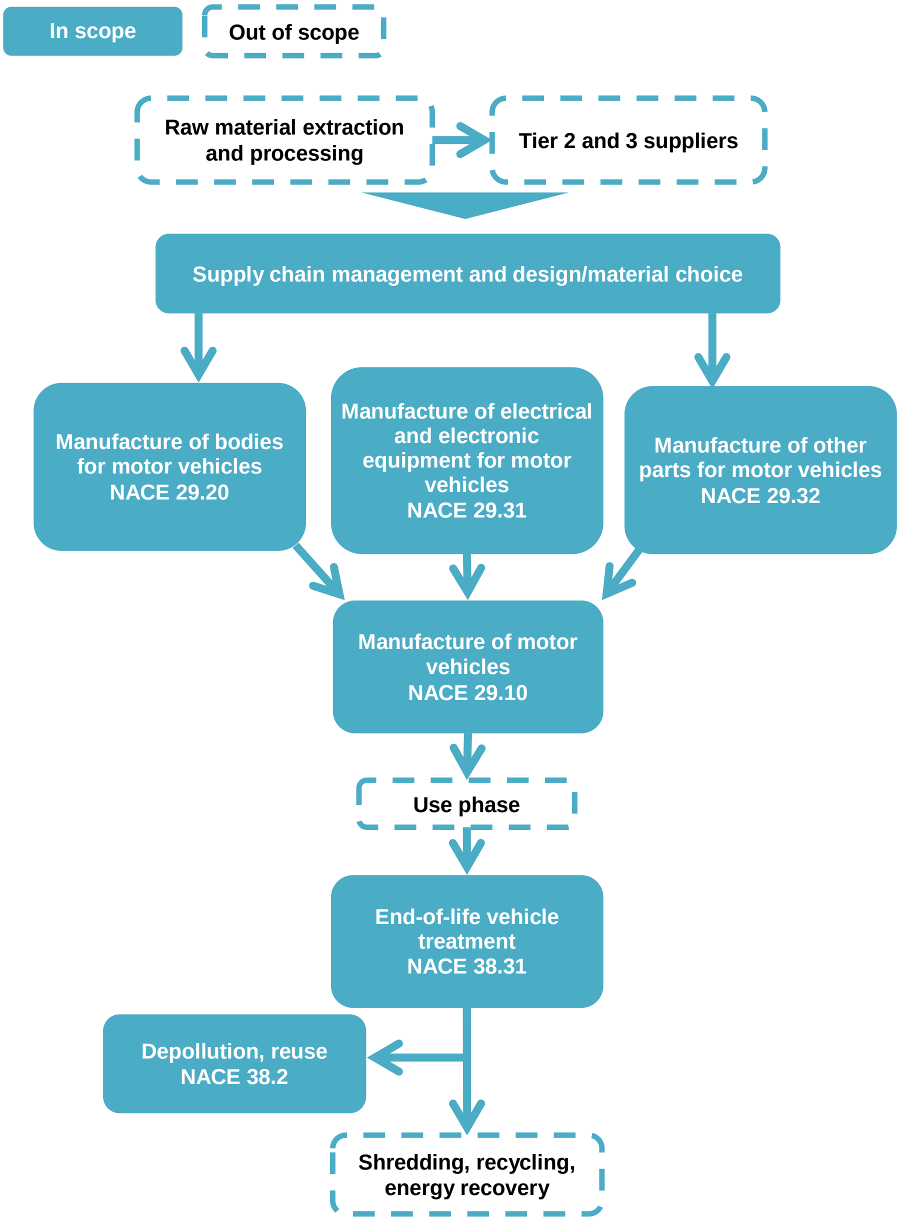
Based on these, the aim is to take into account environmental impacts throughout the value chain of a vehicle while aiming to avoid overlaps with other available texts.

Following the considerations in the above section, **Figure 9** presents the scope based on the overview already illustrated in section 1, with certain aspects marked as *"out of scope"* for the following reasons:

- **Tier 2 and 3 suppliers, raw materials etc.:** The focus of this report will be on OEMs and Tier 1 suppliers, since these represent areas where the car manufacturing industry can have the most significant and direct influence over environmental impacts. Therefore, Tier 2 and 3 suppliers are considered only in terms of supply chain management and indirectly through vehicle design.
- **Primary material transformation stages:** (including primary production of metals, plastics, glass etc.) are already covered under the related studies on Best Available Techniques (BAT) reference documents, known as BREFs, that have been adopted under the Integrated Pollution Prevention and Control (IPPC) Directive (2008/1/EC) and the Industrial Emissions Directive (2010/75/EU). These reference documents are available online[18]. Further details and specific references to relevant documents are provided in *Section0.*
- **Main processes covered by other Sectoral Reference Documents on Best Environmental Management Practices:** These include several general industrial operations related to fabricated metal products, and electrical and electronic equipment. Further details and references are provided in *Section 0.*
- **Use phase:** The use phase is very significant in terms of overall life cycle impacts (especially regarding greenhouse gas and other emissions), but this phase is covered by other existing policies centred on the automotive product and the main focus of this report is on improving manufacturing processes at the organisational level. Therefore, impacts generated during vehicle use, maintenance and retail are not explicitly included; rather, they are considered in the cross-media effects in terms of potential trade-offs between environmental burdens in different life cycle stages.
- **Shredding, post-shredder treatment and general material recycling:** The focus of the study is on the depollution and reuse aspects of ELV treatment before the vehicle is shredded. Once the vehicle hulk reaches the shredder it is typically mixed with other waste streams and subject to more general recycling and recovery operations, which are not automotive-specific. The relevant processes are covered in the Best Available Techniques (BAT) reference document (*BREF) on waste treatment industries*, for which the latest revision is expected to be available online in the near future[19].

[18] http://eippcb.jrc.ec.europa.eu/reference/
[19] http://eippcb.jrc.ec.europa.eu/reference/

Figure 9: overview of the scope for this study



A summary of major environmental aspects and pressures and how they are addressed in this document but also in broader references is shown in ***Table 5***.

Table 5: Summary of environmental aspects and pressures

Main environmental aspect	Related environmental pressure					In scope	BEMPs
	Energy / CC	Resource / waste	Water	Emissions	Eco / biodiversity		
Supply chain management						✓	**BEMPs on supply chain management (Section 3.6)**
Engineering and design						✓	**BEMP on design for sustainability (3.6.3)** **BEMP on remanufacturing of components (3.7.1)**
Manufacturing and assembly stage							
Press shop						✓	Reference to the BEMPs for the Fabricated Metal Products manufacturing sector[20] **BEMPs for environmental, energy, waste, water and biodiversity management (Sections 3.1, 3.2, 3.3, 3.4, 3.5)**
Body-in-white						✓	**BEMPs for environmental, energy, waste, water and biodiversity management (Sections 3.1, 3.2, 3.3, 3.4, 3.5)**
Paint shop						×	Reference to BAT in BREFs for STS, STM
Manufacture of powertrain and chassis						✓	Reference to the BEMPs for the Fabricated Metal Products manufacturing sector **BEMPs for environmental, energy, waste, water and biodiversity management (Sections 3.1, 3.2, 3.3, 3.4, 3.5)**
Manufacture of other components						✓	Reference to BAT in BREFs for FMP, SF, IS, TAN, GLS, POL, TXT etc. Reference to the BEMPs for the EEE manufacturing sector[21]

[20] The Best Environmental Management Practices for the Fabricated Metal Products manufacturing sector are currently under identification and more information and updates are published at: http://susproc.jrc.ec.europa.eu/activities/emas/fab_metal_prod.html

Assembly lines						✓	**BEMPs for environmental, energy, waste, water and biodiversity management (Sections 3.1, 3.2, 3.3, 3.4, 3.5)**
Plant infrastructure						✓	**BEMPs for environmental, energy, waste, water and biodiversity management (Sections 3.1, 3.2, 3.3, 3.4, 3.5)**
Use phase						×	
End-of-life Vehicles (ELVs) stage							
Depollution						✓	Reference to ELV Directive[22], batteries directive[23] **BEMP on implementing an advance environmental management system (3.1.1)** **BEMP on depollution of vehicles (4.2.1)**
Salvage and reuse						✓	ELV Directive and batteries directive **BEMP on implementing an advanced environmental management system (3.1.1)** **BEMP on component and material take-back networks (4.1.1)**
Dismantling and recycling of components						✓	ELV Directive and batteries directive **BEMP on implementing an advance environmental management system (3.1.1)** **BEMP on plastic and composite parts (4.2.2)**
Post-shredder treatment						×	Reference to BAT in the BREF for WT

Colour coding:		Cell contents:	
	High impact (>20% life cycle impacts in this category excluding use phase)	✓	Included in the scope of the study
	Medium impact (10-20% of impacts)	×	Not included in the scope of the study
	Low impact (<10% of impacts)		

Sources: The relative importance of each stage established from: (Sullivan, 2010); (Galitsky & Worrell, 2008); (Mercedes, 2009); (Renault, 2011); (Schweimer, 2000); (Enertika, 2013); (DEFRA, 2003); (Schmidt, 2007), (Ford, 2007); (GM, 2012); (Environment Australia, 2002); (Ai Group, no date); (Volkswagen, 2012); (GHK, 2006); (Optimat, 2013); (Weiland, 2006); (Bras et al, 2012); (Warsen et al, 2011); (BMW Group, 2012); (Volvo, 2013); (VCS, 2013); (ACEA, 2013); (Schneider et al, 2010).

[21] The Best Environmental Management Practices for the Electrical and Electronic Equipment manufacturing sector are currently under identification and more information and updates are published at: http://susproc.jrc.ec.europa.eu/activities/emas/eeem.html

[22] http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32000L0053

[23] http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32006L0066

2.2 Structure and use of this document

Structure

The structure of the document reflects the two key areas outlined in the scope: manufacturing from the perspective of automotive OEMs and other manufacturers in the automotive supply chain; and processes linked to the handling of End-of-Life Vehicles (ELVs) on the other. These form the two main chapters around which the document is articulated.

Within each Chapter, BEMPs can be grouped according to topics and environmental aspects they are addressing, and follow the structure described below:

Table 6: Structure of BEMPs presented in the report

	Area	Key aspect	#	BEMP
MANUFACTURING	CROSS CUTTING MANUFACTURING	3.1.Environmental management	3.1.1	Implementing an advanced environmental management system
		3.2.Energy management	3.2.1	Implementing detailed energy monitoring and management systems
			3.2.2	Increasing the efficiency of energy-using processes
			3.2.3	Renewable and alternative energy use
			3.2.4	Optimisation of lighting in automotive manufacturing plants
			3.2.5	Compressed air
			3.2.6	Electrical motor optimisation
		3.3.Waste mgmt	3.3.1	Waste prevention and management
		3.4.Water management	3.4.1	Water use strategy and management
			3.4.2	Water-saving opportunities in automotive plants
			3.4.3	Water recycling and rainwater harvesting
			3.4.4	Green roofs for stormwater management
		3.5. Biodiversity	3.5.1	Ecosystem management reviews and strategy
			3.5.2	Biodiversity management
	SUPPLY CHAIN, DESIGN AND REMANUFACTURING	3.6.Supply Chain Management and Design	3.6.1	Integrating environmental requirements into supply chain management
			3.6.2	Collaborate with suppliers on packaging reduction
			3.6.3	Design for sustainability using Life Cycle Analysis (LCA)
		3.7. Remanufacturing	3.7.1	General best practices for remanufacturing components
END-OF-LIFE VEHICLE		3.1.Collection	4.1.1	Component and material take-back networks
		3.2 Treatment	4.2.1	Depollution
			4.2.2	General best practices for plastic and composite parts

Target stakeholders

The implementation of BEMPs remains a voluntary process which has to be adapted to the specific situation of each organisation considering their adoption (EMAS registered companies, when an SRD is available for their relevant sector, have to take the document into account).

It is therefore important for stakeholders to prioritise the BEMPs which are most likely to be useful for them. The following table illustrates the specific stakeholders concerned by the present document which are most likely to find the BEMPs in each section of relevance:

Table 7: Major target stakeholders per BEMP group (X= main target, (x)= also potentially relevant)

	Area	Key aspect	Stakeholders					
			OEMs	**Tier 1 suppliers**	**Tier 2+ suppliers**	**Remanu-facturers**	**ATFs**	**Shredders**
MANUFACTURING	CROSS-CUTTING MANUFACTURING	Environmental management	X	X	X	X	X	(x)
		Energy management	X	X	X	X	X	(x)
		Waste management	X	X	X	X	X	(x)
		Water management	X	X	X	X	X	(x)
		Biodiversity	X	X	X	X	X	(x)
	SUPPLY CHAIN, DESIGN, AND REMANUFAC-TURING	Supply Chain Management, logistics and design	X	X	X			
		Remanufacturing	(x)			X		
END OF LIFE VEHICLE HANDLING	ELV logistics	Collection				(x)	X	
	ELV treatment						X	(x)

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3 BEST ENVIRONMENTAL MANAGEMENT PRACTICES FOR CAR MANUFACTURERS AND SUPPLIERS

3.1 ENVIRONMENTAL MANAGEMENT

3.1.1 Implementing an advanced environmental management system

SUMMARY OVERVIEW:				
BEMP is to implement an advanced environmental management system (EMS) across all sites of the company. This enables continuous monitoring and improvement across a range of environmental factors. An EMS is a voluntary tool that helps organisations to develop, implement, maintain, review and monitor an environmental policy and improve their environmental performance. Advanced systems can implemented according to ISO 14001-2015 or preferably EMAS, which are internationally recognised systems certified or verified by a third party, and focus on *continuous improvement* and *benchmarking* of the organisation's environmental performance.				
Relevant life cycle stages				
Management	Design	Supply chain	**Manufacturing**	End-of-life
Main environmental benefits				
Energy consumption	**Resource use and waste**	Water use & consumption	**Emissions to air, water, soil**	Ecosystems & biodiversity
Environmental indicators				
• Sites with an advanced environmental management system (% of facilities/operations) • Number of environmental performance indicators (EPIs) that are in general use throughout the whole organisation and/or which are reported on in environmental statements; • Use of internal or external benchmarks to drive environmental performance (Y/N)				
Benchmarks of excellence				
• **An advanced EMS is implemented across all production sites globally**				
Cross references				
Prerequisites	**N/A**			
Related BEMPS	• Implementing detailed energy monitoring and management systems; • Water use strategy and management • Ecosystem management reviews and strategy • Plant utilities and infrastructure • Key manufacturing processes			

Description

An environmental management system (EMS) is a tool that helps operators to develop, implement, maintain, review and monitor environmental policy. The decision to adopt an EMS is voluntary; however, industry in general and the automotive sector in particular are increasingly choosing to address environmental concerns through the improvement of internal environmental management practices – especially by implementing an EMS (Comoglio & Botta, 2011).

As such, many major European and global OEM manufacturing plants use a certified or verified environmental management system. Advanced systems can be based on those implemented according to ISO 14001 or EMAS (EU Eco-management and audit scheme – also available as "EMAS Global") (VCS, 2013), (EMAS Register, 2014): these are both internationally recognised systems certified or verified by a third party.

EMAS incorporates the management system requirements of ISO 14001, but has an additional emphasis on legal compliance, transparency, environmental performance and employee involvement. The latest revision of the ISO 14001 standard (ISO 14001:2015) has thus already been incorporated in EMAS, in particular novel aspects relating to Risk management as well as an increased focus on taking into account indirect aspects of the organisation's activities. EMAS' additional dimensions make it preferable for an advanced environmental management system.

While a non-standardised EMS could be effective if properly designed and implemented, the use of a standardised scheme provides additional credibility[24].

In addition, it is important that an advanced system stress the dimensions of *continuous improvement* and *benchmarking* of the organisation's own performance in order to track and encourage these improvements. Finally, an advanced environmental management system (depending on the environmental assessment performed) will aim at being implemented across all sites of the organisations to ensure that the environmental impacts are adequately captured.

Extensive and detailed guidance on the implementation and operation of EMS is provided in other documents (see for example the European Commission EMAS website[25]) and is therefore not elaborated in detail here.

Achieved environmental benefits

Significant short-term benefits can usually be gained following first implementation, where "low-hanging fruit" can be identified and improved. Over the longer term, an EMS can help an organisation to maintain and improve its environmental performance level to the highest standards.

An effective EMS leads to *continuous improvement* in management actions and environmental performance, informed by monitoring of key performance indicators. The greatest benefits will result from integration into the overall management and operation of a process, site or organisation. There are limited numbers of studies quantifying the deployment of EMSs specifically in the automotive sector, but some empirical evidence has shown that (Comoglio & Botta, 2011):

- Implementing an EMS in the automotive sector was found to increase the number of companies committed to achieving environmental improvements, as well as widening the environmental aspects involved;

[24] Empirical studies of the performance of EMSs have shown that the introduction of an EMS can be expected to be at least somewhat beneficial to the environmental performance of most facilities, as well as to their operational and management efficiency and in some cases to their regulatory compliance (Commission for Environmental Cooperation, 2005), (Comoglio & Botta, 2011).

[25] http://ec.europa.eu/environment/emas

- Quantification of the environmental improvements achieved in practice varies widely, but is generally positive (the mean percentages reported were highly heterogeneous, varying from 16.9% improvement in use of resources to 42.7% improvement with respect to releases to water);
- There is a direct link between the resources devoted to improvement and the improvement achieved.

Appropriate Environmental performance indicators

An important indicator is to monitor uptake of EMS across the organisation as a whole – i.e. the number of sites with an advanced (e.g. certified or verified) environmental standard (% of facilities or operations).

A significant dimension to be implemented in an advanced EMS is the use of indicators and benchmarking (itself); this can be reflected for instance in:

- number of EPIs which are in general use throughout the whole organisation and/or which are reported on in environmental statements;

- use of (internal or external) benchmarks to drive environmental performance (Y/N)

For this last indicator, the benchmarks can be defined as internal or external benchmarks. Generally a large company with multiple sites will find it more natural to use internal benchmarks, calibrating on the best in class for comparable operations across sites. For smaller companies or more specific operations, external benchmarks can also be used, such as the ones provided in the present report as Benchmarks of Excellence.

N.B. For reference, appropriate environmental indicators used within an EMS are measured at the process level, such as those associated with each of the best practice techniques described subsequently in this document. Suggested indicators are based on those most commonly used in internationally-accepted standards, as well as in the car manufacturing industry, and therefore aim to reduce the administrative effort associated with monitoring. Common EMS indicators used by the automotive industry to measure environmental aspects are listed in **Table 8** (Comoglio & Botta, 2011).

Table 8: Typical EMS indicators and normalisation indices used by the automotive industry

Direct Indicators	**Relative factors / normalisation indices**
• Fuel consumption [l or m^3] • Electricity consumption [kWh] • Annual volume [m^3] of wastewater released • Weight [kg] of recycled waste • Weight [kg] of hazardous and non-hazardous waste • Weight [kg] of produced waste, hazardous/non-hazardous waste • Emission of TOC, dust, oily smoke, CO, CO_2, O_2 etc.	• Per number of product units • Per number of worked hours • Per number of employees • Per weight [kg] of raw materials used • Per weight [kg] of produced units

Source: (Comoglio & Botta, 2011)

Note that in the context of this BEMP, it is not these indicators themselves that are proxies for the implementation of the technique, but *the use of indicators and benchmarks* that is pursued.

Cross-media effects

When properly implemented, an EMS is designed to address and improve the overall environmental impact of an organisation, including indirect impacts.

In particular, the latest revision of the ISO standard (ISO 14001:2015), also part of EMAS requirements, includes an increased emphasis on environmental risk assessment for the organisation, both for the risks to and from the environment. This aims to reduce the possibility of adverse environmental effects through the implementation of the EMS.

Operational data

According to the Association of European Automotive Manufacturers (ACEA), most (>85%) vehicle manufacturers have implemented ISO 14001 for at least some production facilities (ACEA, 2013). Frontrunner organisations have certified or verified 100% of their facilities, and so best practice is currently moving on to implementing more ambitious targets and certifying other activities. For example, many are also extending the requirements to the supply chain, as well as service workshops/dealerships (ACEA, 2013). EMAS is often applied at the site level whereas ISO 14001 is also applied at the corporate level (ACEA, 2013).

General guidance on the implementation of EMAS is available from the official website:

- General guidance[26], which can be used in conjunction with the sector-specific guidance in this document.
- Organisations with non-standardised EMS can find step-by-step information on how to move to the more ambitious EMAS system in the "Step up to EMAS" study[27]. This provides specific information for 20 of the most commonly used EMS.
- For small and medium sized enterprises (SMEs), a simplified system – EMAS easy (http://www.emas-easy.eu/) – has been developed that allows EMAS to be implemented in a way that is proportional to the size and capabilities of smaller businesses.

However, the general guidelines provided on the implementation of EMSs allow considerable freedom in terms of the environmental criteria concerned, particularly if organisations do not have environmental managers with expertise in environmental impact assessments. Volkswagen developed a comprehensive EMS approach to be applied throughout Volkswagen's production sites. (Gernuks et al, 2006).

[26] http://ec.europa.eu/environment/emas/index_en.htm

[27] http://ec.europa.eu/environment/emas/emas_publications/publications_studies_en.htm#Step%20up%20to%20EMAS

Table 9: Case study on the development of an EMS at Volkswagen

- Environmental issues that affect the Volkswagen brand as a whole are outlined in an environmental manual for the Volkswagen brand.
- Volkswagen documents an EMS in a specific manual for each production site, supported by an Eco Audit Team who perform environmental audits and help to prepare statements in compliance with the EMAS framework.
- In addition, a separate environmental management system according to ISO 14001 exists at Volkswagen's research and development department, dealing with product-related environmental issues.
- To determine appropriate environmental targets, a key objective is the integration of relevant production departments and their technical experts.
- For quantitative monitoring, several methods were compared in terms of being easy to understand for internal participants, having good reproducibility and being relatively quick to apply. After conducting this assessment the "Ecopoint" method[28] was selected, as it best fitted the practical needs of the company – although it was recognised that this method may not be suitable in all cases (for example, a possible limitation is that the Ecopoint method uses political targets and legal thresholds which are only partly based on scientific knowledge).
- For qualitative monitoring the "ABC" method was selected, which is based on compliance with legal thresholds. The importance of a factor is classified as:
    - A (most important) if it is higher than 80% of the legal threshold;
    - B if it is 50-80% of the legal threshold;
    - C (least important) if it is <50% of the legal threshold.
- The quantitative and qualitative indicators help Volkswagen to identify and prioritise areas for improvement. Volkswagen annually collect environmental data from their production sites for control and communication purposes (e.g. within the EMAS' environmental statement). These data comprise emissions to air (CO_2, Nox, etc.), emissions to water (COD, N, heavy metals, etc.), and waste generation.
- Targets for improvement are developed in collaboration with several actors, including the following three key members:
    - The head and representatives of the department affected, as they know their process best and may discover potential areas of technical improvement in the process;
    - The person responsible for environmental protection of the production site, to contribute his environmental knowledge;
    - Experts in special environmental aspects (e.g. energy manager) to coordinate measures concerning this subject.
- The environmental manager of the production site compiles each department's targets and generates the environmental program for the whole production site. The environmental program is then published in Volkswagen's environmental statement.

Source: (Gernuks et al, 2006)

[28] The Ecopoint method is a simplified single-score environmental impact approach. Further information is available online at: http://www.earthshift.com/software/simapro/ecopoints97

It may also be advantageous and cost-effective to organise environmental management globally so that best practices can be shared across all facilities, although there are challenges to achieving this including differences in culture, time zones, regulation etc. (Osborne – personal comm., 2014).

A concrete example is BMW, who uses a system based on ISO 14001 *and* EMAS for all production locations throughout the world, as well as all central planning departments of the production network. By integrating environmental management into all production processes, BMW were able to reduce their consumption of resources significantly as follows (BMW Group, 2015):

- Energy consumption: Reduced by 2.7% from 2.25 to 2.19 MWh/vehicle in 2015 compared to 2014 (a reduction of 36% compared to 2006);
- CO_2 emission: Reduced by 13.6% from 0.66 to 0.57 t/vehicle in 2015 compared to 2014 (a reduction of 45.7% compared to 2006);
- Process wastewater: Reduced by 4.3% from 0.47 to 0.45 m³/vehicle in 2015 compared to 2014 (a reduction of 45.1% compared to 2006);
- Waste for disposal: Reduced by 18.9% from 4.93 to 4.00 m³/vehicle in 2015 compared to 2014 (a reduction of 78.9% compared to 2006);
- VOC emissions: Reduced by 5.4% from 1.29 to 1.22 kg/vehicle compared to 2012 (a reduction of 51.4% compared to 2006).

Applicability

An EMS is typically suitable for all organisations and sites. The scope and nature of the EMS may vary depending on the scale and complexity of the organisation and of its processes, as well as the specific environmental impacts involved.

In general the most environmentally significant aspects of automotive manufacturing (i.e. the painting processes and metal-forming operations) will be prioritised and the environmental improvement options outlined in specific policies and guidance. However, many other processes are not specifically covered by existing guidance and the scope for additional environmental improvements is still considerable.

In some cases, aspects of water management, biodiversity or land contamination may not be covered or monitored in EMSs implemented by firms in the automotive sector (Comoglio & Botta, 2011); this report (in Section 3.4 WATER MANAGEMENT and Section 3.5 BIODIVERSITY MANAGEMENT) may offer useful guidance on these aspects.

Economics

The costs of introducing a standardised (e.g. ISO 14001 or EMAS) EMS are likely to be somewhat higher compared to non-standardised systems due to the need for verification. For smaller companies, the costs tend to be proportionally higher, and therefore a simplified EMAS system is available for SMEs. Ongoing costs are likely to be lower once the required systems are in place and staff become familiar with their obligations.

Table 10 provides an indication of the costs and benefits for organisations of different sizes from implementing EMAS.

Table 10: Costs and benefits of implementing EMAS

Organisation size	Potential annual efficiency savings (€)	Implementation costs (€)	Annual costs (€)
Micro	3,000 to 10,000	22,500	10,000
Small	20,000 to 40,000	38,000	22,000
Medium	Up to 100,000	40,000	17,000
Large	Up to 400,000	67,000	39,000

Notes: Potential annual efficiency savings are based on energy savings only, and do not include resource efficiency savings.

Source: European Commission (2013)

The costs indicated in Table 10 may be slightly higher compared to ISO certification costs. According to one expert, the additional efforts for the first environmental statement are around 5-20 man-days and the 3-10 man-days for updates, although the time required depends on the availability of key indicators (Schleicher, 2014). Precise costs are difficult to estimate specifically for the car manufacturing sector as many factors vary significantly, including the registration fees, day rates charged by verifiers, level of staff training etc. (Schleicher, 2014).

Most EMSs are expected to result in financial benefits due to cost savings from consuming fewer resources, producing less waste, operational efficiencies and reduced liabilities (Commission for Environmental Cooperation, 2005).

In general it is thought that larger organisations are better able to recover the costs of implementing EMAS (European Commission, 2013). However, the economics of an EMS are likely to be highly site-specific and the figures supplied above are indicative only (Milieu et al, 2009).

Other economic benefits that are more difficult to measure directly include (European Commission, 2013):

- Registration to EMAS or another accepted EMS can be an advantage for government procurement or business-to-business procedures, and in some cases it may be a requirement;
- EMAS-registered organisations can expect regulatory relief. There may be benefits for companies involved in manufacturing sectors, with advantages under legislation e.g. on energy efficiency or deriving from the Industrial Emissions Directive;
- Supporting the maintenance and in some cases the improvement of the corporate image.

Driving force for implementation

Implementation of an EMS can help to (European Commission, 2012):

- Minimise risks, especially in the context of systems based on EMAS and ISO14001:2015;
- Improve company credibility and image;

- Address key management challenges around resource efficiency, climate protection and corporate social responsibility;
- Demonstrate compliance with legal or customer requirements (supply-chain driven requirements are particularly the case for suppliers e.g. Tier 1);
- Provide performance measurement against set targets;
- Improve employee and stakeholder engagement in environmental protection activities.

An additional driving force for uptake of EMAS in particular is that EMAS-validated firms are often ranked differently in corporate sustainability ratings – however, to date it is mainly German production facilities that use EMAS (ACEA, 2013).

Reference organisations

Some frontrunner organisations ensure that all of their sites have an advanced certified or verified EMS. For example:

- BMW Group use a system based on ISO 14001 and EMAS for all production locations throughout the world, as well as all central planning departments of the production network (BMW, 2012);
- Since 1995, the Volkswagen brand's German sites have participated in EMAS while its production sites worldwide have undergone environmental certification procedures to conform with the international standard ISO 14001 (Volkswagen, 2013);
- All General Motors (GM) manufacturing facilities have implemented the GM EMS, which is based on ISO14001 and certified according to ISO14001 or verified according to EMAS. All new GM manufacturing operations are required to implement and certify their EMS 24 months after the start of production or the date of acquisition by GM (Nunes, 2011).
- FCA is committed to implementing and maintaining its Environmental Management System (EMS) at its production plants, compliant with the ISO 14001 standard. At the end of 2015, 146 Group plants, representing 100% of industrial revenues and 97% of manufacturing employees, were ISO 14001 *certified*. The plants still awaiting certification have adopted an EMS which *complies with* the ISO 14001 standard (FCA, 2015).

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3.2 ENERGY MANAGEMENT

3.2.1 Implementing detailed energy monitoring and management systems

<table>
<tr><td colspan="5">SUMMARY OVERVIEW:
BEMP is to implement across manufacturing sites detailed energy monitoring at the process level, in conjunction with an energy management system that is certified or verified by a third party, in order to optimise energy consumption.

Best practice energy management plans include the following aspects, formalised according to a management system that requires organisational improvements, such as a system certified according to ISO 50001 or integrated in EMAS:
• Establishing an energy policy, strategy, and action plan;
• Gaining active commitment from senior management;
• Performance measurement and monitoring;
• Staff training;
• Communication;
• Continuous improvement;
• Investment</td></tr>
<tr><td colspan="5">Relevant life cycle stages</td></tr>
<tr><td>Management</td><td>Design</td><td>Supply chain</td><td>Manufacturing</td><td>End-of-life</td></tr>
<tr><td colspan="5">Main environmental benefits</td></tr>
<tr><td>Energy consumption</td><td>Resource use and waste</td><td>Water use & consumption</td><td>Emissions to air, water, soil</td><td>Ecosystems & biodiversity</td></tr>
<tr><td colspan="5">Environmental indicators</td></tr>
<tr><td colspan="5">• Number of facilities with detailed energy monitoring systems (# or % of facilities/operations)
• Number of facilities with an energy management system certified ISO 50001 or integrated in EMAS (# or % of facilities/operations)</td></tr>
<tr><td colspan="5">Benchmarks of excellence</td></tr>
<tr><td colspan="5">- Specific energy management plans are implemented across all sites
- Detailed monitoring per process is implemented on-site
- The plant implements energy management controls, e.g. to switch off areas of the plant during non-productive times for sites with detailed monitoring</td></tr>
<tr><td colspan="5">Cross references</td></tr>
<tr><td>Prerequisites</td><td colspan="4">• Implementing an advanced environmental management system;</td></tr>
<tr><td>Related BEMPS</td><td colspan="4">• Increasing the efficiency of energy-using processes
• Renewable and alternative energy use
• Optimisation of lighting in automotive manufacturing plants
• Rational and efficient use of compressed air</td></tr>
</table>

Description

While automotive manufacturing facilities are relatively efficient in general, significant opportunities remain to reduce energy demand. Due to the complexity of different processes and technological variation, there are a wide range of potential options for plant-wide energy efficiency. In particular, many of these opportunities exist outside of the core energy-consuming production processes for which there is separate, specific guidance (such as paint and metal-forming operations).

An *energy* management system (EnMS) can be based on a standardised or customised form. Implementation according to an internationally accepted standard can give higher credibility to the EnMS and also open up opportunities for gaining certification against certain industry standards. The purpose is similar to that of establishing an *environmental* management system (EMS) (see Section 3.1.1 Implementing an advanced environmental management system), but with a clear emphasis on energy consumption. While many plants across Europe have chosen to use an environmental management system, there are additional benefits to incorporating the aspects of an EnMS as described below.

Energy monitoring is a key element of implementing an energy management system, allowing a precise knowledge of energy flows occurring on a site. The level of detail required for monitoring needs to be tailored to the priorities established by the management system and may not be applied evenly throughout the factory: finer monitoring will be required for identified hotspots. Monitoring needs to be carried out at the appropriate responsibility/ management level to trigger action (and not be diluted in a more remote overhead), since the value of the information collected for monitoring is only as good as the energy-saving measure implemented as a reaction.

In addition, real-time information, although not a prerequisite for efficiency improvement, can be exchanged between production systems, departments and production sites, potentially leading to continuous improvement of energy use in manufacturing sites.

Energy management plans and target-setting are important to allow energy efficiency to be incorporated into management activities. Plans generally include the following aspects (Carbon Trust, 2013):

- **Establishing an energy strategy:** involves setting out how energy will be managed. It will contain an action plan of tasks, which will initially involve understanding the organisation's current position and establishing the management framework. It is usually done at corporate level for the entire company. The targets and action plan are then broken down in targets for each plant;
- **Gaining active commitment from senior management**: without the support of senior managers, the effectiveness of the energy management plan is likely to be compromised. Clear responsibilities for energy consumption must be allocated at corporate level and/or at plant level;
- **Performance measurement:** identifying energy savings is an ongoing process which must be supported by detailed energy monitoring and analysis to determine potential opportunities for saving;
- **Staff training:** in energy efficiency and carbon reduction can help change behaviour in the workplace, to reduce unnecessary energy consumption;
- **Communication:** employee engagement and communications are an important part of developing an organisation's culture of energy efficiency;

- **Continuous improvement:** Energy optimisation based on "treasure hunt" methodologies, i.e. cross-functional teams leading periodical reviews of energy using processes on the factory floor (genchi genbutsu) to identify energy saving opportunities;
- **Investment:** energy efficiency investments often have to compete directly against other demands for capital budgets. Budgets for energy efficiency should therefore be ring-fenced to ensure they are not diverted, and a proportion of the energy savings must be retained for further efficiency measures. Appraisal of investments will be made on a whole life cycle basis.

Table 11 shows how best practice measures can be distinguished from good practice and fair practice, when considering each of the above aspects.

Table 11: Energy management matrix

	Best practice	Good practice	Fair practice
Energy policy, strategy and action plan	Energy policy and action plan in place and reviewed regularly, with active commitment of top management.	Formal policy but no active commitment from top management.	Un-adopted policy.
Organisational structure	Fully integrated into senior management structure with clear accountability for energy consumption.	Clear line management accountability for consumption and responsibility for improvement.	Some delegation of responsibility but line management and authority unclear.
Performance measurement	Comprehensive performance measurement against targets with effective management reporting.	Weekly performance measurement for each process, unit or building.	Monthly monitoring by fuel type.
Training	Appropriate and comprehensive staff training, tailored to identified needs.	Energy training targeted at major users following a needs assessment.	Ad-hoc internal training for selected people as required.
Communication	Extensive communication of energy issues within and outside of organisation.	Regular staff briefings, performance reporting and energy promotion.	Some use of organisational communication channels to promote energy efficiency.
Continuous improvement	"Treasure hunts" cross-functional teams regularly inspect the shop floor for new energy saving opportunities	Occasional audits of energy using processes.	Staff are asked to report spontaneously on identified savings opportunities
Investment	Resources routinely committed to or ringfenced for energy efficiency. Consideration of energy consumption in all procurement.	Same appraisal criteria used for energy efficiency as for other cost reduction projects.	Low or medium cost measures considered only if payback period is short.

Source: adapted from (Carbon Trust, 2013)

Organisations will aim to achieve best practice measures across all of these aspects. Without proper integration and strong communications across the organisation, energy management becomes easily marginalised and undermined. Common weaknesses that lead to poor energy management include the following issues (Carbon Trust, 2013):

- No active support from senior management;
- Lack of specific targets and commitments;
- Out-of-date documents/targets;
- EnMS is not supported by a strategy with the ability to deliver.

Target setting will be based on challenging but achievable targets that can be determined through analysis of energy data and/or benchmarking against internal or external performance.

The implementation of an EnMS will preferably be done according to formal standards that require organisational improvements, such as **ISO 50001**. ISO 50001 is a standard introduced in 2011, which specifies the requirements for establishing, implementing, maintaining and improving an EnMS. It is modelled after ISO 14001 (environmental management standard) and ISO 9001 (quality management), but differs in that it requires an organisation to demonstrate that it has improved its performance. In addition, adherence to these standards will allow energy management efforts to be officially certified and recognised.

ISO 50001 has been successfully implemented in many industries and frontrunner automotive manufacturers have already implemented it across the majority of their sites; therefore best practice is to implement more ambitious targets. For example, FCA group reports that in 2015 all of their main plants (representing about 94% of total energy consumption) were certified to the new standard (FCA, 2015).

Alternatively, organisations implementing EMAS can also integrate the aspect of energy management under the umbrella of the EMAS management system with a comparable level of requirements.

Achieved environmental benefits

EnMSs are useful where incremental gains are being sought through process refinement and efficiency measures, without requiring radical redesigns of the process. While the energy savings brought about by each individual measure are typically small, the cumulative savings can be substantial.

Organisations with a poorer starting point may achieve more significant short-term improvements, but there are typically opportunities still available even for firms that are relatively advanced in their techniques. For example:

- Nissan Smyrna (USA) implemented an EnMS, leading to energy savings of 264,000 GJ per year (7.2% in 2012 compared to 2008 levels) (Clean Energy Ministerial, 2013). This was achieved in addition to efforts in previous years to reduce energy consumption. For example, the plant had already implemented no- and low- cost measures such as turning off machinery when not in use. The savings due to the new EnMS were therefore in addition to the 11.4% saving achieved in previous years.

In such cases, an EnMS helps to ensure continuous improvement as well as maintenance of high standards.

In specific cases, the importance of energy expended in the production of each vehicle can be considered on par with the issue of man hours per unit—the area of overriding concern just a few years ago, according to one plant manager (Holt, 2012). A plant with an output of 1,000 vehicles per day can use several hundred thousand MWh of electricity per year (Siemens, 2013).

One key application is to identify opportunities to switch off sections of the plant during non-productive times. The coordinated deactivation of power loads that are not required during long periods of production standstill – such as company vacations – can reduce the energy use by up to 80%. Over shorter breaks – such as lunchtimes – savings of up to 40% can be achieved (Holt, 2012). Real-world examples of implementation include:

- At the BMW engine plant in Steyr (Austria), energy demand is measured every 15 minutes at some 700 monitoring points. This detailed information was used to identify and shut down everything not in use, and enabled the plant to reduce base load energy consumption from eight to five MW (Siemens, 2013);
- Seat Martorell (Spain) implemented an EnMS solution from an external provider which monitors all energy and material flows. Energy consumption can be assigned to the respective cost units on a usage-related basis, even where complex calculation models are used (Holt, 2012). This allowed them to identify and implement significant energy savings across the plant through simple measures such as detecting leaks or allocating loads more efficiently. Without the need for additional investments, these measures resulted in energy cost savings of between 5% and 10% (Holt, 2012);
- Tracking real-time energy use for General Motor's US manufacturing sites resulted in nearly 2.5 million data points, which are monitored every minute to create real-time energy performance indicators (General Motors, 2013).

Increasing energy efficiency also provides ancillary benefits, such as greater productivity, fewer rejected parts and wastes, and reduced emissions to the environment (in addition to lower energy expenditures, cf. economics section) (US DoE, 2008).

Appropriate environmental performance indicators

The level of implementation is a key factor and therefore indicators include:

- Number of facilities with an energy management system certified ISO 50001 or integrated in EMAS (# or %);
- Number of facilities with detailed energy monitoring systems (# or %).

Results can be monitored at the facility level in terms of energy consumption (kWh/MWh) per functional unit[29], e.g. vehicle (at assembly plants) or per engine (at engine manufacturing plants), which are standard industry measurements.

The actual figure is dependent on the functions handled at each plant. Those with their own bodywork shops, foundries and stamping shops will clearly use more energy than simple assembly plants. Even within a single plant, a comparison over time may be difficult due to changes in utilisation or changes in the models produced. Thus, the need for adequate process-level monitoring is stressed, potentially involving detailed real-time monitoring.

[29] in this and other indicators, the term 'functional unit' refers to a representative unit as described in the Preface (*Box 1*).

Cross-media effects

Energy management will be integrated with other environmental objectives and consider the overall environmental impact (see *Section 3.1.1 on* Implementing an advanced environmental management system as well as 3.6.3 *Design for sustainability using Life Cycle Assessment (LCA)*). It may not be possible to both maximise the total energy efficiency and minimise other consumptions and emissions (i.e. energy may be required to reduce emissions to air, water and soil).

Operational data

Energy management contains a continuous improvement process that follows the general scheme of plan, do, check and act. This means, that improvement measures are planned, implemented and evaluated. The evaluation is based on the assessment of the energy performance in terms of energy consumption and energy efficiency. Supporting methods and tools for these tasks include analysis procedures (Müller et al., 2012), approaches (Hopf & Müller, 2013) and visualization tools (Hopf & Müller, 2015).

Energy management has significant influence on the planning and management of manufacturing systems. Especially, the acquired information on the energy performance of a system is an important input for subsequent planning processes, such as the integration of a new manufacturing process in an existing factory (Müller et al., 2013).

Examples of specific initiatives implemented at each step are outlined below, based on Nissan Smyrna plant's joint project with the U.S. Energy Department's Advanced Manufacturing Office (AMO) to implement an EnMS (Clean Energy Ministerial, 2013) and (Roden, 2011):

- **Establishing an energy strategy**: Nissan's group-wide corporate Green Program aims to reduce CO_2 emissions by 20% across all Nissan manufacturing facilities by 2016 (based on tonnes of CO_2 per vehicle compared to fiscal year 2005). Nissan's Smyrna facility then developed an energy management policy (nationally applicable), set objectives for improving its energy performance, developed an energy profile for the site, and calculated its energy baseline (2008).
- **Gaining active commitment from senior management**: Nissan established a North America Energy Team to achieve corporate energy reduction goals in its U.S. region. This cross-functional team is led and supported at the executive level by Nissan's Sr. Vice President and Director/Plant Manager. The Vice Chairman for Nissan America participates in Energy Team Meetings and award ceremonies, and actively supports energy efficiency initiatives company-wide. This executive-level support has been critical to the success of Nissan's energy efficiency efforts.
- **Performance measurement:** The plant uses a sophisticated sub-metering system, which measures values every six seconds. The sub-metering system was improved and retrofitted in 2010 to better measure, calibrate, and verify energy consumption values. Plant staff analyse data several times per day and senior management review it every week.
- **Staff training:** Nissan's Energy Team attended training in statistical techniques to analyse and normalise energy data. The Energy Team provides educational materials that teach both technical and non-technical staff easy ways to conserve energy and identify energy savings opportunities. Modelled after the company's safety awareness program, each

work group has a Green Team technician who serves as an environment/energy representative

- **Communication:** Nissan implemented a data visualisation project that made the energy consumption data accessible to everyone. The monitoring data helped plant personnel to recognise their own impact on energy use. They implemented a behaviour-based sustainability approach to encourage employees to take ownership of sustainability objectives. Nissan also regularly sponsors employee Earth Day Fairs, Energy Fairs, and Family Day Fairs that provide employees and their families with access to key residential sustainability professionals.
- **Investment:** Shifting the culture and convincing plant officials to invest in energy efficiency initially posed a major challenge. Some believed the company had already seized all opportunities to reduce energy usage; however, the performance measurement data highlighted correctable, previously undetected energy losses.

Applicability

An energy management system certified ISO 50001 or integrated in EMAS is applicable to any plant or site. For example, almost all of Volkswagen's European sites have now been certified to ISO 50001 (22 sites), with other sites planned to follow over the next few years (Volkswagen, 2013).

Introducing detailed energy monitoring and management systems can be beneficial for any facility, as information from sub-metering can be used to identify measures that would not be detectable otherwise. Retrofitting of these monitoring systems is possible, and energy management plans should be implemented and continually updated accordingly. The purpose of *detailed* monitoring is ultimately to finely identify sources of inefficiencies and allocate the corresponding responsibility and action at the adequate management level, rather than to a collective overhead. Therefore, while not systematically essential, detailed monitoring will be considered at the appropriate level to incite action.

One of the key applications is to identify the causes of plant *base load* – consumption at times when production is minimal or stopped. Baseload energy consumption can account for up to 30% of the working day total (Siemens, 2013). Tracking energy consumption at a high level of detail also enables the introduction of other measures, by adapting the control software to production machinery (Siemens, 2013).

Economics

Energy efficiency measures are usually among the most economically attractive measures which improve environmental performance, as they have a direct positive impacts on energy costs. The examples below from Nissan and General Motors provide illustrations of actual costs and returns.

Nissan Smyrna (USA) implemented an EnMS to meet the requirements of the US Superior Energy Performance (SEP) certification (see "driving forces for implementation" below). Nissan invested $331,000 (€238,000) to implement SEP (including internal staff time) with a payback period of four months (Clean Energy Ministerial, 2013). The capital and operations projects implemented at the plant are saving Nissan around $1.2 million (€0.86 million) per year, with annual cost savings attributable solely to SEP of $938,000 (€675,000) (Clean Energy Ministerial, 2013). The plant is expected to retain the savings over time through the ongoing use of the management system.

Table 12: EnMS costs and savings

	Cost (€)
EnMS development and data collection	€158,000
SEP/ISO 50001 audit preparation	€22,000
External technical assistance	€32,000
Energy monitoring and metering equipment	€15,000
SEP/ISO 50001 third part audit	€12,000
Total costs	**€238,000**
Annual operational savings	**€675,000**
Marginal payback	**4 months**

Notes: Exchange rate $ to € assumed to be 0.72 over relevant period.

Source: (Clean Energy Ministerial, 2013).

Typically payback periods are less than six months and implementation costs are low. Example one-year returns versus implementation costs at individual General Motors plants include (Sustainable Plant, 2011):

- For weld water pumps/cooling tower/fans, chilled water and exhaust fans: 700%;
- For hydraulic pumps, ovens, weld water pumps/cooling towers/fans: 400%;
- HVAC and line lighting: 500%;
- Ventilation, line lighting, air supply/exhaust: 500%.

Driving force for implementation

Several driving forces have been identified, including (Clean Energy Ministerial, 2013):

- Cost savings;
- Tax rebates;
- Certification standards. For example, in the USA the SEP is a market-based plant certification programme. To be certified under SEP, an industrial plant must implement an EnMS in conformance with ISO 50001 and make verified improvements in energy performance;
- National and European regulation or schemes to encourage increased energy efficiency, such as the Energy Efficiency Directive (2012/27/EU), e.g. with incentives for SMEs and energy audits for large companies;
- Setting an example for companies in the supply chain.

Reference organisations

BMW engine plant in Steyr, Austria (Siemens, 2013);

Seat production facility in Martorell, Spain (Holt, 2012);

Nissan vehicle assembly plant in Smyrna, Tennessee, USA (Clean Energy Ministerial, 2013);

FCA Group plants, representing approximately 94% of the Group's total energy consumption, are ISO 50001 certified (FCA, 2015).

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3.2.2 Increasing the efficiency of energy-using processes

<table>
<tr><td colspan="5">SUMMARY OVERVIEW:
BEMP is to ensure that high levels of energy efficiency are maintained, by conducting regular reviews of energy-using processes and identifying options for improved controls, management, repairs and/or equipment replacement.

Major principles that can be followed to increase energy efficiency across facilities are:
• Carrying out energy performance reviews;
• Automation and timing for baseload reduction;
• Zoning;
• Checks for leaks and losses;
• Installing insulation over pipes and equipement;
• Seeking opportunities to install heat recovery systems such as heat exchangers;
• Installing cogeneration systems (combined heat and power – CHP)
• Retrofitting;
• Switching or combining energy sources.</td></tr>
<tr><td colspan="5">Relevant life cycle stages</td></tr>
<tr><td>Management</td><td>Design</td><td>Supply chain</td><td>Manufacturing</td><td>End-of-life</td></tr>
<tr><td colspan="5">Main environmental benefits</td></tr>
<tr><td>Energy consumption</td><td>Resource use and waste</td><td>Water use & consumption</td><td>Emissions to air, water, soil</td><td>Ecosystems & biodiversity</td></tr>
<tr><td colspan="5">Environmental indicators</td></tr>
<tr><td colspan="5">• Implementation of regular reviews of systems, automation, repair, maintenance and upgrades (% of sites)
• Overall energy use (kWh) per functional unit per year</td></tr>
<tr><td colspan="5">Benchmarks of excellence</td></tr>
<tr><td colspan="5">• N/D</td></tr>
<tr><td colspan="5">Cross references</td></tr>
<tr><td>Prerequisites</td><td colspan="4">• Implementing detailed energy monitoring and management systems;</td></tr>
<tr><td>Related BEMPS</td><td colspan="4">• Compressed air
• Optimisation of lighting
• Electrical motor optimisation
• Alternative energy sources</td></tr>
</table>

Description

While BEMP 3.2.1 described high-level energy management practices to be put in place, this BEMP describes concrete measures which can be put in place to increase the efficiency of energy-using systems and processes in car manufacturing.

Many manufacturing installations in automotive plans have in some aspects evolved organically based on initial plant design combined with the need to expand or accommodate for novel or increased production. Meanwhile, some technologies become obsolete (in energy efficiency terms) towards the end of their useful life. Therefore, installations may not reap all the benefits of energy efficiency of new facilities designed from scratch, which creates opportunities to identify and implement energy savings.

Energy efficiency measures can be applied to different utility networks: typically

- electrical systems (including lighting, electrical motors)
- compressed air systems
- HVAC (heating, ventilation and cooling)
- steam distribution
- if applicable, associated utilities such as hot or cold process water; industrial gases etc.

This best practice focusses on the optimisation of energy using processes through improved controls, management and equipment. The present BEMP illustrates general principles and concrete examples for the most common energy efficiency opportunities; while specific BEMPs (see *Related BEMPs* above) investigate specific cases where more detail is warranted.

Major principles can be followed to increase energy efficiency across the utilities:

- Energy performance review: It should be emphasised that in order to gain the greatest benefits, it is important to have an accurate energy efficiency monitoring system (see *3.2.1*: *Implementing detailed energy monitoring and management systems*). Based on the monitoring data, existing automotive plant performance will be evaluated. Taking a systems approach to optimising these areas typically involves the following steps (Galitsky & Worrell, 2008):
    - Identify and document the conditions and specifications of the energy-using processes to provide a current systems inventory;
    - Determine the needs and the actual use to determine whether units are properly sized and meeting current requirements;
    - Develop guidelines for proactive repair/replacement decisions;
    - Develop and implement predictive and preventative maintenance programs.

Continuous maintenance is also an essential aspect of long-lasting and high environmental performance. This includes activities such as cleaning, repair, re-calibration, testing, and/or the replacement of components.

- Automation and timing for baseload reduction: this also builds on detailed energy data made available by energy monitoring put in place as per the recommendations of BEMP 2.

  - On a larger time frame, switch-off plans for non-production periods (breaks, weekends, etc.) can be defined.
  - On a shorter time frame, if instant energy data is available, this enables immediate control of deviations and switching off unnecessary equipment.

Equipment which is temporarily out-of-use (e.g.: during meal breaks, or non-production shifts) should be automatically switched off. This applies to utilities (compressed air, cooling water) or supply systems (lighting, ventilation, heating). Whenever possible, this will be achieved by autotimers or time switches, to avoid omission (whenever the switching off is dependent on operators, omissions will on occasions occur, thus increasing costs and base-load).

Different devices can be used: PLC devices, time switches, or motion detectors – all to avoid energy consumption during idle times.

A comprehensive plan should be devised, including all relevant energy consumers (production equipment, extraction systems, compressed air, dryers, pumps, tools, all types of conveyors, heating, cooling circuits, process baths, ventilation, lubrication systems, wax or glue application, lighting (high and low level)…). Exceptions will be managed independently / manually.

- Zoning: the same principle as above applies to the space, rather than time, dimensions. Zonal management allows cutting off sections of networks which are temporarily not in use. As above, zoning can be scheduled or enacted automatically (presence sensors, valves) or manually.
- Check for leaks and losses: regular review with appropriate tools (infrared sensors for heat, ultrasound for air leaks, …) together with prompt repair and maintenance will avoid losses going undetected for long periods and may also save additional costs by preventing further degradation of equipment.
- Install insulation over pipes and equipement, and seek opportunities to install heat recovery systems such as heat exchangers.
- Retrofitting: it should be checked regularly whether equipping an installation with more recent and generally more efficient technologies might be economically sensible. Since the processes carried out and/or the models manufactured at a plant may change, equipment purchased in previous years may no longer be optimal for its current application. Therefore proper system reviews, repair, maintenance and upgrades are an essential part of ensuring continuous high performance.
- Switch or combine energy source: for instance, the installation of a combined heat and power (CHP) or heating, cooling and power unit; or the switch to renewable fuel sources.

Decisions on how to optimise processes may also be defined by decision support criteria. For example, at existing Volkswagen plants, ecological objectives are met either by replacing or upgrading machinery or by redesigning production processes (depending on the age of the production equipment). Headquarter experts collaborate closely with each individual factory and devise customised development plans for each site (Volkswagen, 2013).

Detailed guidance on general approaches for the optimisation of specific energy-using systems and equipment is provided in the **Reference Document on Best Available Techniques for Energy Efficiency**[30] (European Commission, 2009). As such, the focus of this section is to provide a selection of real-world examples of

[30] http://eippcb.jrc.ec.europa.eu/reference/BREF/ENE_Adopted_02-2009.pdf

achieved improvements in car manufacturing plants with respect to energy using processes.

A forthcoming Sectoral Reference Document on **Best Environmental Management Practices for fabricated metal products** will cover the environmental aspects of many generic processes relevant to metallic components that are used in vehicle production.

Achieved environmental benefits

The energy efficiency improvement potential will vary depending on the starting point and the processes/components that are targeted. Examples and typical improvements achieved in the automotive industry are described below:

- **Cogeneration** can offer energy savings of 15-45% compared to the use of electricity and heat from conventional power sources (Brown, 2007);
- **Waste heat recovery.** Heat generated from processes may be used as an additional heat source for supplying production heat or space heating. For example, Volkswagen Salzgitter saves 7.3 GWh per year recovering air compressors' waste heat for space heating (Industrieanzeiger, 2012). VW's Cordoba (Argentina) plant saves 2,800 MWh of energy per year by using energy recovered during production processes to operate the air conditioning systems in offices. In VW's Martin plant in Slovakia, heat pumps enable exhaust heat from cooling water to be reused. This reduces energy consumption by 2,450 MWh per year (Volkswagen, 2014);
- **Increasing automation**. In Volkswagen's Foshan plant, around 70% of the processes in the body shop are automated – robots place every weld spot accurately to the millimetre and save around 70% on energy (Volkswagen press release, 2014). The energy savings are delivered through a combination not only of more efficient servo spot welding machines but also due to lower lighting and HVAC requirements for robot operation.
- **Just-in-time production.** Toyota's Valenciennes plant have recently installed a 'just-in-time' paint oven, which has resulted in energy savings of €65,000 per year (Toyota – personal comm., 2014).
- **Timers** are used at Toyota's Valenciennes plant for space heating, lighting and air pressure optimisation. Simple solutions such as shutting down certain equipment on weekends have saved the plant €60,000 per year (a 25% reduction in energy consumption) (Toyota – personal comm., 2014).
- **Energy-efficient welding, handling and transfer robots:** Newer robots incorporate shutdown or standby functions depending on which states they are in. For example, Comau robots consume 33-58% less energy when waiting for an interlock and 80% less energy in standby mode (Fiat – personal comm., 2014).

Appropriate environmental performance indicators

Energy consumption (kWh) per functional unit or per year for the whole plant (MWh/y) are standard industry measurements for general plant efficiency. The actual figure is dependent on the functions handled at each plant. Thus, the need for detailed process-level monitoring is stressed. Adequately defining functional units will help capture relevant process performance.

Within a single plant, a comparison over time may be difficult due to changes in utilisation or changes in the models produced. The implementation of regular reviews of systems, automation, repair, maintenance and upgrades can also be monitored (% of sites).

Cross-media effects

In general, there do not appear to be significant cross-media effects in the optimisation of energy using systems. Those will generally be linked to the impact of manufacturing the new hardware to replace (e.g. more efficient lightbulbs) or insulate the inefficient existing systems.

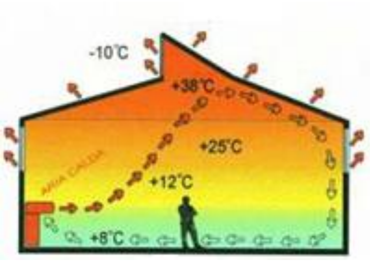
Operational data

The following examples are case studies representing best practice in the sector for several methodologies and utility networks:

- Destratification fans:

Installation of destratification fans that push down the warm air increases the average temperature at floor level, and decreases the temperature at roof level (and the subsequent heat losses).

Figure 10: Principle of destratification fans and example installation



Source: ACEA(2016)

The technology allows the reduction of thermal energy used by the heating system and facilitates air recirculation. The system is very useful in high ceiling buildings but cannot be applied in case of dusty and smoky spaces.

Destratifiers were installed firstly in a small model area with high ceiling (a laboratory) at the site of an ACEA member (ACEA 2016). The economic benefit has been monitored considering the amount of thermal energy used before and after their installation. The hygrometric wellness of operators was also tested. Thanks to the good results obtained, the project was expanded to another three sections of the plant.

N.B. The benefit is closely related to the buildings size (ceiling height).

Source: ACEA(2016)

Figure 11: Example of implementation

- Insulation of hot points in heat network:

Many specific points in heat networks e.g. valves appear as hotspots as they are not routinely insulated. However they can still account for significant heat losses (estimated at 300-500€ per valve per year if the fluid is > 90°C – source ACEA (2016)). Insulation allows reducing losses tenfold. It should be noted that maintenance is made more difficult as access to the valve is reduced.

- Heat recovery from boiler outlet:

Harnessing residual energy from one process to avoid using energy in another is highly dependent on local plant conditions, i.e. typically the proximity and heat grade of heat demand points where the energy can be reused.

As one example, in Gestamp's Santpedor (Barcelona) plant (Gestamp 2013), hot points in the boiler system were observed, used to raise the temperature of the heating and paint pre-treatment baths. Several possibilities for heat re-use were investigated. The available heat was at an operating temperature of 110°C. Meanwhile, a nearby curing oven was operating at an average temperature of 193°C, raised from ambient. The implemented solution consisted in rerouting exhaust gases from the boiler (without need for repressurisation) to the curing oven via insulated pipes, after checking that product quality would be unaffected.

- Heat recovery from furnace flue gases (Gestamp 2016)

This system, implemented at Gestamp aims to recover heat from the flue gas (exhaust) from the plant's furnace 1, in order to heat/preheat both air and water. The installation therefore consists of two heat recovery subsystems:

- Air-to-water heat exchanger for domestic hot water (DHW) and HVAC;

- Air-to-air cross-flow heat exchanger in order to pre-heat inlet air for combustion in furnace 1 flue gas duct

The flue gas flow has the following characteristics:

- Flow rate = 2.190 kg/h

- Temperature = 300 ºC

The inlet air for the furnace has the target characteristics:

- Flow rate = 1.031 kg/h

- Ambient (inlet) temperature = 25 ºC

- Max temperature = 60ºC

The hot water for domestic and HVAC use has the following characteristics:

- Flow rate = 9.100 kg/h

- Temperature = 50 ºC

In order to ensure an efficient recovery system, it is necessary to insulate the entire flue gas duct network, as well as to install modulating flow dampers into the expansion boxes, to ensure that the gas temperature remains constant at 300°C, maximizing the recovery system.

The installed components were therefore selected as follows:

The air-to-water heat recovery module provides the heat exchange between the exhaust gases and the hot water (return) from the general circuit. Manufactured from 316 stainless steel tube with a large transfer area, with counterflow mounting; without intermediate welding, minimizing the number of welds, as well as a low profile minimising the pressure drop on the gas side.

The heat exchanger has a feed water control system through a 2-way modulating valve group, which optimises heat recovery.

The air-to-air heat recovery module provides the heat exchange between the exhaust air and the fresh inlet air for combustion in the furnace. Cross-flow plates type with stainless steel plates sealed together with a heat resistant elastic material, with the aim of eliminating any leak of new intake air. The section should have a flow damper bypass device, to enable control of the recovery efficiency, and a drain tray for condensates collection and evacuation. The module side panels should be equipped with manhole to allow cleaning, maintenance and disinfection. All transition ducts and accessories are of the same material as the existing pipes (or can be in stainless steel 316) and also insulated with high density rockwool plate coating.

- Use of kinetic energy recovery systems in engine testing rigs

After the final assembly stages of engines off the production line, most or all engines undergo some testing in dynamometer test cells to verify that they meet quality and performance requirements. Engine testing usually falls under two broad categories, "cold" testing and "hot testing".

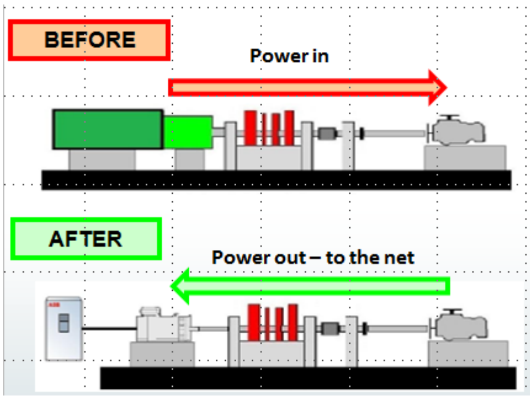
In cold testing, oil is added to the engine, but no coolant or fuel is fed to the engine and the ignition is not operated. An external motor drives the crankshaft while sensors monitor the behaviour of the engine.

In hot testing, the engine actually runs. All fluids are provided and the engine functions through simulated operation. The engine can be allowed to run unloaded, but in most cases an external load is mounted on the crankshaft to simulate vehicle loads.

Depending on product complexity, quality requirements, warranty policy etc., a manufacturer may choose to pass some or all of its engines through cold testing and even up to 100% of engines through hot testing, or only a sample.

This best practice technique, which employs principles known in the existing technology of KERS (kinetic energy recovery system) used in F1 competition, is illustrated in **Figure 12** below. It consists in the replacement, during loaded hot testing of engines, of the passive (dissipative) brakes applied to the engine to simulate loads, by dynamometric brakes which can recover electrical energy from the braking applied. This electricity is then fed back to the plant's network through appropriate signal conditioning.

Figure 12: Basic principle of kinetic energy recovery vs. common practice



The technique originated in an ACEA member OEM in a project started at the end of 2013 after one deepened analysis and cost deployment of the consequential losses of energy from missed recovery (WCM loss type 4). The technique has been in operation since April of 2014.

The phase of realization consisted in the substitution of the existing passive brakes that simulate the load during the test of produced engines with dynamometric brakes able to produce electric energy. Such brakes work in *active* way (as a starter) starting the endothermic motor at beginning of the test in substitution of the pneumatic actuator. Thereafter, they work in *passive* way during the execution of test. In this mode, while the brake acts like a load for the necessity of engine test, it becomes an electric energy generator. The energy produced is introduced in the electric network through a Converter Panel Board essentially constituted by an inverter, a regenerative rectifier and a dedicated software package.

Thanks to this system, the test cabinet became energetically independent producing energy to meet the needs of auxiliary systems (electric system, ventilation system, cooling system, lighting system) and introducing the surplus in the plant’s network.

The payback time of the investment is calculated to be under 3 years.

The electrical energy savings represent less than 10% of the whole plant's consumption.

Applicability

The techniques mentioned in this BEMP are applicable in principle for both new plants and existing installations. However, the potential for optimisation is usually greater in existing installations which have developed organically over many years to meet the evolving constraints of production, where synergies and rationalisations may deliver more obvious results.

There are a wide range of energy consuming systems and processes to which optimisation measures can be applied across processes and systems. However, the precise measures will vary depending on the specific plant – more detailed guidance is provided in the **Reference Document on Best Available Techniques for Energy Efficiency** (European Commission, 2009).

Not all plants will be able to implement cogeneration (CHP); in plants with little thermal process or heat requirements, cogeneration will not be a cost-effective strategy.

Economics

In general, the economic case for investments in energy-saving equipment has strengthened in recent years due to increases in energy prices and greater volatility. Investments are often economical where the energy costs are a major part of the total costs of ownership.

Driving force for implementation

The economics of energy saving measures tends to be a major driving force. In addition, voluntary programmes such as the US EPA ENERGY STAR programme are encouraging further efficiency improvements.

Reference organisations

Gestamp (heat recovery)

Denso, ACEA (destratification fans)

ACEA (KERS)

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3.2.3 Renewable and alternative energy use

SUMMARY OVERVIEW:				
BEMP is to use renewable energy generated on-site or off-site to meet the energy needs of an automotive manufacturing facility, depending on the local renewable resource. After striving to reduce energy use as much as possible, renewable or alternative energy sources that can be considered include: • On-site renewables, e.g. solar thermal, solar photovoltaic, wind turbines, geothermal, biomass or hydroelectric generation • Alternative (potentially lower-carbon) on-site sources such as combined heat and power (CHP) or trigeneration • Purchase of off-site renewable energy, either directly or through major utilities				
Relevant life cycle stages				
Management	Design	Supply chain	**Manufacturing**	End-of-life
Main environmental benefits				
Energy consumption	Resource use and waste	Water use & consumption	**Emissions to air, water, soil**	Ecosystems & biodiversity
Environmental indicators				
• Share of production sites assessed for potential and opportunities for use of renewable energy sources (%) • Share of site energy needs met by renewable sources (%) • Energy consumption from fossil fuels (MWh or TJ) per functional unit				
Benchmarks of excellence				
• All production sites are assessed for potential use of renewable energy sources • Energy use is reported, declaring the share of fossil and non-fossil energy • A policy is in place to drive an increase in renewable energy use				
Cross references				
Prerequisites	• Implementing detailed energy monitoring and management systems; • Increasing the efficiency of energy-using processes			
Related BEMPS	N/A			

Description

Renewable energies have the potential to lower the carbon footprint and emissions linked to the use of energy generated from fossil fuels. Renewable energy is defined as: *"energy generated by fuel sources that restore themselves over a short period of time and do not diminish"* such as sunlight, wind, rain, biomass and geothermal heat (EPA, 2014). Alternative energies can also be an option to consider on the way to using more renewable energies, by using fossil or non-renewable sources more efficiently.

The first priority must always be to reduce energy consumption as far as possible before considering fuel switching to a renewable source – see relevant guidance in *BEMPs 3.2.1* on *Implementing detailed energy monitoring and management systems* and *3.2.2* on *Increasing the efficiency of energy-using processes.*

Once options for energy efficiency have been fully explored, renewable energy will be considered to reduce the emissions of the remaining demand. The renewable energy could be generated on-site, through the installation of equipment harvesting the potential available sources; or off-site, i.e. through the purchase of renewable energy from external suppliers, such as through "green" electricity tariffs. In some cases this may be a more cost-effective option, particularly in locations with low renewable energy generation potential.

Energy is consumed throughout all processes involved in manufacturing cars. In 2012, almost 40 million MWh of energy was consumed by the European car manufacturing industry (equivalent to over 11 million tCO_2) (ACEA, 2013).

For **on-site energy** generation, the suitability of different renewable energy projects depends on the nature of the demand, local natural resources and the existing supply network. **Table 13** shows a summary of possible renewable / alternative energy sources that could be suitable for many car manufacturing sites.

Table 13: On-site renewable and alternative energy examples

Energy Source	Brief description
Solar thermal: Flat plate	Flat plate or evacuated tube solar collectors can be placed on building roofs or in adjacent areas to heat water directly. This can be used to match low/medium temperature needs with water as an energy carrier.
Solar thermal: CSP	Concentrating solar power (CSP) technology uses mirrors to reflect the sun's rays onto a heat transfer fluid that can be used to supply heat for end-use applications (including at high temperatures) or to generate electricity through conventional steam turbines. There are four main types (trough, Fresnel, tower and dish). The trough is the most mature technology, while solar dishes may also be suitable for distributed generation.
Solar photovoltaic	Photovoltaics (PV) convert sunlight into electricity. Generated electricity may be used for onsite processes or fed into the grid to benefit from feed-in tariffs for solar electricity, where relevant.
Wind turbines	Building-mounted wind turbines with a capacity of 1-6 kW are an emerging technology with low electricity outputs and currently offer a poor return on investment compared with alternative renewable energy options. Therefore, best practice is to install on-site free standing turbines of tens to hundreds of kW capacity where space and wind conditions allow, or to invest in large off-site wind turbines.

Energy Source	Brief description
Biomass heating	Biomass energy (or bioenergy) utilises energy stored in plants, as well as plant material and organic material from animals. The main source is usually wood or pellet boilers that may be used to heat water for industrial processes. Sustainably sourced biomass may represent an environmentally fuel source for heat or steam.
Landfill gas	When waste is deposited into landfills anaerobic decomposition occurs. During this decomposition stage, landfill gas is produced, which is made up largely of methane.
Geothermal heat	Geothermal energy is generated from within the Earth. This heat can be contained as either steam or hot water and can then be used to generate electricity or heat buildings.
Hydroelectric generation	Various types of hydroelectric schemes are currently being utilised: 1. Storage schemes involve impounding water in a reservoir that feeds a turbine and generator that are usually located within the dam itself; 2. Run-of-river (micro-hydro) schemes use the natural flow of a river. Both storage and run-of-river schemes can be diversion schemes, where water is channelled from a source to a remote powerhouse containing the turbine and generator.
Combined Heat and Power	Installing co-generation or tri-generation (combined heat, power and cooling) typically to replace a gas burner which only converts gas to heat, can be a more efficient use of the fossil resource.

Source: Adapted from (European Commission, 2012)*,* (IRENA, 2013)*,* (DECC, 2013)

It is important to note that ultimately, most organisations generating their own renewable energy on-site also import and export to the grid (this may be compulsory depending on the local legal context) i.e. the renewable energy produced is not necessarily used directly but rather can be counted towards the general reduction in fossil intensity of the organisation.

Significant changes are currently taking place as manufacturing plants develop from mere energy consumers to being active participants in the energy supply network (Müller et al., 2013). Hence, it is important to be aware of technical and organizational possibilities for generating, storing and distributing energy.

Off-site energy generated from renewable sources can also be purchased on the market either through national or regional utility suppliers, or more rarely by contracting directly with a renewable energy supplier e.g. a PV or wind farm located near the site. Most EU countries have at least one locally available energy utility offering "green" tariffs i.e. certified renewable energy contracted through the supplier but corresponding to a regular connection and distribution from the grid. Certification or assurance ensures that the contract corresponds to additional energy generation i.e. that the renewable energy is not otherwise accounted for or the credit claimed elsewhere, maximising the incentive effect for the further development of renewable energy.

Achieved environmental benefits

Renewable energy sources have significant potential to reduce greenhouse gas emissions, as well as reducing primary energy consumption from finite fossil fuel resources. The environmental benefits are highly variable from project to project. Ultimately renewable energy use can be a key instrument for organisations aiming to achieve carbon neutrality.

Life cycle GHG emissions, expressed per kWh heat or electricity produced are shown in as an illustration of values related to the electricity source (European Commission, 2012). For reference **Table 15** presents approximate values for conventional (fossil) generation with current conversion technologies.

Table 14: Overview of Life Cycle gCO_2^e per kWh of electricity produced with different sources.

Energy Source	Life cycle gCO_2-eq/kWh
Solar thermal (flat plate)	46
Solar photovoltaic	154
Wind turbines	18
Biomass heating (wood chip)	28
Biomass heating (wood pellet)	56
Landfill gas	246
Geothermal heat	120
Hydroelectric generation	10-30

Source: Adapted from (European Commission, 2012), (DECC/DEFRA, 2013), (Rybach, 2010), (EDF, 2014)

Table 15: Overview of average gCO_2 per kWh of electricity produced with conventional sources.

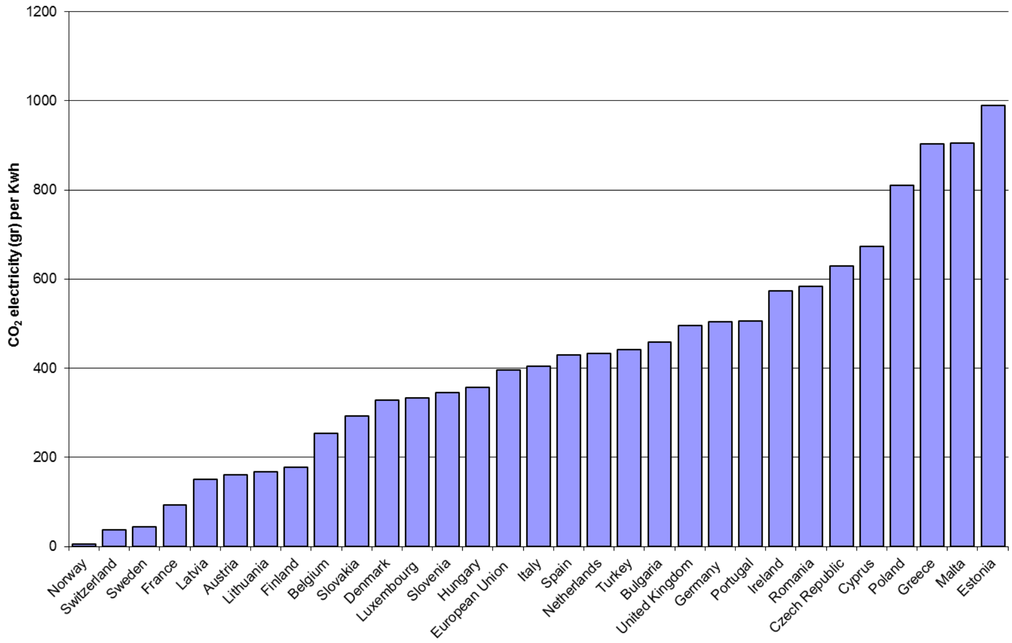
Energy Source	gCO_2/kWh
Coal	940
Natural gas	550
Oil	770

Source: Adapted from EIA, 2016

However data on life cycle GHG emissions for a national electricity mix are usually available in all current Life Cycle Assessment softwares; or the data on the electricity mix is available from the supplier. These more accurate values should be used to calculate emission factors.

As an indicative guideline, the chart below illustrates typical grid intensities for European countries (locally applicable values should be used as stressed above). This might help in particular decide whether a particular altenative energy solution such as CHP is actually preferable to sourcing electricity from the grid.

Figure 13: Grid intensity for European countries, 2009



Source (EEA, 2011)

Appropriate environmental performance indicators

Key indicators to monitor the implementation of this BEMP are:

- Percentage of production sites assessed for potential and opportunities for use of renewable energy sources;
- Percentage of site energy needs met by renewable sources;
- Energy consumption from fossil fuels (MWh or TJ) – per produced unit.

Most manufacturers measure energy consumption (in MWh) per functional unit and use this as benchmark.

Cross-media effects

While often renewable energy is thought of as being "clean", in practice there are often cross-media effects. With careful implementation, these can be mitigated so that the overall environmental impacts will be positive. The main cross-media effects and options to mitigate them are summarised in

Table 16.

Table 16: Overview of cross-media effects for different renewable options

Energy Source	Potential cross-media effects	Mitigation options
Solar thermal	The production of solar thermal collectors requires energy and materials, and emits greenhouse gases. The energy embodied in solar thermal systems is typically paid back within two to three years of operation depending on site specific application, so that energy produced over the remaining ~20 year operating lifetime creates a large positive balance.	Maximise output through optimised siting and installation (e.g. south orientation), and ensuring a long operational lifetime (cleaning and maintenance).
Solar photovoltaic	Toxic materials in manufacturing and potential concerns with End-of-Life waste. As with solar collectors, the production of solar PV cells requires energy and materials and emits greenhouse gases. Owing to lower conversion efficiencies and more complex production methods, (material / energy) payback times are estimated at three to four years against 30-year operating lifetimes. It is expected that payback times will be reduced to approximately one year with anticipated thin-film technology.	As above.
Wind turbines	Damage to wildlife (e.g. bird strike – although evidence on the biodiversity impact suggests that it is relatively small). Embodied energy in wind turbines typically represents less than one year's electricity output over typical operating lifetimes of 20 years.	Maximise output through appropriate siting (e.g. in areas of high and consistent wind speeds).

Energy Source	Potential cross-media effects	Mitigation options
Biomass heating	Air pollution (local). Wood burning emits CO, Nox, hydrocarbons, particles and soot to air and produces bottom ash for disposal. These substances indicate incomplete combustion performance, and occur especially during start-up, shut-down and load variation. Wood chip boilers typically emit slightly more polluting gases than pellet boilers owing to lower fuel homogeneity, but emissions are low compared with other solid fuel boilers. Indirect land use change (ILUC) impacts of biofuels may also be of concern – This relates to the consequence of releasing more carbon emissions due to land-use changes around the world induced by the expansion of croplands for ethanol or biodiesel production in response to the increased global demand for biofuels.	CO, hydrocarbons, soot and black carbon particles can be reduced by using continuously operating wood chip or wood pellet boilers as well as exhaust treatment.
Landfill gas	Methane leakage can occur during the landfill gas collection process and piping to a point of use e.g. in an automotive plant. Rain, snow, and liquids created by the compaction and decomposition of solid waste, which can seep through a landfill cell ("leachate") is a potential pollutant of groundwater or surface waters. If not operating the landfill site but purchasing landfill gas, the company will ensure that landfill gas *suppliers* have appropriate measures in place to mitigate potential adverse effects.	Venting systems can be installed to prevent methane from diffusing underground, and to collect any gas released and burn it off. Drains can be installed to collect leachate that has percolated through the solid waste, which is then pumped to wastewater recovery points for treatment.
Geothermal heat	Many systems use an antifreeze solution to keep the loop water from freezing in cold temperature conditions. These solutions have very low toxicity, but many release CFCs and HCFCs, which add to environmental concerns.	Antifreeze solutions with low emissions should be selected.

Energy Source	Potential cross-media effects	Mitigation options
Hydroelectric generation	The reservoir of water for hydroelectric power releases large amounts of methane emissions. This is due to plant material in flooded areas decaying in an anaerobic environment, and forming methane. Hydroelectric power sites may also negatively affect the surrounding agriculture and wildlife. There may also be water quality issues due to changes in temperature and dissolved oxygen concentrations in the water released from the dam.	Oxygen concentrations in reservoirs may be increased by aerating reservoirs or installing advanced aerating turbine runners. Installation of "fish-friendly" turbine technologies can reduce downstream passage mortality.

Source: Adapted from (European Commission, 2012) (IPCC, 2007), (CSE, 2011), (KAB, 2013), (NHA, 2010)

Operational data

Some examples of how the renewable energy sources have been utilised by the car manufacturing industry, and the associated benefits achieved, are listed below:

- DENSO Barcelona (Spain) has installed rooftop PV panels on most of the practicable areas on the roof of the facility. The close to 1,000 panels covering 5.000 m² represent over 250kW installed capacity and produce around 400MWh a year, or estimated savings of over 100 tCO_2.

Figure 14: Rooftop PV at DENSO

- At BMW's Leipzig plant (Germany) all of the energy required to produce the i3 model is supplied by renewable energy. Four Nordex N100/2500 **wind turbines** produce 26 GWh a year, which exceeds the facility's requirements to produce the i3 – the excess is redirected to other processes at the Leipzig site (meeting around a fifth of the overall power requirement of the plant (BMW, 2013), (BMW Website, 2014);
- The energy required at Volkswagen's facility in Polkowice (Poland) has been since 2012 completely met by local **hydroelectric power** instead of conventional power (Volkswagen, 2016). Since 2012, all the electric power required by the plant has been generated by local hydroelectric power plants. Thanks to the use of energy from renewable sources and the reforestation programs that have been initiated, the Volkswagen Motor Polska plant is 100 percent carbon-neutral;
- The SEAT Martorell (Spain) plant covers a surface area of 2.8m sq metres, of which 10% is covered with PV panels with a rated capacity of about 11 MW, costing an estimated €35 million. This corresponds to about 53,000 PV panels installed across 276,000 m^2 of workshop and storage facility roofs

producing a total of up to 17.8m kWh a year, with an estimated CO_2 reduction of 7000 tonnes a year.

- The array is expected to generate 15 million kWh per year, equivalent to 25% of the energy required for the annual production of the new SEAT Leon. The environmental savings achieved include the reduction of 7,000 tonnes of CO_2 per year (Business Green, 2013);
- In 2007, the Volvo Group presented the world's first CO_2 neutral automotive factory in Gent, Belgium. Investments were made in **wind power** to provide electricity. Around 50% of electricity here is produced by three 2 MW wind turbines. The windmills have a mast height of 100 m and the sails a radius of 40 m. All three are located inside the Volvo site (Volvo, 2012). In addition, a **biomass plant** has been installed for heating with a modern boiler that works on wood pellets and if necessary can switch to other environmentally friendly materials. In addition to this, on the roof of the boiler are 4,250 m^2 solar panels with an annual production of 500 MWh. As a result CO_2 emissions have declined by 14,000 tonnes annually (Volvo, 2012);
- Examples of projects from the BMW Group to increase its use of renewable and alternative energy are (BMW Group, 2015):
    - Since October 2015, a combined heat and power plant of an independent operator (Bio2Watt) has been supplying renewable energy to the plant in Rosslyn/ZA. The power plant runs on biogas drawn from waste from cattle and chicken farms as well as from food production plants. In 2015, the plant delivered 3.1 GWh, or 4.5 % of the entire electricity volume required by the plant.
    - As part of BMW's "**Gas to Energy**" project (initiated in 2001), four turbines were installed at its Spartanburg plant (USA) to pipe in methane gas from a nearby landfill site. The methane gas is used to turn the turbines which supply about 50% of the total electricity and hot water demands for the BMW site (and 100% of the energy used by the paint shop). In 2009, BMW Group replaced the original four turbines with two new highly efficient turbines. The new turbines increase the electrical output from 14% up to almost 30%. Implementation of the new landfill gas program reduces CO_2 emissions by 92,000 tonnes per year. Before this project was implemented, this gas was collected and burned in flares located at the landfill site in an effort to reduce odours and methane gas emissions (Climate Vision, n.d.) (AMS, 2007);
- At Toyota's TMMF plant in Valenciennes, a **biomass boiler** has replaced the gas heating used to heat baths. The wood pellets burnt in the boiler are sourced locally (northern France and Belgium), and provide an annual supply of 11,200 MWh, and reduce total CO_2 emissions from the plant by 6% (~1,200 tons/year) (Toyota – personal comm., 2014). In addition, a **solar wall** was installed on the south face of the plant, to preheat air by 5-10C as it enters the plant. The wall has a $400m^2$ surface, and provides an output of 233 kWh/m^2. This provides 25% of the space heating required to heat the press shop and CO_2 savings of 25.21 tons/year (93 MWh/year). The payback period in this case is expected to be ~4-5 years (Toyota – personal comm., 2014).
- VW Kraftwerk GmbH is a wholly-owned subsidiary of Volkswagen AG, tasked with supplying energy for the Volkswagen Group. It sources energy on the market and also operates its own power plants. Among these operations, it also provides energy solutions to customers outside the Group, using alternative and renewable sources when feasible e.g. all gas plants operated

by Kraftwerk run on CHP with efficiencies over 60% (compared to 38-42% for comparable condensation units).

Detailed operational guidance for the installation of alternative energy sources is provided in the **Best Practice Report for the Construction Sector** (European Commission, 2012).

In general, professional assistance should be sought to carry out feasibility studies for each site before installation of renewable energy generation, in order to determine the most environmentally beneficial and cost-effective sources. For example BMW Group reported that in 2010 around 80% of their production plants were assessed for their technical or physical potential for use of renewable energy sources (BMW, 2010).

This feasibility study will allow estimations to be made on factors such as:

- Estimated capital cost of the plant;
- Estimated operational and maintenance costs;
- Estimated payback period of the plant;
- Estimated internal rate of return.

Renewable energy may increasingly be harnessed by using hybrid systems that link different renewable sources. For example, heating may be provided by a combination of solar thermal and biomass. Some systems use district heat (often based on renewable sources) to balance electricity generation from variable sources, for example by using excess power generation on very windy days to heat water directly or with heat pumps (REN-21, 2013).

Applicability

The use of on-site renewable energy generation can be an attractive option to reduce carbon emissions from energy consumption. Currently, the uptake in on-site renewable generation varies widely between manufacturers and is influenced by various factors such as capital costs, potential cost savings or other financial returns, and the renewable energy potential of the specific site.

The potential to exploit particular renewable energy resources on-site depends on the location and site-specific factors such as climate, shading, available space, etc.

Table 17: Applicability of different on-site renewable technologies

Energy Source	Applications
Solar thermal	Flat plate and tube solar thermal can be applied to any building with suitable exposure to the sun. They can be placed on building roofs or in adjacent areas. CSP requires high direct solar irradiance to work and are therefore more interesting options for installation in very sunny regions (e.g. Southern Europe).

Energy Source	Applications
Solar photovoltaic	Solar photovoltaic cells can be installed on, or integrated into, the building envelope – in particular roofs, exterior walls and shading devices. Car and engine plants often have a large surface area of roofing (typically flat or 'serrated' types) that offer a good starting point for solar schemes.
Wind turbines	Applicable to buildings with suitable wind resource. There are no special environmental or landscape designations, however locations cannot be too close to airports, and may face opposition from local residents due to aesthetic reasons (AMS, 2007). Another potential issue is space. For example, Volvo's plant in Ghent was limited to constructing three wind turbines due to space constraints (AMS, 2007).
Biomass heating	Best suited to non-urban areas with a local wood supply and where combustion emissions pose a lower health risk. Transportation can be very expensive if the wood has to travel a long distance to get to its final destination, it is not an efficient option.
Landfill gas	Isolated or remote areas are best suited to avoid the potential variety of adverse impacts on these sites including nuisance odours.
Geothermal heat	Generally locations near to places with volcanic activity, places with geysers, hot water springs are potential geothermal sites. Areas subject to tectonic plate movements and frequent earthquakes are also potential areas. However, it is not necessary that these have to lead to a viable thermal reservoir. There could be blind geothermal resources as well with no indications at the top surface.
Hydroelectric generation	Requires a good topographical location along the path of a river. The perfect site is one where there is a wide and flat valley. The rock structure on which the dam will be constructed needs to be strong enough to sustain the weight of a dam and the water stored in it. The flow of water where the dam is constructed should be sufficient enough to fill the dam.

Source: Adapted from (European Commission, 2012), (IRENA, 2013), (British Columbia Ministry of Environment, 2010), (Bright Hub Engineering, 2010)

There can also be barriers in environmental permitting. Large–scale renewable energy technologies are subject to all the necessary environmental permits of major industrial facilities. Renewable energy generation using new technologies can face permitting hurdles until permitting officials are familiar with the environmental effects of the generation processes (EPA, 2014).

Off-site energy purchase is more generally applicable. This allows partnering with nearby energy producers (subject to comparable constraints as those listed above) or simply selecting a renewable energy option from a utility company offering that option, which is becoming a mainstream offering in most EU Member States.

Economics

The costs of renewables are site specific, as many of these components can vary according to location. Costs are very variable, due to the diversity of resources on specific sites and the power output required. Most types of renewable energy also have some economies of scale, so larger installations have a lower per-kW installation cost.

Table 18 provides indicative economic costs and the levelised cost of energy (LCOE), exclusive of subsidies or policy incentives (REN-21, 2013). The LCOE is the cost price of energy outputs (e.g., €/kWh) of a project that makes the present value of the revenues equal to the present value of the costs over the lifetime of the project. Subsidies may be available for the installation of many technologies, reducing net installation costs and payback periods. Although these are highly significant in determining the overall costs of a project, such schemes vary across countries and are subject to changes or certain conditions. Therefore, they are not explicitly included in the indication of costs below.

Table 18: Indicative costs comparisons for renewable energy sources

Technology	Type(s)	Plant size	Conversion efficiency	Capacity factor	Capital Costs (€/kW)	Typical energy costs (LCOE – €cents/kWh)
Solar thermal: Industrial process heat	Flat-plate, evacuated tube, parabolic trough, linear Fresnel	100 kWth–20 MWth	-	~100%	300 – 700	3 – 12
Solar thermal: Concentrating solar thermal power (CSP)	Parabolic trough, no storage	50–250 MW	-	20–40%	2,900 – 5,300	7 – 28
	Parabolic trough, with 6h storage			35–75%	5,200 – 7,200	12 – 27
Solar PV	Rooftop, fixed tilt	100-500 kW	10–30%	10–25%	1,100 – 1,900	12 – 28

Technology	**Type(s)**	**Plant size**	**Conversion efficiency**	**Capacity factor**	**Capital Costs (€/kW)**	**Typical energy costs (LCOE – €cents/kWh)**
	Ground-mounted utility-scale	2.5–250 MW (peak)			900 – 1,400	9 – 28
Wind	Onshore	1.5–3.5 MW	-	25–40%	1,300 – 1,300	4 – 12
Bioenergy combustion	Boiler/steam turbine Organic MSW	25-200 MW	25-35%	50-90%	600 – 3,300	4 – 15
	Co-fire				100 – 600	3 – 9
Bioenergy CHP	For heat and power	0.5–100 kWth	60–80%	70–80%	400 – 4,400	3 – 9
Bioenergy heat plant	Hot water / heating / cooling	0.1–15 MWth	80–90%	~50–90%	300 – 900	3 – 21
Biogas	Landfill gas	1–20 MW	25–40%	50–90%	1,400 – 1,600	3 – 5
Geothermal power	Condensing flash	1-100 MW	-	60-90%	1,500 – 3,100	4 – 9
	Binary				1,800 – 4,500	5 – 10
Hydropower	Off-grid/rural – run-of-river, hydrokinetic, diurnal storage	0.1–1,000 kW	-	30–60%	900 – 2,600	4 – 29

Notes: Conversion factor 0.73 USD to EUR at time of publication of reference. Several components determine the levelised costs of energy (LCOE), including: resource quality, equipment cost and performance, balance of system/project costs (including labour), operations and maintenance costs, fuel costs (biomass), the cost of capital, and productive lifetime of the project.

Source: (REN-21, 2013)

It is also important to note that the rapid growth in installed capacity of some renewable technologies and their associated cost reductions mean that data can become outdated quickly; solar PV costs, in particular, are changing rapidly (REN-21, 2013).

Driving force for implementation

The main driving forces for installation of renewable energy sources are (European Commission, 2012):

- Government financial assistance for renewable energy installation;
- Corporate social responsibility;
- Energy security.

Reference organisations

Many manufacturers have installed on-site renewable energy, although to varying degrees and using different technologies.

As an example, Volkswagen meets one-third of its energy needs from renewable generation across the group as a whole (Volkswagen, 2013) – the level achieved at individual sites varies depending on the local renewable sources, and can reach up to 100% where hydroelectric power is available (see examples above).

Across BMW Group, the share of renewable energy, as a percentage of total power consumed, reached 48% in 2013 (BMW, 2013).

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3.2.4 Optimisation of lighting in automotive manufacturing plants

SUMMARY OVERVIEW:

BEMP is to reduce energy use for lighting through a combination of optimal design, positioning, using efficient lighting technologies and zonal management strategies

An integrated approach to optimise lighting energy efficiency needs to take into account the following elements :

- Space design: wherever possible, using daylight in combination with artificial light.
- Optimising the positioning and distribution of luminaires: height and space between luminaires, within the constraints on maintenance, cleaning, reparability and cost.
- Increasing the efficiency of lighting devices: choice of efficient technical solutions (at system level) which deliver sufficient brightness for safe working.
- Management of lighting on a "zonal" basis: lighting is switched on or off according to requirements and presence.

Combining the measures above can be the most effective and comprehensive way to reduce energy use for lighting.

Relevant life cycle stages				
Management	Design	Supply chain	**Manufacturing**	End-of-life
Main environmental benefits				
Energy consumption	Resource use and waste	Water use & consumption	Emissions to air, water, soil	Ecosystems & biodiversity

Environmental indicators

- Implementation of improved positioning, energy-efficient lighting (% of lighting areas within a site, % of total sites).
- Implementation of zonal strategies for lighting (% of lighting areas within a site, % of total sites).
- Energy use of lighting equipment (if measured at detailed level), in kWh/year for a plant or kWh/m²/year
- Average efficacy of luminaires throughout plant (lm/W)

Benchmarks of excellence

- The most energy efficient lighting solutions appropriate to specific work place requirements are implemented at all sites
- Zoning schemes are introduced in all sites

Cross references

Prerequisites	• Implementing detailed energy monitoring and management systems;
Related BEMPS	• N/A

Description

Lighting can account for a significant proportion of electricity consumption at a car manufacturing plant and its optimisation can be among the cheapest energy-saving measures available. Lighting is used either to provide ambient light throughout the facility or to provide task lighting to specific areas.

Some of the guidance in this section has been adapted from the Best Practice Report on Best Environmental Management Practices for the Construction Sector (European Commission, 2012), where additional technical descriptions of the lighting options can be found. However, the guidance that follows has been tailored to make it more specific and relevant for the automotive sector, particularly considering the applications and operational data.

The most important issue when optimising lighting for manufacturing facilities is to find the appropriate lighting solution that will both provide energy and environmental benefits while also adapting to the functional requirements of the workplace, particularly specific demand for lighting adapted to the work being conducted as well as adaptation to existing (e.g. architectural) constraints on the space illuminated.

Towards this end, several steps can be taken to optimise lighting energy efficiency:

- **Space design:** wherever possible and desirable, daylight will be used in combination with artificial light, providing both energy savings during daytime and increased well-being.
- **Optimising the positioning and distribution of luminaires**: height and space between luminaires are key factors, to be weighed against considerations of maintenance, cleaning, reparability and cost.
- **Increasing the *efficiency* of lighting devices**. Lighting should achieve high levels of energy efficiency while still ensuring sufficient brightness for safe working. Efficient bulbs include (some) halogen lamps; fluorescent lamps and other gas discharge lamps; and light emitting diodes (LEDs) (European Commission, 2012).
- **Management of lighting on a "zonal" basis**, so that lighting is switched on or off according to requirements in particular areas without affecting work elsewhere.

Combining the measures above can be the most effective and comprehensive way to reduce lighting energy.

- **Space design:** Some of these solutions might only be available at building design stage, while others can be accommodated with light retrofit.

- **Optimising the positioning and distribution of luminaires:**

It is recommended to reduce the lamps' height when possible. The reason is that the closer the lamps are to the surface, the lower the power required to achieve the desired illuminance levels and hence, higher savings are achieved.

This action cannot be performed in areas where, due to the developed activity, heights cannot be modified, that is the case for example of areas with large (tall) machinery, cranes passing areas, passing trucks with loads or stacking areas. The picture opposite shows an illustration within a Gestamp plant, where the lamps' height was reduced.

Figure 15: Reduction of lamps' height in a Gestamp plant (Gestamp 2016)

Previous location

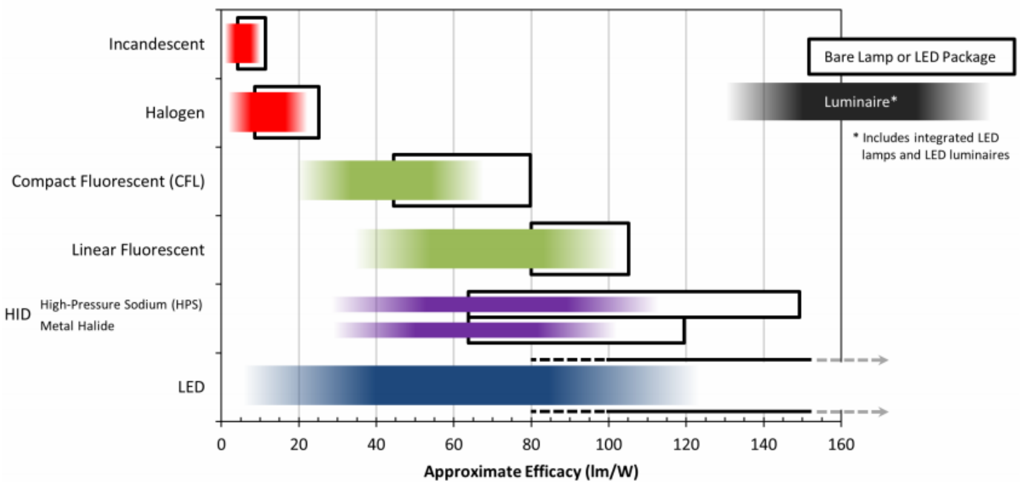
Current Location

In addition, when due to the type of activity, the required illuminance levels are> 500 lux, the light provided by the lighting system will be complemented with localized lamps located specifically for the required task.

- **Increasing the efficiency of lighting devices:**

Figure 16 shows the approximate range of efficacy for different light sources. There is a large range because all luminaire types are grouped together—but in general, the efficacy of current Light Emitting Diode (LED) products is similar to fluorescent and High Intensity Discharge (HID) products. However, the variability in LED products is greater than for the more mature technologies and the products are improving rapidly (US DoE, 2013). Of the light source technologies listed, only LED is expected to make substantial increases in efficacy in the near future.

Figure 16: Approximate range of efficacy for various common light sources



Notes: Efficacy refers to the emitted flux (lumens) divided by power draw (watts). The black boxes show the efficacy of bare conventional lamps or LED packages, which can vary based on construction, materials, wattage, or other factors. The *shaded regions show luminaire efficacy, which considers the entire system, including driver, thermal, and optical losses. Source: (US DoE, 2013)*

For the non-domestic sector, linear fluorescent tubes are the most common efficient lamps mainly used for commercial lighting in offices, commercial buildings and low-bay industrial applications (below 5 meters) (AEA Technology, 2012). T5 lamps (also known as T16) are the most efficient of all fluorescent tubes, with efficacy values from 38 to 106 lm/W, good colour rendering and colour appearance, and a lifetime of up to 48,000 hours (AEA Technology, 2012).

- **Regulation of lighting on a "zonal" basis:**

The purpose of regulating lighting is to minimize electricity consumption by adapting the artificial light contribution to the plant's needs at each instant. The regulation can vary from simple switches to complex centralized multi-sensor systems.

The most commonly used sensors for lighting control systems are:

- Presence/movement sensors. Widely used in corridors or service areas.

- Photoelectric sensors. These sensors capture the natural light and the lighting system acts according to the luminosity. Different types of regulation can be performed: on/off, by steps or continuous.

The electrical circuit supplying the lighting system and its zoning capabilities will determine the potential savings of the regulation system. More savings will be achieved if areas without personnel working can be switched off or if some lights can be progressively switched off according to the daylight.

In terms of regulation, there are many possibilities. The complexity can range from a very complex system such as DALI (Digital Adressable Lighting Interface), to very basic systems controlled by switches and/or timers. The ideal system will be determined by the potential savings and its investment cost.

- **Systems-level consideration:** The 4 dimensions above need to be taken into account for the optimisation of a lighting system.

A study for the lighting change will be undertaken where the costs, savings and illuminance levels in each area are examined. The measures/actions involved in the change in order to optimise the lighting system need to be well justified.

An option to reduce the investment cost is using high power lamps so that the total number of luminaires is reduced and hence the total cost. When this solution is considered, uniformity problems might arise, which needs to be also taken into account.

When the plant's areas are not perfectly rectangular or irregular in heights, it is recommended to use lamps of lower power ranges in order to complement the high power ones and reach the desired illuminance levels (instead of using high power ones everywhere). Hence, a well dimensioned project will have the high power lamps to supply the majority of the plant's surface, while the lower power ones will complement the areas not reached by the high power lamps.

When locating and choosing the lamps' required power, it is important to consider the elements/equipment within the plant. Machinery with a considerable height may cause shadows or block the light. For instance, a high power lamp on top of a high machine will generate shadows and unnecessary illuminance levels on top of the machine.

Regarding lighting systems with regulation capabilities, it is important to consider how the on/off cycles may affect the lamps' service life, depending on the chosen lamp technology. Such cycle may reduce drastically the lighting system's service life.

Achieved environmental benefits

The main environmental benefit is a reduction in electricity consumption.

For example, one manufacturer claims that **LED lighting** can reduce operational lighting energy consumption by up to 60% compared to traditional lighting (Philips, 2014). Other systems may also improve efficiency - for example the T5 system of **linear fluorescent lamps** from Schneider Electric is used at Volkswagen Chattanooga, where it reportedly achieves an appropriate illumination level with an energy expenditure of less than 4 W per square metre of floorspace (around 20% savings compared to conventional lighting systems) (Farish, 2012). At Hyundai's Korean plants, metal lamps (430 watts) have now been replaced **by electrode-less lamps** (150W) and **high efficiency fluorescent lighting** (54 W×3 bulbs), cutting annual CO_2 emissions by a stated 6,000 tonnes (Brooks, 2010, Hyundai, 2009).

For external lighting, **LED lighting used in external locations** also minimises light pollution (Farish, 2012). At Audi Ingolstadt, introduction of LED lighting in multi-storey parking areas achieved savings of 97.5 kWh per parking space per year, with the additional benefit of being less harmful to wildlife by lowering the attraction for insects (Audi, 2013).

In terms of **management of lighting on a "zonal" basis**, electricity savings at Volvo's Torslanda plant (Sweden) from turning off lights during non-working hours were estimated at 630 kW (56%) in the final assembly plant, 370 kW (30%) in the paint shops and 210 kW (18%) in the press shop (Galitsky & Worrell, 2008). An intelligent lighting system controlled by daylight and motion sensors installed at Hyundai Nošovice (Czech Republic) reduced power consumption by 30% (Helvar, 2013). For example, at lunch hour the corridors are lit more brightly and the workstations are dimmed.

Appropriate environmental performance indicators

At the organisational level, the implementation of luminaire optimisation, energy-efficient lighting and zonal strategies can be measured (% of lighting areas within a site, % of total sites). For a single site, efficient lighting can be installed throughout the entire facility (Volkswagen, 2012).

At the luminaire level, products can be compared in terms of efficacy (lm/W). In use, energy consumption for lighting is typically measured per m^2 or per year.

Appropriate environmental indicators can therefore be based on:

- implementation of optimised lighting (% of lighting areas within a site, % of total sites)

- implementation of zonal strategies (% of lighting areas within a site, % of total sites)

- electrical consumption of lighting equipment (if measured at detailed level), in kWh/year for a plant

- average efficacy of luminaires throughout plant (lm/W)

Cross-media effects

Generally, since most impacts occur during the use phase, the environmental impacts over the luminaire life cycle are proportional to the efficiency in use. Fluorescent lamps contain small amounts of mercury, which means appropriate recycling methods have to be used (European Commission, 2012).

Operational data

Importantly, efficacy should not be the only factor when comparing products. Other performance characteristics, such as colour quality, luminous intensity distribution, and dimmability must be included in the decision (US DoE, 2013). These factors interlink to affect the overall performance and energy efficiency of the system. Detailed operational guidance is provided in the Reference Document for Best Environmental Management Practice in the Construction Sector (European Commission, 2012).

These major technical parameters are briefly described below (based on AEA Technology, 2012):

- Luminance efficacy – Measured in lumens per watt (lm/W), it describes the efficiency at which a lamp converts electricity into light. Usually, the higher the value the more efficient the lamp;
- Colour performance – Described by the Colour Rendering Index (Ra), it is the ability of the lamp to show colours accurately. Ranging from 0 to 100, with the best performing lamps having values above 80. Colour performance requirements typically vary according to work areas;
- Colour appearance – Described by the correlated colour temperature and measured in Kelvin (K), it characterises colour warmth and coolness: the warmer (redder) the light, the lower the Kelvin value; and conversely, the cooler (bluer) the light, the higher the Kelvin value. For example a GLS lamp will have a warm colour temperature of 2,700-3,000 K, to be compared with a cool colour temperature of 4,000-6,000 K for a lamp which mixes reasonably well with daylight, such as a cool white fluorescent tube;
- Lamp life – For most lamps this is the time when half of the lamps in a sample fail and is measured in hours. In addition, the number of On/Off cycles before failure is also a relevant criterion.
- Dimmability – the ability of a lamp to operate at a discrete or continuous fraction of its rated power.

The European standard UNE-EN 12464-1 defines certain parameters/characteristics that need to be achieved by indoor light sources to ensure comfort and visual needs levels at workplaces. To go further, some users can therefore use additional functional metrics for lighting, for instance the following two indicators (see "Guía Técnica de iluminación eficiente"):

•Maintained Illuminance: The illuminance is the luminous flux divided by surface (lm/m²). Maintained Illuminance is defined as the value below which the average illuminance (lux) it is not allowed to fall, for a given task.

•Unified Glare Rating (UGR): Index used to quantify the glare caused by the light sources. It has a range of 10-31, the higher the value, the higher the glare.

There is specific guidance on best practices for **motor vehicle plant lighting** in a USA context, provided under the US EPA ENERGY STAR programme. A spreadsheet listing best practice lighting levels from companies participating in EPA's ENERGY STAR Motor Vehicles is available for download[31].

This provides a summary of the best practice lighting levels used by companies participating in the programme. The full guidance is very extensive and therefore not duplicated here in whole – as a general overview, Table **19** presents lighting levels in lux[32] for different manufacturing areas. The manufacturing areas covered include: assembly, body welding, paint, press, plastics, powertrain, casting, utilities, administrative and other areas.

Table 19: Guidance on best practice lighting levels in motor vehicle plants

Process area	Min (Lux)	Max (Lux)
General occupied building areas	100	300
General unoccupied building areas	10	50
Assembly	150	500
Body welding	300	1,000
Press	150	600
Plastics	150	1,500
Powertrain	100	1,000
Casting	150	1,500
Utilities	150	500
Administrative	100	500
Parking lots	12.5	30

Source: (EPA, 2010)

N.B. The values above are guidelines only, and – in addition to the detailed specifications mentioned in the guidelines – the illuminance will be first and foremost adapted to the specific requirement of the process where lighting is provided.

[31] http://www.energystar.gov/buildings/tools-and-resources/motor-vehicle-plant-lighting-level-best-practices

[32] Illuminance, measured in lux or lumens per m^2, is a measure of intensity of light (as perceived by the human eye) that passes through a surface.

Case study: Gestamp overhaul of light installation (source: Gestamp 2016)

Methodology

a) Technology change

Previous to the technology change, the plant had installed 400W metal halide lamps. The existing technology was replaced with T5 fluorescent lamps. With the fluorescent technology the lighting characteristics of the plant were improved, previously they had an average of 91 lux, with the new technology an average of 176 lux was achieved. The installed power was considerably reduced with its consequent electricity savings.

b) Reducing the number of required lamps

In Building 1 the number of installed lamps remained the same, the 400W lamps were replaced with luminaires with four 49W T5 fluorescent tubes each. In Building 2 the number of installed lamps was reduced, the 400W lamps were replaced with luminaires with four 80W T5 fluorescent tubes each, Table *20*.

Table 20: Lamps' characteristics before and after the lighting system change

Building 1	**Technology**	**Units**	**Power**	**Total**
Before	Metal halide	97	445W (1 x 400W [+ 45W]*)	43,2kW
Actual	Fluorescent T5	97	207W (4 x 49W [+ 11W]*)	20,1kW
Building 2	**Technology**	**Units**	**Power**	**Total**
Before	Metal halide	504	445W (1 x 400W [+ 45W]*)	224,3kW
Actual	Fluorescent T5	333	329W (4 x 80W [+9W]*)	109,6kW

*Values in brackets relate to consumption apart from the light source

Service life (according to supplier: OSRAM) is for Luminaires: 100.000 h and for Fluorescent tubes: 45.000 h.

c) Regulation/Control

A control system activated by daylight sensors was installed. Depending on the natural light captured by the sensors inside the plant, groups of luminaires are switched ON/OFF. The ON/OFF sequence (which luminaires to turn ON or OFF according to the light captured) was programmed by a Siemens team in collaboration with the plant's maintenance team. Using the control system, the plant's artificial lighting is adapted to the daylight (the plant has windows and skylights).

The three-phase contactors within the electrical panel are PLC controlled; which contactors to close or to open are defined according to the light sensors inputs and the predefined ON/OFF sequence. This solution has a lower control capability compare to that of a DALI control system, but since it does not need its own wiring for the entire facility, the cost is much more affordable.

Results

Table *21* shows the consumption comparison of the previously installed technology (metal halide) and the current one (fluorescent T5). Table *22* shows the annual savings in % and in MWh in each Building and the total savings. In both tables only savings due to the installed power are considered, that means without any type of control.

***Table 21*: Energy consumption before and after the lighting system change**

Building 1	**Technology**	**Units**	**Power**	**Total**	**h/year**	**MWh/year**
Before	Metal halide	97	445W	43,2kW	5.500	237,4
Actual	Fluorescent T5	97	207W	20,1kW	5.500	110,4

Building 2	**Technology**	**Units**	**Power**	**Total**	**h/year**	**MWh/year**
Before	Metal halide	504	445W	224,3kW	5.500	1.233,5
Actual	Fluorescent T5	333	329W	109,6kW	5.500	602,6

***Table 22*: Yearly savings according to the installed power**

	Building 1	**Building 2**	**Total**
Savings (%)	53,5	51,0	51,4
Savings (MWh)	127	631	758

In order to replace the metal halide lamps for T5 fluorescent lamps, an investment of 205.900€ was required. Considering the savings shown in in Table 4 of 758MWh per year and assuming an average electricity price of 0,1€/kWh, annual savings of 75.800 €/year are achieved. As a result, a 2,7 years payback is obtained (Table 5).

***Table 23*: Savings and Payback without regulation**

Investment (€)	**Yearly savings (MWh)**	**Electricity price (€/kWh)**	**Annual savings (€)**	**Payback (years)**
205.900	758,0	0,1	75.800	2,7

Savings presented in Table *22* and

Table *23*, show only the savings due to the installed power reduction (due to technology change). When considering the lighting control system, these savings are expected to increase; since the lights turn off depending on the daylight, lamps will be switched on for fewer hours. It is difficult to quantify exactly the savings percentage due to the regulation; it is estimated that the regulation will imply additional savings above 10%, reaching in such way total savings higher than 62% (regulation plus technology change).

Assuming savings of 62%, Table *24* shows the annual savings and Payback due to changes in the lighting system (technology change and the regulation system installation). The required investment was 239.100 €: 205.900€ technology change and 33.200 control system. Savings of 62% implies annual savings of 912 MWh; assuming an average electricity price of 0.1 €/kWh, annual savings of 91,200€/year are obtained, which means a 2,6 years Payback.

***Table 24*: Savings and Payback with regulation**

Investment (€)	Yearly savings (MWh)	Electricity price (€/kWh)	Annual savings (€)	Payback (years)
239.100	912	0,1	91.200	2,6

Applicability

Most fluorescent lamps do not provide full brightness immediately after being turned on. This is particularly relevant to amalgam compact fluorescent lamps (CFLs), which can take three minutes or more to reach full light output. HID lamps have even longer warm up times, ranging from several minutes for metal halide to ten minutes or more for high-pressure sodium (HPS). Therefore LEDs have an advantage when used in conjunction with occupancy sensors or daylight sensors that rely on on-off operation as they reach full brightness almost immediately (US DoE, 2012). For external work areas, the use of the LED technology may not provide sufficient brightness for safe working, although it can be used in less critical areas such as parking lots.

Economics

When economic effects of measures for electric motors are calculated, a life cycle cost consideration is crucial. This is due to the fact that up to 97 % of the life cycle cost relate to operation costs, whereof the main component are energy costs (Siemens, 2009).

Therefore in general investment in efficient artificial light sources is more than compensated by the lifetime savings. Current estimates for the cost and performance of different lighting types are shown in Table **25**.

Table 25: Typical current international values and ranges for commercial lighting applications

Technology Variants	Metal halide	High pressure sodium (SON)	Fluorescent tubes Triphosphor coated	LED
Typical applications	Commercial uses with good colour rendering: high bay areas (indoor space with high ceiling), floodlighting, external lighting, retail, hotels	High bay areas, flood lighting, street lighting, etc., that need to be lit for a long periods	Offices, commercial buildings, and low bay industrial uses (below 5 m)	A variety of different applications

Technology Variants	Metal halide	High pressure sodium (SON)	Fluorescent tubes Triphosphor coated	LED
Typical size (W)	70-400 (up to 1,000 available)	30-400	T8[33]: 10–70 T5: 6–80	1-16
Energy efficiency or 'efficacy' (Lm/W)	70-107	65-103	T8: 60-100 T5: 38-106	>25-100
Lifetime (hours x 1,000)	6-20	12–28.5	T8: 12–60 T5: 16–48	12- >50
Colour Temperature (K)	3,000-6,000	2,000	2,700–6,500	2,800-6,500
Colour Rendering Index (CRI)	65-96	25	80 – 85	80
Product cost (€/unit)	11 – 50 (special types over 100)	8 – 25	T8: 2 – 19 T5: 3 –10	11 – 57

Source: (AEA Technology, 2012).

The rated lifetime can be especially important where access is difficult or where maintenance costs are high, and in many cases the maintenance savings (as opposed to energy savings) are the primary factor determining the payback period for a lighting product (US DoE, 2012).

Further economic factors in selection include (source: Gestamp 2016): currently prices for LEDs are much higher than those of T5 fluorescent lamps. While offers can sometimes be presented with similar prices to those of fluorescent lights; the problem is that certificates guaranteeing the technical specifications and performance may not be offered. The Spanish Association of Manufacturers of Lighting (ANFALUM) warns of caution regarding offers with no reliable certificates or warranty.

Another factor that needs to be considered is that a malfunctioning tube (T5) can be replaced for another one spending in the order of 10 euros per tube; whereas for LEDs the entire luminaire must be replaced, which is translated in higher expenditures.

Since LED technology is constantly and rapidly evolving, in the near future the advantages of this technology may be such that it may become the recommended technology. As a result a lighting system change is recommended when the change implies a difference in installed power ≥ 40% and a Payback <3 years.

Driving force for implementation

One of the main driving forces is the potential for cost reduction. In Europe, Regulation (EC) 244/2009 came into force which sets efficiency requirements for CFLs and GLS lamps and aims to remove the most energy inefficient non-directional lamps from the market in favour of more energy efficient alternatives (AEA Technology, 2012).

[33] The two most commonly used types of fluorescent tubes have two common diameters: 26mm (T8) and 16mm (T5).

Reference organisations

Organisations mentioned in this BEMP include:

- Gestamp, multiple sites
- Hyundai, Nošovice (Czech Republic);
- Volkswagen, Chattanooga (USA);
- Volvo, Torslanda (Sweden).

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3.2.5 Rational and efficient use of compressed air

SUMMARY OVERVIEW:

BEMP is to reduce energy consumption by mapping and assessing the use of compressed air, by optimising compressed air systems and eliminating leaks, by better matching supply and demand of air, by increasing the energy efficiency of compressors and by implementing waste heat recovery.

Compressed air usage can be optimised according to a vast portfolio of measures in three areas:

Demand-side measures:
1. Avoid and replace misuse of compressed air
2. Review usage of compressed air tools
3. Monitor and control demand
4. Set up awareness programmes

Distribution network and system measures:

5. Identify and minimise leaks
6. Depressurisation
7. Zoning
8. Use of valves

Supply-side measures:

9. Size and manage compressor system according to demand
10. Increase the overall energy efficiency of the compressed air system
11. Regular inspection of system pressure
12. Increase the energy efficiency of major system components
13. Regular filter inspection
14. Energy efficient dryers and optimal drain selection
15. Install waste heat recovery

Relevant life cycle stages				
Management	Design	Supply chain	**Manufacturing**	End-of-life

Main environmental benefits				
Energy consumption	Resource use and waste	Water use & consumption	Emissions to air, water, soil	Ecosystems & biodiversity

Environmental indicators

- Specific electric energy use of the compressed air system (kWh/Nm³ of compressed air, at the specified operating pressure of the compressed air system)

Benchmarks of excellence

- **The compressed air system has an energy use of less than 0.11 kWh/m³** [for a compressed air system operation at a pressure of 6.5 bars effective, with volume flow normalised at 1013 mbar and 20°C, and pressure deviations not exceeding 0.2 bar effective.]
- **After all air consumers are switched off, the network pressure remains stable and the compressors (on standby) do not switch to load condition.**

Cross references	
Prerequisites	• Implementing detailed energy monitoring and mgmt. systems
Related BEMPS	• Increasing the efficiency of energy using processes

Description

Compressed air is a very versatile operation medium and thus widely used in automotive manufacturing. The advantages of compressed air applications lie in the safety of this energy source, the speed and precision as well as the low weight of air tools. For example, it is an effective way to clean components without damaging them, as no liquids are used which could cause harm to the components or leave behind a residue. Compressed air can also be used to clean machinery involved in the manufacturing process. Furthermore, compressed air technology is often used to power manufacturing equipment, e.g. assembly tools, such as air driven machinery that is used to hold, position, and assemble automotive components.

However, compressed air is a major challenge in the energy management of a manufacturing site as it can account for up to 10% of annual electricity consumption.

The following BEMP is articulated around a series of management and technical measures which can be followed sequentially or in parallel in order to optimise the use of compressed air throughout industrial facilities. They can be grouped in measures which aim at reducing the demand for compressed air, measures optimising the distribution system, and finally optimising the production of compressed air:

Demand-side measures:

1. Avoid and replace misuse of compressed air
2. Review usage of compressed air tools
3. Monitor and control demand
4. Set up awareness programmes

Distribution network and system measures:

5. Identify and minimise leaks
6. Depressurisation
7. Zoning
8. Use of valves

Supply-side measures:

9. Size and manage compressor system according to demand
10. Increase the overall energy efficiency of the compressed air system
11. Regular inspection of system pressure
12. Increase the specific energy efficiency of major compressed air system components
13. Regular filter inspection
14. Energy efficient dryers and optimal drain selection
15. Install waste heat recovery

1. <u>Avoid and replace misuse of compressed air</u>

Experience shows that many compressed air connections have been made incorrectly, for minor jobs that could have been done using another more efficient source. Because of this, prior to installing the air connections it is important to analyse whether the compressed air is suitable for the intended function. As well, it is important to check whether compressed air can be replaced in some processes by other methods.

A clear example that can be often seen in plants is the use of compressed air for cleaning down workbenches, floors and/or personnel. In this case, solutions that are more efficient are preferable, such as brushes or vacuum cleaners.

In order to minimize the misuse, the price of the compressed air system can be made available to the people within the plant, whereby its misuse is likely to be reduced. This could be integrated in the energy awareness programs mentioned in paragraph 4.

2. Review usage of compressed air tools

Although compressed air technology is highly useful for manufacture and nearly all companies make use of it, it is an inefficient and expensive energy carrier when used in non-specific applications, such as to drive tools like drillers and screwdrivers. In fact, compressed air is usually supplied by electrical compressors and has to be distributed by distribution networks that are vulnerable to leaks; as a result, at least ten times of the final energy stored within compressed air is consumed during its production (Diemer & Feihl 2011). In the case of compressed air used to drive drillers and screwdrivers a substantial reduction in the energy consumption, more than 90% (Niermeier 2013b), can be achieved by **using electric tools instead of compressed air ones**. However, a number of other aspects are to be examined when considering electric tools as an alternative to compressed air:

• Durability: In general, compressed air tools have a longer life compared to electrically driven tools;

• Waste generation: once reached their end-of-life, electrically driven tools generate waste electrical equipment and, if battery-powered, the disposal of batteries is one of the main issues. Compressed air tools are instead easier to recycle;

• Use of critical raw materials: electrically driven tools use some critical raw materials (in motors and batteries).

• Safety in ATEX environments: Electrically driven tools cannot be used in a number of environments, where sparks or heat cannot be produced (e.g. explosive atmosphere).

• Lower power-to-weight size ratio: electrically driven devices have a lower power-to-weight size ratio compared to compressed air tools, causing more effort for operators to carry out their job.

Against this background, a strategic approach for best environmental management practice in the field of compressed air systems will firstly assess the compressed air processes in use for automotive manufacturing and evaluate the potential to substitute, when feasible and in light of the considerations above, compressed air tools by electrically driven devices. This would lead to a substantial reduction in the energy use of the company.

3. Monitor and control demand

By monitoring the compressors' demand, it is possible to evaluate the expenditure due to compressors' operation. These data are very important in order to evaluate whether the system is operating under optimal conditions or not. Through the monitoring system, parameters such as off-load operating hours or kW/(m^3/min) can be monitored, which are indicators of how well (or not) the system is being operated. An optimal compressed air system will minimize the number of hours compressors are operated in off-load mode (i.e. consuming without producing compressed air).

Moreover, the monitoring system enables the evaluation of the impact of the measures adopted, assisting in the implementation of all the techniques in this BEMP.

4. Set up awareness programmes

Training and energy awareness programs are important in order to minimise bad habits and the unnecessary waste of energy at the plant, as well as to encourage good habits. It could be something as simple as notifying a leak when it is detected. The concept of awareness is disassociated from purely technical, objective parameters; therefore, it is difficult to identify which method is optimal. On the other hand, it is quite difficult to measure the results of the awareness measures. Each plant must implement its own program according to the characteristics and needs of that plant. These types of measures, which entail a change of behaviour of people at the plant, require persistence if results are to be obtained.

5. Identify and minimise leaks

The single most important measure, as well as the easiest, in terms of rational use of compressed air is the identification and elimination of air leaks. It can be shown that air leaks with even very small diameters (e.g. 1 mm) can cause substantial losses in terms of both energy and costs. Compressed air system leaks can account for 10-30% of the compressors' demand, in worst cases reaching up to 50%.

Their detection is possible by simple methods of sensory perception in many cases, but also air leaks that are hidden or difficult to access can be easily located with ultrasound measuring instruments.

6. Depressurisation

During plants' inactive periods, compressors remain in operation if they are not switched off. Network leaks behave like small consumers, reducing the system's pressure and making the compressors work to keep the pressure at the predetermined values. The depressurisation of the network during inactive periods is interesting from an energy efficiency viewpoint, if the losses during the inactive period are greater than the energy required to re-pressurise the network.

The option of installing small compressors for activities and/or processes operating 24/7, can also be considered. It will be more efficient in terms of energy to have a small compressor for that activity than to keep the whole network pressurised.

7. Zoning

Zoning responds to the same principle as depressurization. It consists in isolating sectors in the network that will not be needing compressed air, thereby avoiding any losses due to possible leakages in that sector during inactive periods. Another advantage associated to zoning is that maintenance and leak repair work can be carried out in areas and/or equipment that have been isolated from the main network. Zoning is carried out at many plants.

Zoning does not only consists of isolating an area of the network. There may be cases where the needs of some equipment may be much greater than those of others, for instance 12 and 6 bar. In such cases, the best solution might be to create **two networks at different pressures** rather than having the whole network working at 12 bar.

8. Use of valves

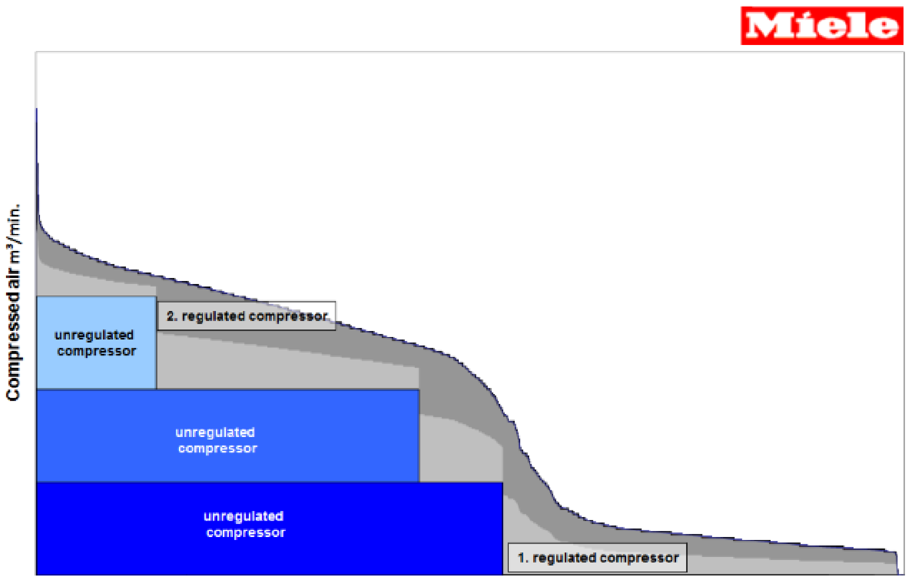
The equipment may be isolated (disconnected) from the network by means of valves when it is switched off, thereby avoiding any leakage associated to the equipment when is not operating. The air supply of equipments may be shut off automatically (by means of electrovalves) or manually. The efficacy of an electrovalve will depend on the operator switching off the machine; if this is not done, the air will not be cut off. There are options whereby machines are switched off automatically when they have not been used for a given period (for instance, 20 minutes); this guarantees that, besides the machine being switched off, the electrovalve is shut off.

9. Size and manage compressor system according to demand

One of the fundamental objectives of an energy-efficient system design is to match the air pressure, volume and quality to the needs of the various end use devices. Within this context it has to be decided whether a centralised compressor station is more suitable than two or more decentralised units. In any case, the supply should be close to the consumptions centres. Furthermore, it is recommended to prefer a system delivering a lower pressure (applicable for most applications) and add pressure boosters for devices that require higher pressure (Radgen & Blaustein 2001).

In addition to this, the system design should be based on the annual load duration curve. As shown in the following illustration, this implies that large, unregulated compressors run base load, while the peaks are covered by the smaller, regulated devices. The latter can also ensure supply during minimal load periods. As a result, compressor running times (operation hours) of the individual compressors decrease, thus reducing both energy consumption and wear of the compressors (Diemer & Feihl 2011).

Figure 17: System design according to annual load duration curve



Source: Miele

If a multi-compressor strategy is choosen, the control of a group of compressors may be conducted using the traditional cascade control or the more up-to-date pressure band control (Kaeser, 2010): With cascade control, each compressor is assigned a defined lower and upper pressure, at which the respective compressor is switched on (or off). The main disadvantage of this control method is the result of a relatively large overall pressure swing. However, the modern pressure band control coordinates the overall system pressure in a so-called pressure band. This means that an additional micro-processor selects appropriate compressors based on the currently required system pressure. A disadvantage is the higher effort for data processing.

10. Increase the overall energy efficiency of the compressed air system and adjust working pressure

It is recommended to check the existing compressed air system in terms for possible improvements concerning overall energy efficiency, especially if the following reasons for pressure drops exist (Diemer & Feihl 2011):

- Piping cross-sections are too small (bottlenecks);
- Added filters or coolers;
- Unsuitable fittings or hose couplings;
- Too long (spiral) hoses, too many couplings.

In terms of increasing the overall energy efficiency of the compressed air system, it has to be taken into account that the specific electricity consumption of the system is directly correlated with its **pressure** level. Furthermore, possible losses through air leakages are also proportional to the pressure level (Dena 2012; Diemer & Feihl 2011). Hence, optimization of the system design is very important prior to the installation of technical solutions.

The experience within industry shows that many times compressed air networks are operated at pressure values higher than those required. Concrete examples (see Operational data section) show network pressure has been reduced in plants, without affecting production. Theoretical values estimate that reducing the operational pressure by a 10% can lead to 5-7% savings in compressors' energy consumption. The way to proceed is simply by making small, incremental reductions, checking that operations are not affected; usually the farthest point will determine/limit the network's pressure.

11. Regular inspections of the operating pressure

Once the appropriate working pressure has been established as above, it is also important to regularly check that the pressure is maintained at its optimal level. Within existing automation settings, the pressure of the system might creep up, threatening the system efficiency. Without the need to deploy additional automation, low-cost solutions can be deployed, along with scheduled inspection tours, to ensure that the working pressure is maintained in the desired operating range.

As in the case of leakage monitoring, this is one of the measures with the highest payback.

12. Increase the specific energy efficiency of major compressed air system components

Concerning the installation of energy-efficient components for an optimized compressed air system, compressors will especially be taken into account, since they represent the system's most important as well as most energy-consuming component. In the selection of compressors, attention will be paid to the highest possible efficiency. In particular, in combination with technique 9 on the sizing of the whole compressor system, and BEMP 3.2.6 on the Optimisation of electric motor usage, the use of **variable speed drives** could be implemented to increase the efficiency of some or all compressors installed.

13. Regular filter inspection

A proper filters control and replacement program can significantly reduce energy consumption. Filters in proper conditions can account for a 0.15% pressure drop, but in bad conditions, they can account for as much as the 10 %. Some filters are provided with a pressure-drop measuring device, this value should be considered for filters replacement. The replacement can be done as well according to the operating hours.

14. Energy efficient dryers and optimal drain selection

Besides compressors, also dryers that are necessary for compressed air systems in order to avoid corrosion can be enhanced in terms of energy efficiency. In this respect, dryers with integrated cold storage are an interesting option.

Regarding drains, three main types of drain methods are commonly used.

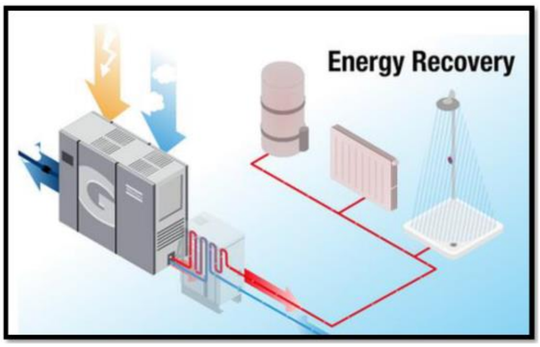
- Mechanical float drains: Through a mechanical system, the water level determines when and for how long the drain takes place, this system is sensitive to dirt and may stick open, discharging the condensate and also, discharging expensive system air.
- Timed drains: These are valves where two parameters can be programmed, frequency and duration of discharge. Since these are defined values, they do not adjust to actual system needs, meaning that the frequency may not be adequate and the duration can be too long (air losses) or too short (fail to remove all the condensate).
- Level sensing drains: This type has an intelligent control system that detects and discharges condensate only when it is present and without the loss of valuable compressed air.

15. Install waste heat recovery

Finally, the recovery of waste heat from the compressor(s) is considered to be a powerful measure in order increase the overall energy efficiency of a compressed air system. When installing appropriate facilities (like plate heat exchanger), large amounts of previously unused heat energy can me made accessible for other car manufacturing processes.

There is a big potential for heat recovery in the process of cooling the compressors' oil. Cooling the oil through a heat exchanger can provide an important source of hot water. Several processes could take advantage / make use of this hot water. In some Gestamp plants, the hot water is used for cataphoresis painting baths. In other plants the heat is used to supply hot water for the dressing room and showers. The figure opposite shows different processes that could benefit from the heat exchanger's hot water (see further examples in the Operational Data section).

Figure 18: Principle of Energy Recovery apparatus



Source: Atlas Copco / mentioned in Gestamp 2016

It is important to identify which compressor will provide more heat (according to its rated power and its hours of utilization) before investing in and installing the heat recovery system.

It has to be noted that the elements mentioned above can be applied separately. However, best results will be achieved through an integrated approach implementing all or most of these measures.

Achieved environmental benefits

As mentioned above, the supply of compressed air requires a particularly high amount of electric energy. As a result, it is estimated that up to 10 % of total electricity consumption of automotive production sites are attributed to compressed air production (Radgen & Blaustein 2001).

When implementing the measures mentioned in the section on **Operational data** below, especially concerning heat recovery, savings in the range of 50% are possible (Radgen & Blaustein 2001), other assessments showing savings potentials of up to 66% (VDMA 2005). Potential energy savings in these areas often remain unidentified due to the complexity of the systems, but existing systems may be optimised to: reduce leakage (savings of up to 20%); reduce unnecessary system pressure (reducing grid pressure by one bar will tend to reduce energy consumption by 10%) and; use variable speed drives (InnoCaT, 2013a). For example, the compressed air system at Toyota's Valenciennes plant is checked every weekend for leaks, using ultrasonic testing. As a result, the current leakage at the plant has been reduced to ~10% (Toyota – personal comm., 2014);

The corresponding CO_2 emissions can also be cut by half. For example, a compressed air system with best management practice can save approx. 0.05 kg CO_2^e per cubic meter of compressed air.

Finally, more than 90% energy savings can be achieved in case compressed air operated tools can be substituted by motor-driven tools (Niermeier 2013b). However, important circumstances for the realisation of these savings potentials are the costs that are associated with the investment of the motor-driven tools as well as the corresponding payback times and the potential drawbacks of the technology.

Appropriate environmental performance indicators

The most appropriate environmental performance indicator for this BEMP is the energy performance of the compressed air system[34]. It can be calculated in kilowatt hours of electricity needed per cubic meter of compressed air (**kWh/m³**).

The indicator refers to the entire compressed air system, meaning that not only the compressors and dryers are evaluated, but also the secondary drives such as fan motors and pumps for the operation of heat recovery. It is therefore not enough to assess the key figures of the manufacturer and test values;

The calculated values refer to standard cubic meters (calculated on the basis of standard conditions: at a pressure of 1.01325 bars and at a temperature of 20°C);

As reference value for the calculated values, the operating pressure level of the compressed air system has to be indicated.

Besides the Energy Performance Indicator for the compressed air system, the energy demand of important individual components of the compressed air system (especially compressor and dryers) can also be taken into account for decisions at the component level. Within this context, besides taking into account the performance at full load, special consideration should be given to the energy efficiency at partial load (e.g. 33%, 50%, 75%).

[34] Standards ISO 50001 and 11011 deal more in detail with the energy efficiency of compressed air systems and how it can be calculated.

Cross-media effects

Improving the efficiency of compressed air systems and the potential substitution of compressed air tools requires additional equipment and consequently generates environmental cross-media effects (e.g. from the use of natural resources, energy for manufacturing). However, these cross-media effects are considered to be minimal for most of the approaches mentioned herein. In fact, where additional equipment is needed for the implementation of the measure (e.g. plate heat exchanger in the case of waste heat recovery), the environmental impacts caused by the additional equipment will be more than offset by the substantial savings of electricity enabled by the respective equipment.

One exception could be the installation of energy-efficient compressors. Here it has to be taken into account that electric motors that enable highest possible efficiency usually require the use of critical metals in their magnets, especially neodymium. Neodymium is regarded as a "critical raw material" in the EU; furthermore, its extraction is associated with heavy burden on the local environment (EU 2014; Schüler et al. 2011).

Additionally, the adoption of electrically driven devices instead of compressed air tools causes the generation of WEEE when the tools and batteries reach their end of life, while compressed air tools are typically easier to handle and recycle at their end of life.

Operational data

Following the different approaches mentioned in the Description section, the corresponding details for implementation and operational data are given for some of these approaches:

<u>2. Assess the potential to reduce the use of compressed air through substitution of compressed air tools by electrically driven devices:</u>

In general, compressed air will only be used in application fields where the corresponding equipment has clear advantages when powered by compressed air instead of electricity. Relevant examples for such reasonable uses are e.g.:

- Control air, for example for valve control;
- Positioning of materials;
- Packaging machines (control & drive)
- Material handling and blending.

However, for other devices such as screwdrivers or drillers it is preferable to check whether the respective functionality can be provided with electrical tools at a much higher efficiency. For screwdrivers and random orbit sanders, for example, it can be shown that electrical tools require about 95% less energy than the respective compressed air devices (Niermeier 2013b).

However, as mentioned in section 4.2.2.1, when considering the potential substitution of compressed air tools, other factors, such as tools' durability, WEEE generation, safety etc., will also be taken into consideration.

4. Awareness

Banners are used in some Gestamp plants in order to inform the operators of the **costs** of compressed air, something that in most cases, people are not aware of. (source Gestamp 2016)

Banners are also used as in the case of a Gestamp plant, at the level of individual working stations, where they inform whether a leakage is detected or not, as shown in the examples below.

Figure 19: Examples of workstation banners

5. Identify and eliminate leaks using appropriate control technology

As shown in the following table, the losses in terms of both energy and costs increase exponentially with the diameter of the leakages. For example, a 10 mm air leak in a network operating at 6 bars causes energy losses of more than 30 kW (or more than 18,000 EUR). However, also relatively small leakages of only 1 mm in diameter should not be neglected.

Table 26: Energy losses and costs caused by air leaks

Diameter of air leak (mm)	Air losses (l/s)		Energy losses (kW)		Costs(€/a)	
	6 bars	12 bars	6 bars	12 bars	6 bars	12 bars
1	1.2	1.8	0.3	1	168	580
3	11.1	20.8	3.1	12.7	1,763	7,112
5	30.9	58.5	8.3	33.7	4,648	18,872
10	123.8	235.5	33	132	18,480	73,920

Source: Öko-Institut according to data from Dena 2012

Many leaks can be located even by simple methods of sensory perception. For example, when machines are not operating, a hiss can be noticed at the place where compressed air is escaping. Leakages at valve terminals can be identified by moving the hand across the valves (Niermeier 2013a).

In order to detect the network leaks in inaccessible areas and within production equipment, an ultrasonic testing device is recommended. This measurement device detects the ultrasonic noise that is caused by the mechanical friction of the escaping gas. This test method has the advantage that it can be used even during operation. Special sensors make it easier to reach the faulty components. With a flexible rod microphone localised hose connections and valves can be reached in running systems. A parabolic microphone is also available for testing of pipes in the ceiling area (Niermeier 2013a).

Figure 20: Ultrasonic testing device with rod and parabolic microphone

Source: Miele

6 Depressurisation

By monitoring the demand, it is possible to compare the energy required to pressurise the network and the energy consumed by leakages during the periods when the equipment is not in operation. The Gestamp plants in Santpedor and Aveiro, for instance, have chosen the option to depressurise the network. In Aveiro plant savings of 13,500€/year are estimated due to this measure.

To maximize savings by depressurising the network, it is important to synchronize correctly the plant's activity and the network's depressurisation and pressurisation. It is important to have a certain degree of flexibility to adapt to the plant's activity. For instance, if the plant programs a depressurisation every Saturday at 22:00 hours, if on a given day activity ends at 14:00 hours, there will be eight hours during which the compressors will be running just to feed the leaks.

10 Increase the overall energy efficiency of the compressed air system and adjust working pressure

As pointed out in the next paragraph, centrifugal compressors can be an interesting option as they are more efficient than screw compressors; however, they are inefficient at partial loads. Therefore, it can be an interesting solution to combine centrifugal and screw compressors, with centrifugal units used for providing the base load, and smaller screw compressors added during the peak loads.

11 Regular inspection of working pressure

For instance, a daily check can be accomplished to check the working pressure, with an inexpensive visual reminder (cf. opposite) added on gauges to ensure that the optimal range is maintained *(source: major Tier 1 supplier)*.

The savings delivered can be significant: in the example opposite, this management / control measure allowed the facility (as an average over 12 months before and after introducing the measure) to drop the energy performance indicator from 0,121kWh/m^3 to 0,108 kWh/m^3.

Figure 21: visual reminder on pressure gauge to facilitate checks

12 Increase the specific energy efficiency of major compressed air system components

In terms of compressor technology, the market in the relevant segment is dominated (75% of sales) by screw compressors, mainly due to their simplicity and reliability (Radgen & Blaustein 2001). Within this segment, however, differences concerning the specific energy-efficiency can be significant. For example, Miele decided to install 2-stage screw compressors with hybrid permanent magnet motors that are characterized by constantly high efficiency also at partial load (Hermelingmeier 2014a).

Centrifugal compressors are more efficient than screw compressors but are inefficient during partial loads and have been used so far only very rarely.

In terms of dryers, efficiency gains can be achieved through units with integrated cold storage. This functionality can be provided by a system based on glycol-water mixture and makes it possible that the dryer will run only if the compressor is running. Hence, no continuous operation of the dryer is necessary, whereas the cold storage provides cooling until the dryer has reached the operating point (Hermelingmeier 2014a).

15 Install waste heat recovery

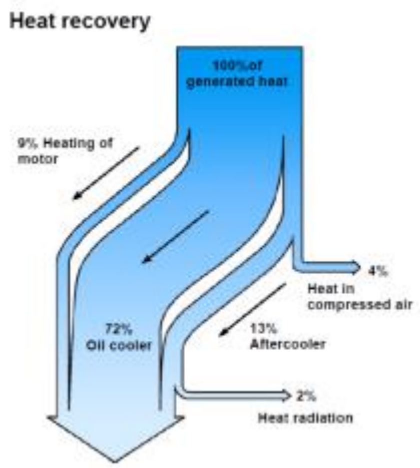
From the electricity supplied to the compressors, over 90% is converted in wasted heat. Using the waste heat for another process will improve the overall system's efficiency. The optimal use of the heat will be dependent on the processes nearby, and their needs for hot water or hot air.

As illustrated by the figure opposite, theoretically, up to 94% of electrical power consumption can be exploited for heat recovery.

In terms of technology, waste heat recovery can be achieved fairly simply and cheaply using waste hot air.

More sophisticated and efficient methods will involve the installation of a plate heat exchanger within the oil circuit of the compressors. The heat exchanger provides hot water with a temperature between 60 and 80°C (Diemer & Feihl 2011; Hermelingmeier 2014a) that can be used for the heating of buildings, drying of products, regenerating the desiccant dryer and other similar purposes.

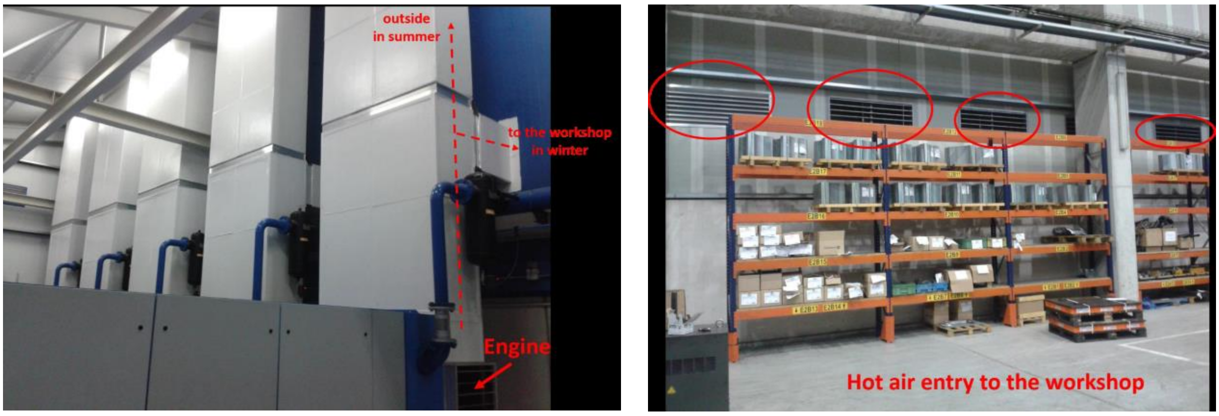
Figure 22: Hot air management implementation



Potentials for waste heat recovery□(Souce: BOGE (2008)

The "easiest" way to make use of the wasted heat is by re-directing the hot air from the after-cooler, introducing it in the closest hall. The installation mainly requires of ducts and fans. Several Gestamp plants do already use this system (Fig. below):

Figure 23: Hot air management implementation



Source: Gestamp 2016

Another very interesting utilization of waste heat recuperated from compressed air systems is the operation of an absorption chiller for air conditioning.

Applicability

Basically, the approaches for improving the energy efficiency of compressed airs systems can be applied by all companies that have such a system at their disposal.

The substitution of compressed air devices as well as the elimination of leakages is broadly applicable for almost all systems, independent of their age and current state.

Concerning the optimisation of systems design, the innovation cycle has to be taken into account. Thus, the recommendations are especially relevant for systems that have "grown" over decades (with implementation of extensions that have originally not been planned) and that need revision. However, it is estimated that this approach is applicable for at least 50% of all compressed air systems (Radgen & Blaustein 2001). In case a centralised system seems to be favourable, enough space is required for all important components, such as compressors, dryer, oil deposition, slitting as well as cooling air supply and noise abatement.

Regarding the use of waste heat a continuous demand for process heat is necessary in order to realise the existing energy and cost savings potentials.

Economics

Due to the relative inefficiency of compressed air production, the electricity required to generate compressed air / vacuum accounts for 20% to 80% of the overall energy costs in a factory[35].

When analysing the cost structure of compressed air systems, it can be shown that 78% of all costs are caused by the energy demand, where the remaining costs are caused by maintenance and investments (Diemer & Feihl 2011).

Thus, when optimising inefficient compressed air processes, companies could save significant amounts of their overall energy demand (between 5% and 50%). In Germany,

35 Cf. http://www.efficiency-from-germany.info/EIE/Navigation/EN/Technologies/industry,did=356360.html?view=renderPrint

compressed air systems from 59 firms were analysed by measurement, whereas an average potential energy and cost savings rate of 34% could be detected (Diemer & Feihl 2011). Payback times for the different measures implemented in German companies typically range between two and four years, depending on the individual age, size and state of the system (VDMA 2005).

The following table shows typical payback times[36] for selected measures applicable for the European scope:

Table 27: Payback times for selected measures

Measure	Payback time (months)
Optimizing end use devices	18
Reducing air leaks	6
Overall system design	18
Drives with high efficiency motors	12
Drives with speed control	9
Recovering waste heat	6

Source: Own table with selected data from Radgen & Blaustein 2001

Driving force for implementation

The major driving forces behind the vast majority of the approaches described above clearly are the corresponding savings potentials (see details in the section above). This is particularly applicable to the elimination of leakages. Against this background, it is valuable to establish an own cost centre for compressed air, which is currently the practice in only very few companies. Such a measure would enable the management to identify the costs that are associated with the production of compressed air, as well as to monitor the success of already implemented measures.

Furthermore, an energy management system according to ISO 50001 with its corresponding audits is regarded to be another important driving force for the identification and implementation of measures for improved efficiency of the compressed air system of a company.

Reference organisations

Gestamp

ACEA Members incl. Volkswagen Group, Daimler Group

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3.2.6 Optimisation of electric motor usage

SUMMARY OVERVIEW:

BEMP is to reduce electricity consumption through the optimal use of electric motors, in particular using variable speed drives to adapt motor speed to demand, typically for applications such as pumps.

Electric motors are present in most manufacturing processes, and can be optimised for higher efficiency. Preliminary steps include a review of power quality, motor controls and motor and transmission efficiency. A further improvement for variable torque load AC engines is to install variable-speed drives (VSDs) to adapt the operation of the motor electronically with minimal losses. This is particularly relevant, and holds the largest savings potential, for common application such as pumps and fans. Short payback often make these investments economically attractive.

Relevant life cycle stages				
Management	Design	Supply chain	**Manufacturing**	End-of-life
Main environmental benefits				
Energy consumption	Resource use and waste	Water use & consumption	**Emissions to air, water, soil**	Ecosystems & biodiversity

Environmental indicators

- Share of electric motors with VSD installed (% of total installed power or of total number)
- Share of pumps with VSD installed (% of total installed power or of total number)
- Average pump efficiency (%)

Benchmarks of excellence

- N/D

Cross references

Prerequisites	• Increasing the efficiency of energy-using processes
Related BEMPS	• Compressed air

Description

Electric motors of various sizes are of very common use in manufacturing processes for all types of application. Car manufacturing processes in particular are likely to employ electric motors as energy conversion devices inside rotational machinery for a range of processes including:

- Ventilation (fans)
- Refrigeration (compressors)
- Exhaust (fume management)
- Hydraulic pumps
- Surface treatment (cataphoresis painting, coating) pumps
- Air compression
- Machining and metalworking using drills, lathes or mills
- Presses
- Conveyor belts
- Elevators
- Grinders
- Rotating heat exchangers
- … other highly consuming electric engines

Each of the above usage will use different types or technologies of electric motors most adapted to the required demand. Not all of the above uses are equally fit for the optimisation of energy efficiency. Around half (source CT2011) of all motor applications have some kind of varying demand, suited for optimisation by better matching speed drive to demand.

The present best practice focusses on the optimisation of AC motors, where the biggest benefits are to be reaped.

The table below summarises key characteristics of common motors and their potential:

Table 28: main load types for electric motors and potential for energy savings

Type	Typical applications	Energy saving opportunities	
Constant power load	machine tools (lathes, milling machines, punch presses …) and centre winders	-	
Constant torque load	conveyors, agitators, crushers, surface winders and positive displacement pumps and air (screw) compressors	+	Power varies linearly with speed.
Variable torque load	centrifugal pumps and fans blowers, HVAC systems	+++	Power follows a cube law* in relation to speed.

** in practice (as reported in real-life operating conditions, see Operational data section), power may be between a quadratic and cubic relation to speed.*

In current automotive factories, typical targets for the improvements of electric motors will focus on **pumps**, where the improvement potential is often large and the economic benefit significant.

1) The preliminary steps in the optimisation of electric motors throughout the plant will involve a review of motor usage efficiency. This will follow some initial steps to review the potential causes of inefficiency throughout the system (example below based on US DOE "Motor challenge" best practice):

- Power Quality

It is important to design and install electrical systems that meet safety codes, minimize downtime, and reduce electrical losses. A qualified electrical engineer should oversee any major electrical system modifications since poor power distribution within a facility is a common cause of energy losses[37].

  - Maintain voltage levels
  - Minimize phase unbalance
  - Maintain high power factor
  - Maintain good power quality (frequency and wave form)
  - Select efficient transformers
  - Identify and eliminate distribution system losses
  - Minimize distribution system resistance
- Motor Controls

To reduce electrical consumption, use controls to adjust motor speeds or turn off motors when appropriate.

For example, equipment often can run at less than full speed or be turned off completely during part of a process cycle. When correctly used, motor controls save significant amounts of energy, reduce wear on the mechanical system, and improve performance.

  - Use Adjustable Speed Drives (VSDs) or Two-Speed motors where appropriate (see section 2))
  - Consider load shedding
- Motor and Transmission Efficiency

When replacing a motor, the most efficient model affordable should be considered. Motors with a wide range of efficiencies are available in most classes (horsepower, speed, and enclosure type). An energy efficient motor will typically cost 10% to 20% more than a standard model. However, this higher cost is often repaid in less than 2 years through energy savings. Optimize motor efficiency by making certain the motor is properly sized. Oversizing and underloading can lead to low power factor and increased losses.

  - Choose a replacement before a motor fails
  - Choose energy-efficient motors
  - Match motor operating speeds
  - Size motors for efficiency
  - Choose motor voltage ratings fit for the electrical systems
  - Minimize Rewind Losses
  - Optimize Transmission Efficiency

[37] Existing facilities should be checked periodically for electrical problems. Since electrical codes are designed primarily for safety, optimizing efficiency often means surpassing code requirements.

- Perform Periodic Checks
- Control Temperatures

2) Variable speed drives

AC engines' rotational speed is (almost) constant (it is determined by the electricity network's frequency and the engines' number of poles). Many applications or systems using these therefore employ oversized motors. In these systems, control elements such as dampers and valves are typically used downstream of the motor to regulate flow and pressure. These devices usually result in inefficient operation and energy loss because of their throttling action.

However, it is often desirable to have a motor operate at two or more discrete speeds, or to have fully variable speed operation. The conventional (mechanical, hydraulic) control elements can often be replaced by incorporating variable speed operation using a dedicated electronic device[38]: this allows regulating current frequency and therefore speed of AC motors and are designated under a variety of names, e.g. **adjustable-frequency drive, adjustable-speed drive, variable-speed drive (VSD), variable frequency drive (VFD), AC drive, micro drive, frequency inverter, inverter** or **inverter drive**. For the purpose of clarity the rest of this BEMP will use the term variable-speed drive and the acronym VSD.

Whilst there are a number of variations in VSD design; they all offer the same basic functionality which is to convert the incoming electrical supply of fixed frequency and voltage into a variable frequency and variable voltage that is output to the motor with a corresponding change in the motor speed and torque. The motor speed can be varied from zero rpm through to typically 100-120% of its full rated speed whilst up to 150% rated torque can be achieved at reduced speed. The motor may be controlled in either direction.

Achieved environmental benefits

The main benefit of using VSDs is related to **energy (electricity) savings** (and associated reductions in emissions), achieved due to their capability to adapt the engine's rotational speed to the system's demand in real time. The use of VSDs can provide additional benefits to the system, which are summarised as follows:

- A more accurate process (flow and pressure) control through improved real time monitoring and control capabilities of the engine and drives;
- Reduced energy consumption for space cooling due to lower dissipated heat
- Reduced mechanical stress and increased hardware lifetime thanks to soft engine start;
- Reduction in maintenance requirements, from one side due to the absence of mechanical control devices and from the other side due to the soft start;
- Improved power factor;

[38] From an electrotechnical standpoint, the most widespread technology is the following. Most electronic VSDs are speed control devices which vary the voltage and frequency input current to an induction motor using a technique called Pulse Width Modulation (PWM). VSDs have become the preferred way to achieve variable speed operation as they are relatively inexpensive and very reliable. VSDs use power semiconductor devices called insulated-gate bipolar transistors (IGBT). Using PWM, the speed of the motor and torque characteristics can be adjusted to match the load requirements. They convert the fixed frequency AC supply voltage to a variable frequency, variable voltage AC supply to the motor and can regulate the speed of an induction motor from about 10% to 200% with wider ranges possible depending on the model and options selected (source CEATI).

- Good dynamic response;
- Capability to be managed using a centralised and/or decentralised approach.

Modern, energy-efficient motors may reduce energy consumption by up to 40% over older models (Galitsky & Worrell, 2008). In combination with frequency converters, electrical drives can be operated on a need-driven basis, allowing up to 70% reduction in energy consumption for fans, pumps or compressors (Holt, 2012), (Siemens, 2009).

Appropriate environmental performance indicators

After a review of potential upgrades for the electric motors in use by the organisation, the following indicator can help keep track of progress in implementing VSD solutions in the facility:

- % of electric motors with VSD installed (installed power kW / kW)

In addition, since pumps represent a key target for the improvements described in this BEMP, a specific indicator can be derived focussed on these machines. For instance, the major pumping systems in use through the facility can be identified and their efficiency calculated (either manually or using engineering tools – cf. for instance (SEAI, 2010)):

- - % of pumps with VSD installed (number or installed power kW / kW)
- [average] pump efficiency (%)

Cross-media effects

- The implementation of variable speed drives entails the purchase and use of additional hardware which generated environmental impacts during its manufacture, transport and installation

- VSDs are typically 92-98% efficient with 2-8% losses being due to additional heat dissipation caused by the high-frequency electrical switching and the additional power required by the electronic components.

Equally motors connected to VSDs experience some additional losses due to heating caused by the high frequency electrical switching. (source CT2011)

Operational data

This section focusses on a detailed real-life example from Gestamp in which several pumps of different sizes were optimised through the use of VSDs in a cataphoresis application (Gestamp 2016).

Case study: Cataphoresis coating pumps at Gestamp plant

Sub-sections a) and b) show the savings based on measurements taken at the plant, sub-section c) shows the expected savings of the VSDs that are in the process of being installed.

a) Shower pumps (surface treatment tunnel)

The annual energy consumption prior to the VSDs' installation was 78.508kWh, after the VSDs' installation, 35.079kWh, hence saving of 55% were achieved, which means annual savings of 3.958€ and a 3,2 years payback.

Table 29 shows the VSDs' average frequency and energy consumption values before and after the VSDs' installation. In Table 2, in order to calculate the annual savings, an average electricity price of 0,091€/kWh is assumed and where:

- Pump M27 (4kW) located at the predegreasing shower. Investment: 4.000€.
- Pump M1 (11kW) located at the degreasing shower. Investment: 4.745€.
- Pump M11 (4kW) located at the Wash AD2 shower. Investment: 4.000€.

Table 29: *Pumps characteristics and consumption before and after the VSDs' Installation*

	Before VSD			After VSD			
Pump	***f*** $_{average}$ (Hz)	Consumption (kWh/year)	Cost (**€**/year)	***f*** $_{average}$ (Hz)	Consumption (kWh/year)	Cost (**€**/year)	Savings (**€**/year)
M27	50	18.374	1.674	44,6	15.034	1.370	304
M1	50	43.430	3.957	35,4	16.704	1.522	2.435
M11	50	16.704	1.522	27,9	3.341	304	1.217

Table 30 shows the VSDs' investment, as well as the savings in Tons of Oil Equivalent (toe), in money (€) and in CO2 tons.

Table 30: *VSDs' investment and savings*

	Investment (€)	**Yearly savings**			**Payback (years)**
		toe	**Ton CO_2**	**€**	
VSD in shower pumps (degreasing, wash AD2, predegreasing)	**12.747**	9,3	20,4	3.958	**3,2**

b) Boiler pump and heat exchanger pump

The annual energy consumption prior to the VSDs' installation was 60.135kWh, after the VSDs' installation, 33.0067kWh, hence savings of 50% were achieved, which means annual savings of 2.741€and a 3,1 years payback

Table 31 shows the VSDs' average frequency and energy consumption values before and after the VSDs' installation. In Table 4, in order to calculate the annual savings, an average electricity price of 0,091€/kWh is assumed and where:

- Pump REC1 (7,5kW) located at the paint boiler. Investment: 4.462€.
- Pump M2 (4kW) located at the degreasing heat exchanger. Investment: 3.994€.

Table 31: ***Pumps characteristics and consumption before and after the VSDs' installation***

	Before VSD			After VSD			
Pump	***f*** average (Hz)	Consumption (kWh/yr)	Cost (**€**/yr)	***f*** average (Hz)	Consumption (kWh/yr)	Cost (**€**/yr)	Savings (**€**/yr)
REC1	50	40.090	3.654	39,7	21.715	1.979	**1.675**
M2	50	20.045	1.827	36,5	8.352	761	**1.066**

Table 32 shows the VSDs' investment, as well as the savings in Tons of Oil Equivalent (toe), in money (€) and in CO_2 tonnes.

Table 32: ***VSDs' investment and savings***

	Investment(€)	**Yearly savings**			**Payback (years)**
		toe	**Ton CO_2**	**€**	
Boiler's pump VSD	**4.716**	4,0	8,6	1.675	**2,7**
Heat exchanger pump VSD	**4.129**	2,5	5,5	1.066	**3,7**

a) New variable speed drives to be installed

The following table shows the VSDs that are due to be installed at the plant. The savings presented are based on estimations done by the company CCEnergia. With an investment of 20.837€ and an expected yearly saving of 6.926€, a 3 years payback is obtained. For the savings calculation, an average electricity price of 0,11€ /kWh is used and where:

- Pump M15 (15kW) located at the paint filtering. Investment: 3.663€.
- Pump M4 (3,4kW) located at the activation shower. Investment: 2.569€.
- Pump M25 (4kW) located at the ultrafiltrated shower. Investment: 3.211€.
- Pump M10 (4kW) located at the Wash AD1 shower. Investment: 3.324€.
- Pump M3 (3kW) located at Wash 1 shower. Investment: 2.373€.
- Pump M6 (4kW) located at phosphating heat exchanger. Investment: 3.313€.
- Pump M5 (4kW) located at the phosphating shower. Investment: 2.384€.

Table 33: *Expected savings*

	Current installation			Future installation			
Pump	***f*** average (Hz)	Consumption (kWh/year)	Cost (**€**/year)	***f*** average (Hz)	Consumption (kWh/year)	Cost (**€**/year)	Savings (**€**/year)
M15	8,7	48.442	5.267	4,5	24.778	2.694	**2.573**
M25	3,0	16.704	1.816	1,5	8.590	934	**884**
M10	3,6	20.045	2.179	1,9	10.310	1.121	**1060**
M3	2,2	12.194	1.326	1,7	9.230	1.004	**322**
M6	3,0	16.704	1.816	1,6	8.920	970	**846**
M5	3,0	16.704	1.816	1,9	10.810	1.175	**640**

Recirculation pumps within the welding cooling systems

The plant has two independent cooling systems, both used to cool the welding equipment (spot welding). The chilled water is distributed along the equipment by circulation pumps.

Prior to the Variable Speed Drive (VSD) installation, the chilled water flow rate was constant regardless of the welding equipment's needs. With the installation of VSD and using temperature transducers, the pumps' rpm and hence the water flow, is adjusted in real time to the system's real cooling needs. That means that depending on the number of welding machines being used, the flow rate will increase or decrease accordingly.

An investment of 9.431€ was required for the installation of both VSDs, with a total annual saving of 5.260€, the Payback is 1,8 years.

- Pump SR1 (11kW) located at the cooling system 1.
- Pump SR2 (11kW) located at the cooling system 2.

Table 34: *Pumps characteristics and consumption before and after the VSDs' Installation*

	Current installation			Future installation			
Pump	***f*** average (Hz)	Consumption (kWh/year)	Cost (**€**/year)	***f*** average (Hz)	Consumption (kWh/year)	Cost (**€**/year)	Savings (**€**/year)
SR1	50	83.620	7.621	43	56.980	5.193	**2.428**
SR2	50	79.920	7.283	42,4	48.480	4.451	**2.832**

Table 35: *Investment and savings*

	Investment(€)	**Annual savings**			**Payback (years)**
Pump		**toe**	**Ton CO_2**	**€**	
SR1	4720	5,7	12,5	2428	1,9
SR2	4711	6,7	14,6	2832	1,7

Welding smoke extraction system's fans

The spot welding machines are equipped with a ventilation system responsible for the fume extraction. At this plant, ventilation ducts are connected to suction towers; each tower is responsible for the fumes of a defined number of welding machines. The fans responsible for the fumes extraction are located at the suction towers, Fig.opposite.

Extraction towe

The fans within the suction towers operate at the same speed regardless the number of welding machines being used. With the installation of the VSDs, a suction power will be assigned to the number of operating machines. In such way, the tower's suction power will increase or decrease when a welding machine is turned on or off respectively.

The VSDs are being installed at this plant. The savings presented are based on estimations done by the company CCEnergia. With an investment of 40.753€, a total annual saving estimation of 16.730€ a 2,4 years payback is obtained. For the savings calculation, an average electricity price of 0,11€ /kWh is used and where:

- TS1 (11kW) is located at suction tower 1. Investment: 6.840€.
- TS5 (11kW) is located at suction tower 5. Investment: 8.858€.
- TS11 (5kW) is located at suction tower 11. Investment: 6.723€.
- TS12 (11kW) is located at suction tower 12. Investment: 7.967€.
- TS13 (11kW) is located at suction tower 13. Investment: 5.183€.
- TS14 (14kW) is located at suction tower 14. Investment: 5.183€.

Table 36: Expected savings

	Current installation			Future installation			
	$P_{average}$ (kW)	Consumption (kWh/year)	Cost (€/year)	P average (kW)	Consumption	(kWh/ year)	**Cost (€/year)**
TS1	6,2	44.568	4.846	1,9	13.752	1.495	**3.351**
TS5	6,2	44.568	4.846	1,8	12.883	1.401	**3.445**
TS11	2,7	19.656	2.137	1,7	12.600	1.370	**767**
TS12	6,2	44.568	4.846	4,0	29.088	3.163	**1.683**
TS13	6,2	44.568	4.846	1,2	8.640	939	**3.907**
TS14	6,2	44.568	4.846	1,6	11.664	1.268	**3.578**

Applicability

As mentioned above, the type of load and appropriate electric motor must be considered first before assessing the improvement potential of optimisation. Retrofitting constitutes the biggest potential for optimisation. However, in newbuild or new purchases as well, adapting the choice of motor as closely as possible to usage will have the potential for optimised operation.

Several factors must be accounted for when considering the VSD installation, the main negative effects that need to be considered are:

- Harmonic distortion.
- Cooling problems at low rotational speeds.
- Mechanical resonance at certain rotational speeds.

In some specific cases it should be noted that VSD use may actually *increase* energy use: e.g. when operating at near full speed there is a crossover point where VSD control can use more energy than fixed speed control (with dampers i.e. flow restrictors, for a fan, or with throttles, for pumps). This is due to the losses in the VSD exceeding the savings from the speed reduction (source CT 2011).

Economics

When economic effects of measures for electric motors are analyzed, a life cycle cost consideration is crucial. This is due to the fact that about 97 % of lifecycle costs relate to operation costs, of which the main component is energy costs (Siemens, 2009).

Typical payback periods for investments in optimisation of electric motors, e.g. pumps, are below 12-18 months.

The above case studies of Gestamp plants also provide illustrative sample economic data.

N.B.: In the above studies, when calculating the paybacks, no funding or economic incentives are taken into account, in such way the results can be compared with other plants (hence "investment" is the VSDs' cover actual market price (according to the provider) plus the installation cost). In addition energy efficiency economic incentives/funding are also a very good opportunity to reduce installations' paybacks. In this case the paybacks shown in the case study were reduced to half of the time and in some cases, even one third of the original payback time due to external funding.

Driving force for implementation

- Electricity costs
- Obsolescence of electrical machinery
- Public funding for energy efficiency

Reference organisations

Gestamp
ACEA Members

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3.3 WASTE MANAGEMENT

3.3.1 Waste prevention and management

SUMMARY OVERVIEW:				
BEMP is to set up an overall organisational waste management strategy with high level targets for waste minimisation, and to apply it at the site level with tailored waste management plans that minimise waste production during operations and establish strategic partnerships in order to find markets for the remaining waste fractions. An effective waste management strategy aims to avoid ultimate disposal by following the waste hierarchy[39] i.e. in order of priority: Reduce through forward planning, prolonging the product's life before it becomes waste, improved methods of manufacturing, and the management of supply chain waste. Reuse materials in their current form. Recycle by putting in place: Collection and segregation; Measurement and monitoring of waste generation Procedures and methodologies Provision of waste logistics Partnerships and stakeholder engagement Recover energy from waste through combustion or more advanced techniques.				
Relevant life cycle stages				
Management	Design	Supply chain	Manufacturing	End-of-life
Main environmental benefits				
Energy consumption	**Resource use and waste**	Water use & consumption	Emissions to air, water, soil	Ecosystems & biodiversity
Environmental indicators				
• Waste generation per functional unit (kg/functional unit) • Hazardous waste generation per functional unit (kg/functional unit) • Waste sent to specific streams, including recycling, energy recovery and landfill (kg/func. unit, % total waste). • Establishment and implementation of an overarching waste strategy with monitoring and targets for improvements (Y/N) • [For multi-site organisations] Number of sites with advanced waste management plans in place • [For multi-site organisations] Number of sites achieving target levels of waste management, such as zero waste to landfill				
Benchmarks of excellence				
• **Waste management plans introduced [in all sites]** • **Zero waste to landfill from all production and non-production activities/sites**				
Cross references				
Prerequisites	• Implementing an advanced environmental management system;			
Related BEMPS	• Integrating environmental requirements into supply chain management			

[39] The Waste Framework Directive (Directive 2008/98/EC) introduces an order of preference for action to reduce and manage waste. This is known as the waste hierarchy. It set the highest priority on waste prevention, followed by waste re-use, then recycling and then (energy) recovery of waste fractions that cannot be prevented, re-used or recycled. Finally, waste disposal is only to be considered when none of the previous routes are possible.

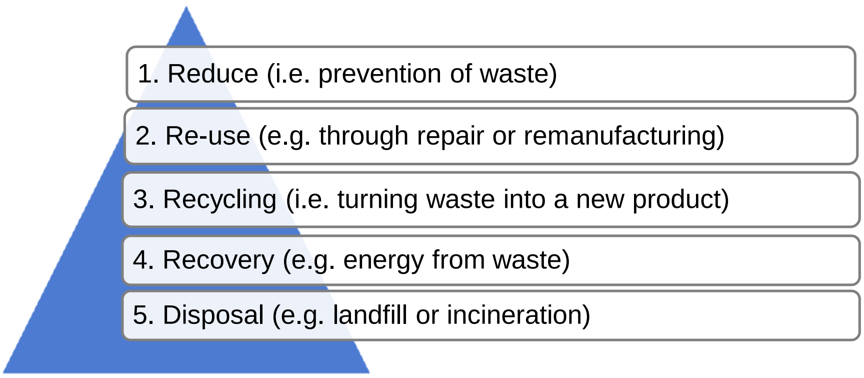
Description

The automotive industry is a resource-intensive industry, thus best practices to prevent and manage waste are important to reducing overall environmental impacts. While most other environmental impacts are concentrated in the use phase of a vehicle, the majority of solid waste (60-80%) is generated during the manufacturing stage (Oakdene Hollins, 2011).

The automotive industry has historically had an intense focus on in-process efficiency. Many waste prevention and management measures have already been implemented due to the sector's strong emphasis on lean production methods, quality control and cost-reduction. However, while these measures have been a key driver, there are still opportunities to improve from an environmental perspective (such as waste prevention, reducing hazardous materials and considering life cycle approaches). In particular this BEMP focusses on harnessing the potential of waste prevention measures.

The use of **waste management plans** (WMPs) is an accepted practice in many industries – the general principles should follow the *waste hierarchy*, as described in the European Waste Framework Directive (see **Figure 24**). Frontrunner organisations have implemented an overall organisational strategy with high level targets for waste minimisation, which is then tailored for specific sites through waste management plans (GM, 2013), (Farish, 2013). These strategies identify the importance of waste in terms of its impact on both environmental and economic performance.

Figure 24: The hierarchy of options for the treatment of waste during the manufacture of vehicles.

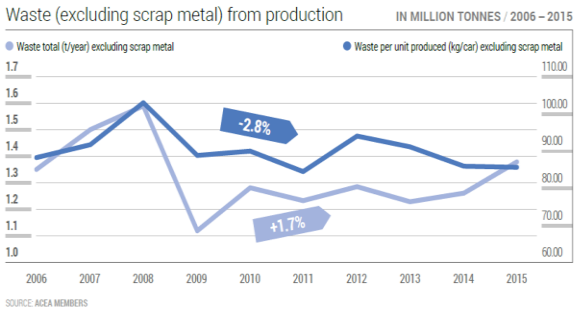


Source: European Waste Framework Directive 2008/98/EC

Greatest environmental benefit is achieved at the top of the pyramid, while landfilling results in no environmental benefit.

In the past, while the focus was on lean principles targeted at reducing waste-to-landfill, there was in some cases an overall increase in overall waste, possibly due to increasing vehicle mass among other factors (Oakdene Hollins, 2011, figure 3). However, the recent trend across the industry (see opposite) tends to mostly indicate a slight decrease of waste generated per vehicle.

Figure25: production waste from European OEMs *Source: ACEA (2016)*



Several manufacturers still send a significant proportion of their overall waste to landfill.

Meanwhile, frontrunner organisations have achieved considerable progress in terms of reaching "zero waste to landfill" and moving up the waste management hierarchy to include targets on "zero waste to landfill and zero waste to incineration".

While zero-waste-to-landfill and zero-waste-to-incineration objectives are often useful proxy targets, it needs to be stressed that the actual achievement will be very dependent on local and regional conditions available to the manufacturer, e.g. solutions offered by waste management companies or municipalities, regional or national price signals on waste disposal etc.

Overall, this suggests that there could be significant potential to improve waste management practices in the automotive industry, particularly around increasing the focus on waste prevention. This section provides additional details on aspects that are specific to wastes generated during the manufacture of cars.

The first step in the implementation of a robust Waste management plan, is to ensure that adequate *monitoring* of waste amounts produced, and distinguishing waste streams, is carried out. This will provide the data to support the execution of the WMP.

Option 1 – Reduce

The first priority in waste management is the prevention or reduction of waste arising, through forward planning, improved methods of manufacturing, and the management of supply chain waste. Particular attention will be given to prevention of waste that will subsequently be difficult to reuse, recycle or recover (including hazardous waste).

Option 2 – Reuse

Reuse refers to the reuse of materials in their current form, prolonging the product's life before it becomes waste. (In this context it can also cover repair and remanufacturing operations of production rejects) .

Option 3 – Recycle

Recycling refers to a recovery operation in which waste materials are reprocessed into products, materials or substances (whether for the original or other purposes).

Best practices for implementing recycling include:

- **Collection and segregation:** techniques established and implemented throughout the business;
- **Measurement and monitoring** of waste generation and provision of resources for its management;
- **Procedures and methodologies** ensure best management options for manufacturing waste;
- **Provision of waste logistics** allows waste to be moved efficiently to the most appropriate treatment process;

- **Partnerships and stakeholder engagement** can be used to foster market conditions that strengthen the market for recycled materials by encouraging a recycling-based society (e.g. by teaching school children about recycling).

One of the most challenging aspects is often to change staff mind-sets and habits. This aspect can be tackled through refresher training sessions and support from on-site Environmental Teams, as has been implemented by Gestamp at their Chattanooga site (Gestamp, 2014).

Option 4 – Recover

If the waste generated cannot be reused or recycled, it will be disposed of using technologies with minimal environmental impact, for example:

- **Waste-to-energy conversion** is the process of generating energy in the form of electricity and/or heat from direct combustion of waste, or fuel from the treatment of waste. Emerging techniques include (Farish, 2013):
  - **Plasma gasification** – turning various materials, including cardboard and sludges, into syngas.
- **Microwaves** – a means of dealing with materials containing organic compounds, such as foundry sand, using a lower energy consumption than present methods.

Achieved environmental benefits

Increasing material recovery and reuse can help to reduce the demand for raw materials, as well as the volume of waste delivered to landfill.

Many automotive manufacturing sites have achieved zero waste-to-landfill (meaning that 100% of waste is diverted from landfill). Toyota, GM and Daimler all have stated their intentions to achieve this goal across their sites. For example, GM reported that in 2012, just over half of its worldwide facilities (total count of 83 manufacturing sites and 19 non-manufacturing sites) are now landfill-free, and on average, 97% of the waste generated from everyday manufacturing operations at these plants is recycled or reused, and 3% is converted to energy (GM, 2012).

Some more advanced best practice sites have managed to exceed this level of environmental achievement, reaching 100% diversion of waste from both landfill and incineration. For example, Toyota's TMUK plant (UK).

Appropriate environmental performance indicators

In terms of environmental achievements, the following indicators are used as standard in the automotive industry:

- Total waste per functional unit (e.g. kg/vehicle);
- Hazardous waste per functional unit (kg/vehicle); and
- Waste sent to various streams, including recycling, energy recovery and landfill (kg/vehicle, % total waste). For example, at the Rolls-Royce plant in Goodwood (UK), no non-recyclable waste was produced in 2013 (BMW, 2013).

These would be reported at the organisational level, but can also be monitored per site – for example, all GM plants monitor, measure and centrally report their performance on a monthly basis where it is evaluated against company-wide waste-reduction goals (GM, 2012). Best practice would be to set targets and monitor waste at the process level. For example, at Toyota, each shop has its own waste target (Toyota – personal comm., 2014).

Appropriate indicators of the level of implementation of a WMP are:

- Whether an overarching waste strategy with monitoring and targets for improvements has been established and implemented

And, for multi-site operations:

- The number of sites with advanced waste management plans in place;
- The number of sites achieving target levels of waste management, such as zero waste to landfill.

An optional indicator is to monitor the **level of non-saleable waste** (Atkinson, 2012). Although this indicator is vulnerable to changes in the price for recycled materials, the market conditions are an important determinant of the potential for reaching waste reduction targets in the most economical way. For example, Toyota use this indicator to ensure that their waste reduction plans are economical – they have reportedly reduced their non-saleable waste by 50% in five years from 40 kg per vehicle to 18.1 kg per vehicle, and aim to reduce this to zero in the future by finding additional viable markets for their waste streams (Atkinson, 2012).

Cross-media effects

In some cases, a greater volume of segregated recyclate/waste streams could increase other environmental impacts, for example:

- A strong emphasis on achieving "zero waste to landfill" may detract from the more fundamental activity of waste prevention (Oakdene Hollins, 2011). Meanwhile, as pointed out above, zero waste to landfill might not be the most relevant objective;
- Increased energy use and fuel consumption in the waste collection/logistics chain. These environmental impacts could be reduced through the use of local waste treatment, as well as optimisation of logistics chains; and
- Increased energy usage may be required in order to reduce waste (Atkinson, 2012). For example, the use of different processes and/or materials may lead to trade-offs between energy usage and waste. Reuse of old machinery may have trade-offs in terms of the energy efficiency that can be achieved.
- Other environmental requirements may hinder the incorporation of waste streams in the recycling loop. For instance, the Regulation on the Registration, Evaluation, Authorisation and restriction of Chemicals (REACH) limits the reuse and recycling of polymers containing certain restricted substances.

Because of these trade-offs, decisions should be considered from a life cycle perspective (see *Section 3.6.3* Design for sustainability using Life Cycle Assessment (LCA)*).*

Operational data

This section presents a series of concrete examples of measures implemented at different sites around the world, illustrating the various techniques – also with varying levels of ambition – that can be carried out in the framework of a continuous improvement process under a waste management plan.

Option 1 – Reduce

Examples of recent waste reduction techniques used in the automotive sector are shown in Table **37**.

Table 37: Case study examples: waste reduction techniques used in the automotive sector

Waste stream	Example	References
Reducing paint sealer waste	Excess paint sealer is considered a hazardous waste if disposed of. The Toyota Cambridge plant installed an automated system in 2012 to capture excess sealer and reapply it to a vehicle without impacting the quality of the paint finish. A reclaim pump system was installed with a valve to control when the reclaimed sealer is used. The reclaimed sealer is only applied on non-visible seams in the inner shell of the vehicle. The system has reduced the volume of virgin sealer ending up as waste by 97% and eliminated 72 barrels of hazardous waste per year – more than 22,000 kilograms – with a payback of less than two months. The system is now being transferred to other plants.	**Toyota, Cambridge (US)** (Toyota, 2013)
Paint sludge	The quantity of paint sludge discharges has been reduced through filtration methods, an action which has resulted in a 20%-30% reduction in sludge, while also generated financial gains. In addition (cross-referenced with recycling activities), Renault has collaborated with a private company (Soliforte), to reprocess paint sludge into cement bricks. Approximately 62 tonnes of paint sludge is used in this process.	**Renault, Flins (France)** (Renault, n.d.) **Renault, Campo Largo (Brazil)** (Renault Brazil, 2013)
General packaging	Many examples involve the introduction of reusable packaging of supplied materials: • 23,000 tonnes of packaging waste saved by Ford (UK) through developing a system of returnable packaging • 3,000 tonnes of waste avoided annually by Toyota (US) through switching to returnable packaging for carpets; • At Honda UK, 99% of local suppliers are now using returnable packaging as standard, some of which have a service life of over 7 years.	**Ford (UK) and Toyota (US)** (Oakdene Hollins, 2011); **Honda, (UK)**(Honda, 2011)

Waste stream	Example	References
Improving material yield from metal-forming operations	In 2012, Volkswagen reduced the width of steel coils used to make parts for the body, at their Wolfsburg site. Additionally, the tools, the component geometries and plates nesting were optimised to improve materials utilisation. The new Golf generates 15% less waste during production than its predecessor.	**Volkswagen, Wolfsburg (Germany)** (Volkswagen, n.d.)
Reducing hazardous waste	• Used liquid flux instead of using powder flux and purchased ready-coated flux materials reduced hazardous waste by 22% in the first year at Denso (UK) • 68 tonnes of waste (55 tonnes of which hazardous) prevented annually by switching from cleaning with methylene chloride to blasting with baking soda (Trimac Transportation) • Switched from single use to washable/reusable wipes for machinery cleaning reduced hazardous waste costs by £5,000 at Denso (UK);	(Oakdene Hollins, 2011);

Option 2 – Reuse

Examples of waste reuse techniques used in the automotive sector are shown in **Table 38**.

Table 38: Case study examples: reuse of waste materials in the automotive sector

Waste stream	Example	References
Coolants	US company, Universal Separators has a system called SmartSkim that can continually recycle and re-use the coolant fluid used to lubricate and control the temperature of machining operations at the point where a cutting tool comes into contact with a metal workpiece. The tool is used by OEMs including Delphi, Nissan, Honda and Toyota. The benefits of the system include a reduction in coolant consumption of between 30-75%. The cost savings can be as much as 90%. An investment of \$15,000-45,000 (€11,500-35,000) could pay for itself within 12-18 months.	**Delphi, Nissan, Honda and Toyota** (Farish, 2013)

Waste stream	Example	References
General packaging	Cadillac Urban Garden contains 250 plant beds made from redundant shipping crates donated from GM's nearby Orion assembly plant for direct use in the community project, rather than being scrapped or recycled.	**GM, Orion plant, Detroit (US)** (Farish, 2013)
Gloves	Following a trial of in-house wash and re-use, the company determined it was uneconomical but now outsources cleaning to wash and re-sell gloves. Gloves which cannot be re-sold are donated to charity.	**Tier 1 supplier, UK plant**
Metals	Metals from stamping and powertrain operations are valuable, especially considering the amount generated on a manufacturing line. Large cutouts like window openings are usually sold on to third parties to make another product, or used within the plant in one-shot presses to make smaller body in white components. The metal grindings and scraps that GM does not re-melt or reuse are sold to third parties such as foundries (see BEMP on metal briquetting for the facilitation of metal scrap re-use or re-sale).	**GM (US)** (General Motors, n.d.)

In addition to the reuse of materials, new plants being built in low-cost countries may be able to benefit from installing previously-used manufacturing equipment, such as (Duval Smith, 2011):

- **Conveyors.** The "FAStplant" modular final assembly system from Dürr can be moved easily if the company changes manufacturing location. Daimler, the first FAStplant customer, went on to relocate its system three times within a period of six years – the setup is currently being used in its fourth location;
- **Paintshops.** Tata Motors installed a previously used paintshop in their Pune plant (India). Engineers collected the paintshop from Nissan (Australia), shipped it to India, then reconditioned it for installation. It was a cost-effective solution and expanded plant capacity from 500 to 750 units per day;
- **Presses.** The market for used standard presses is established, but for large or special presses the market is limited. If the mechanical structure is reliable and there is no major damage or any cracks, the cost for a complete refurbishment is between 30 and 50% of the sale price.

There is also an established industry for robot repair, which optimises maintenance schedules and therefore extends machine lifetimes. For example, Fiat (now FCA)'s Tychy plant (Poland), use Comau Robotics with 'stress analysis' software, which helped Fiat to reduce mechanical breakdowns to zero, whereas in 2007, Fiat had at least 20 breakdowns a year caused by robots (Duval Smith, 2011).

Option 3 – Recycle

Examples of waste recycling techniques used in the automotive sector are shown in **Table 39**:

Table 39: Case study examples: recycling of waste materials in the automotive sector

Material	Example	Manufacturer & site
Plastics	Closed loop control to optimise process, reduce parts inventory, minimise parts scraps, including part recycling (plastic scraps could be ground, melted and incorporated back into injection process)	**Toyota, Valenciennes (France)** (Toyota – personal comm., 2014)
Electronics	At Toyota's Valenciennes plant, electronic waste is completely dismantled on-site to achieve greater financial value from sale of the materials (e.g. copper and aluminium).	**Toyota, Valenciennes (France)** (Toyota – personal comm., 2014).
General packaging	Cardboard shipping materials from the GM Marion Stamping and Fort Wayne Assembly plants are recycled into sound-absorber material in the Buick Lacrosse's headliner. Plastic caps and shipping aids from the Fort Wayne facility are converted into radiator shrouds for the Chevrolet Silverado and GMC Sierra pickups built at the plant	**GM, Marion Stamping and Fort Wayne (US)** (General Motors, n.d.)
Tungsten	Tungsten is a scarce metal used in dies and cemented carbide tools in car manufacturing. Until recently ~60% of cemented carbide product scrap was shipped overseas and ~10% discarded, only 20% was recycled. Through collaboration with a cemented carbide recycling company, Toyota established a recycling system able to recover tungsten from cemented carbide product scrap in 2010. An optimum recycling system was built for each product type, which also improved the economic viability of recycling by reducing the amount of sorting required.	**Toyota (Japan)** (Toyota, 2013)

Material	Example	Manufacturer & site
Aluminium	Aluminium swarf contaminated with machining coolant that was previously transported off-site for recycling is now recycled . • Stage 1 was to reduce the coolant contamination by utilising a centrifugal coolant recycling system to wash and dry the contaminated swarf. This also recovered 10% of coolant waste. • Stage 2 was to re-melt the dry swarf safely in their own furnaces. Toyota used heat recovered from the furnace exhaust to dry the swarf before melting. Aluminium yield increased from 70% to 93% exceeding the reducing aluminium deliveries by 10%, and reprocessing costs by 40%.	**Toyota (UK)** (SMMT, 2013)
Carbon fibre	Scraps left over from the production of Carbon Fibre Reinforced Plastic (CFRP) components can be returned to the production process.	**BMW, Leipzig (Germany)** (BMW, 2013)
Foundry sand	Sand used in casting for moulds and cores can be re-processed for re-use in the casting process. The sand is usually mixed with additives (organic or inorganic binders, clay…) which have to be separated prior to reuse.	**FIAT (now FCA), Teksid in: Teksid Aluminum, Carmagnola (Italy); Teksid do Brasil, Betim (Brasil); Teksid Hierro de Mexico, Monclova (Mexico).** (FIAT, 2012)
Organic waste	Toyota's Georgetown, Kentucky, plant has 7,000 employees and seven cafeterias. All of the organic waste from the cafeterias, including the oils and greases, as well as the paper and other waste from the offices, is composted.	**Toyota, Georgetown (US)** (Atkinson, 2012)

Material	Example	Manufacturer & site
Paper	Toyota's plant in Indiana installed a paper pulper in 2009 to recycle paper products from the cafeteria. In 2010, it expanded the recycling program to paper products from the plant's bathrooms and break rooms. The pulper shreds the paper products and mixes them with water to form a slurry. Most of the water is then removed and reused by the pulper. The pulp is then sold to a paper recycling facility to make paperboard and cardboard boxes. In the past three years, almost 227,000kg of paper have gone through the pulper.	**Toyota, Indiana (US)** (Atkinson, 2012)
Coolants	GM, Daimler and Chrysler (US) have been using waste management specialist Preferred Filter Recycling (PFR) to achieve complete 'cradle-to-cradle' re-use of filter media used to capture machining coolants, 'wet' and 'dry' paint materials, floor spills and airborne contaminants generated during manufacturing operations. A six-stage heat-based process reduces them, and the residual contaminants they contain, into resins that can be moulded into new products. Critically, the polypropylene filters, infused with otherwise vexatious wet paint sludge, produce a robust resin that can be used to make industrial-grade pallets which enable the re-use of the sludge. The process offers clients distinct cost savings in the range "5-10%" over alternative waste disposal methodologies.	**GM, Daimler and Chrysler (US)** (Farish, 2013)

Further examples of successful approaches used by Toyota are outlined in **Table 40**.

Table 40: Case study on recycling management at Toyota (France) (Toyota – personal comm., 2014)

Toyota's TMMF plant, near Valenciennes reduced waste per vehicle by 39% between 2001 – 2013, achieving zero waste to incineration (without energy recovery) in 2007.

Collection and segregation. At TMMF, 126 categories of material are segregated on the factory line. Each process on the factory floor has specific wastes that are allocated a specific bin. Colour coding, transparent containers and picture labelling is used to make identification easier. Indeed, making recycling intuitive for busy employees has been a key principle, even where this has resulted in separating parts to a greater degree than is necessary such as placing red parts into a red bin, regardless of whether they can be recycled together with different-coloured parts of the same material. Recycling bins are then sorted by trained staff. Accurate sorting has allowed TMMF to eliminate emissions associated with processes at segregation and pre-treatment centres, as well as transport between these sites.

Measurement and monitoring is also a key tool to ensure continuous improvements.

- Internal waste audits are conducted every day, and results are visualised weekly and monthly.
- Waste segregation on each line is monitored at the end of each shift, so that individuals who repeatedly put waste in the wrong bin can be provided with further training.
- Every individual bag of waste is audited for quality before being removed from the plant. However, not all waste streams need to be checked with the same stringency (e.g. plastics need to be checked more thoroughly than metals).

Optimised logistics can reduce fleet emissions. For example, baling of paper and cardboard has reduced collections significantly, by allowing greater density of packing. Minimal storage on site reduces potential damage or loss of stock.

Partnerships are critical to creating a recycling-based market. TMMF works with Green Metals, a waste management firm, to identify potential markets for all materials.

Option 4 – Recover

Illustrative case study examples of the environmental achievements at automotive plants are described in **Table 41**. For more detailed information on waste-to-energy conversion best practice, please see the forthcoming guidance on **Best Available Techniques (BAT) reference document (BREF) on waste treatment industries** (the draft revised document is now available online[40]).

Table 41: Case study examples of waste recovery by automotive plants

Material	Example	Manufacturer & site
Used oils and evaporation concentrates	Renault supplies waste oils and evaporation concentrates from powertrain plants as a replacement for fossil fuels (such as petrol coke, coal, fuel oil) in cement kilns. The high temperature cement production process can fixate almost all of the heavy metals contained in the waste.	**Renault,** (Renault, n.d.)
Waste water	Paint sludge filter cakes are dried in a condenser, and the water is recovered from a condenser (~800l/day). Paint sludge cakes are used as a substitute fuel in cement kilns, due to their high calorific value. At Toyota's plant in Valenciennes, ~50% of all plant waste comes from wastewater treatment and paint sludges, around half of which is from the paint shop	**Toyota, Valenciennes (France)** (Toyota – personal comm., 2014)

[40] http://eippcb.jrc.ec.europa.eu/reference/BREF/WTbref_1812.pdf

Applicability

Limited local recycling infrastructure and waste disposal regulations in certain regions can be a barrier to diverting waste from landfill – in these cases, working with local stakeholders is an important aspect of the waste management plan (GM, 2013).

The choice of the most appropriate waste treatment option involves consideration of logistics as well as material properties and occasionally economical value. For example, a global supply chain could incur logistical costs that will discourage the re-use of transport media (e.g. pallets) and instead create a need for recycling. In contrast, a local supply infrastructure will be more suitable for a 'return and re-use' policy that will help to avoid the need for waste management.

SMEs may not be able to afford the capital cost of some waste reduction techniques which can require new equipment, training or software. Business support is expected to be very beneficial for SMEs. However, it needs to be structured and in depth because the automotive industry is process intensive and developing cleaner production strategies cannot generally be copied as such from one company to another (Oakdene Hollins, 2011).

Finally, highly ambitious objectives such as zero waste to landfill may not be achievable for some facilities depending on the degree of vertical integration of the processes in the plant.

Economics

Direct cost and benefit information is difficult to present, as it is highly dependent on specific business operations and approaches. General Motors report that their initial investments were $10 (€7.5) for every tonne of waste reduced, but that investment costs have decreased over time – programme costs have since been reduced by 93% and total waste has been reduced by 62% (GM, 2012). Fiat (now FCA) reported that projects across their plants have reduced generated waste by 2.5% over 2012-2013 and have led to overall savings of around €4.5 million in 2013 (Fiat – personal comm., 2014).

- **Waste prevention:** The main cost saving achieved from waste prevention are due to less raw material being purchased and reduction in re-work costs. Avoidance of disposal costs (such as Landfill Tax or incineration costs for hazardous wastes) are an additional incentive (Oakdene Hollins, 2011).
- **Recycling and reuse**: Although revenues from recycling will vary from year to year depending on market conditions, they can generally offset the upfront costs and make recycling activities economical. For example, GM estimated its annual by-product recycling and reuse revenue at about $1 billion (€0.8 billion[41]) per year in 2012 (GM, 2012).

Better management of waste is expected to lead to better resource and risk management, thereby increasing revenue, saving costs, boosting asset values and potentially share prices. Specific costs that could be considered, include:

- The offset of landfill tax and compliance with hazardous waste regulations;
- Raw material use reduction;
- Waste logistics;
- Internal training;
- New equipment.

All costs should be considered with regards to their payback period which will be business and plant specific.

[41] Converted using average exchange rate for 2012: http://www.irs.gov/Individuals/International-Taxpayers/Yearly-Average-Currency-Exchange-Rates

Driving force for implementation

The key driving forces for optimal waste management within the automotive industry are the need to:

- Address key management challenges around resource scarcity (Toyota, 2013).
- Generate revenue from waste streams and mitigate rising waste management/landfill costs (GM, 2013) (Brown, 2008);
- Demonstrate compliance with legal or customer requirements;
- Improve employee and stakeholder engagement in environmental protection activities (Toyota, 2013);
- Improving corporate image (Brown, 2008).

Policy drivers to reduce waste include:

- **The Waste Framework Directive** to ascend the waste hierarchy.
- **Restrictions on hazardous waste:** Minimising hazardous waste in painting and cleaning activities has been a key focus due to regulatory pressure (both environmental and workplace health and safety)

Emerging techniques

An example of an emerging technology is **near net shape manufacturing**, which aims to produce components that are close to the finished size and shape, requiring a minimal amount of finishing process (e.g. machining). Example processes include closed die forging, investment casting, metal injection moulding and more recently additive layer manufacturing (ALM). Various materials can be processed in this way including metals, ceramics and polymers. This allows a reduction in the number of processing steps, as well as waste material. These techniques are already being used in the motorsport industry, for weight critical components with high temperature requirements, but are yet to be developed for use in high volume production (Mercury Centre, n.d.). The forthcoming Sectoral Reference Document on Fabricated Metal Products investigates some cases where near net shape may already be a best practice.

The emergence of new vehicle technologies (particularly hybrid and electric vehicles) will offer different challenges in all life phases of vehicles. Waste prevention and management opportunities may be radically different.

Reference organisations

Examples of best practice used in this section have been sourced from Delphi, Gestamp, Nissan, Honda, and ACEA members including Toyota, GM, Renault, FCA group.

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3.4 WATER MANAGEMENT

3.4.1 Water use strategy and management

SUMMARY OVERVIEW:

Water management is an issue of increasing concern that is typically not covered in detail in standard environmental management systems. Therefore BEMP is to implement monitoring and to conduct a review of water management issues according to a recognised consolidated framework for water management which allows organisations to:

1. Assess water usage and discharge;
2. Assess risks in local watershed and supply chain;
3. Create a plan on how to use water more efficiently and improve wastewater discharge;
4. Collaboration with the supply chain and other organisations;
5. Hold the organisation and others accountable;
6. Communicate results.

Relevant life cycle stages				
Management	Design	**Supply chain**	**Manufacturing**	End-of-life
Main environmental benefits				
Energy consumption	Resource use and waste	**Water use & consumption**	Emissions to air, water, soil	Ecosystems & biodiversity

Environmental indicators

- Water use per functional unit (m^3/functional unit)
- Sites that have conducted a water strategy review (% of facilities/operations)
- Sites that have monitoring for water consumption and use (%)
- Sites that have separate water monitoring for production processes and sanitary use (%)

Benchmarks of excellence

- **Introduction of a water strategy according to a recognised tool, such as the CEO Water Mandate, integrating an assessment of water scarcity**
- **Water use on-site is measured per site and per process, if appropriate using automated software**

Cross references	
Prerequisites	• Implementing an advanced environmental management system;
Related BEMPS	• Water recycling and rainwater harvesting • Water-saving opportunities in automotive plants • Ecosystem management reviews and strategy

Description

For most environmental categories, the use phase of a car accounts for the largest share of life cycle impacts. However, in the case of water the use phase is relatively insignificant – most water is consumed at earlier stages in the life cycle. Even so, the major impacts typically occur in the supply chain rather than at the manufacturing facility, and thus a high level of importance is attached to conducting reviews of water across the entire value chain as well as at the plant level.

Although monitoring and benchmarking should be carried out as part of a complete Environmental Management System (see BEMP 3.2.1 *ENERGY MANAGEMENT*), water use is typically not accounted for comprehensively within standard EMSs (Comoglio & Botta, 2011). To help organisations address this aspect, additional guidance is provided in this section.

A large number of voluntary frameworks for water management exist, and it can therefore be challenging to keep track of developments (see the section on "reference organisations" for a list of voluntary initiatives and manufacturers using them). For convenience, this document presents a consolidated framework for water management as outlined in **Figure 26**. This broadly follows the United Nations Global Compact CEO Water Mandate, which is one of the more comprehensive frameworks, and draws in specific guidance from other voluntary initiatives where they add additional dimensions.

Figure 26: Water management framework

Source: (The CEO Water Mandate, 2014)

A brief outline of each stage is provided below:

1. **Assess water usage and discharge:** By quantifying water use and consumption, as well as wastewater arisings by process or department, the site or organisation can begin to identify the key water using activities;

2. **Assess risks in local watershed and supply chain:** Risks depend on the nature of efficiency of water use, potential pollution from operations and the local conditions (hydrologic, environmental, social and political). In particular, priorities will be focussed in identified areas suffering from potential scarcity;
3. **Create a plan on how to use water more efficiently and improve wastewater:** Develop an action plan in agreement with senior management to determine steps to improve water management, responsibilities and timescales;
4. **Collaboration with the supply chain and other organisations:** Companies can have a direct impact on water management in their own business, as well as an indirect impact by encouraging and facilitating actions by others;
5. **Hold the organisation and others accountable:** actions will only be sustainable and efficient if governments, businesses, civil society and other stakeholders work together;
6. **Communicate results:** Adequately report water management while minimising administrative burdens. Such reporting increases corporate accountability for their actions and better allows stakeholders to inform and guide company practices.

For further details, please refer to (The CEO Water Mandate, 2014).

Achieved environmental benefits

By better understanding how water is used, organisations can benefit from reductions in water use and improved water and effluent management.

The key direct and indirect environmental benefits of optimised water use and management are:

- Protection of water resources
- Decrease in energy usage (and associated emissions) linked to water pumping and treatment
- Biodiversity and ecosystem protection

There are a range of water minimisation techniques and solutions that have been applied and proven effective at the plant level. For example, Fiat (now FCA) report that they have saved 2.1 billion m^3 of water in 2013 across their production plants (Fiat – personal comm., 2014).

Appropriate environmental performance indicators

The basic indicator on water use is the water use per functional unit (e.g. m^3/vhcl).

A key indicator at the site and process level is the implementation of detailed water use and consumption monitoring (Comoglio & Botta, 2011):

- Sites that have monitoring for water consumption and use (%);
- Sites that have separate water monitoring for production processes and sanitary use (%).

Organisations should aim to monitor the relevant indicators outlined at least at the plant level. More detailed monitoring at the process level may be implemented for the most water-intensive processes (e.g. with automated software) but it is unlikely to be needed for all processes.

A range of more detailed environmental indicators can be derived from the European Water Stewardship Standard (European Water Partnership, 2012). Other tools may be combined with the water footprint assessment for more extensive and complementary assessments – for more information see (ISO, 2014).

Cross-media effects

When implementing a water management programme, it is important to consider the wider impacts. The reduction in water volumes can cause an increase in the concentration of pollutants in the remaining effluent and a corresponding decrease in the quality of discharge water, unless compensation measures are taken. This may affect the treatment required to meet the requirements for discharge quality.

Operational data

This section provides more detailed operational information for each of the steps in the framework outlined above.

Step 1: Assess water usage and discharge

The water footprint of a product is the volume of freshwater used to produce the product, measured over the full supply chain. It is a multidimensional indicator, showing water consumption volumes by source and polluted volumes by type of pollution (Berger et al. 2012).

A best practice water footprint assessment will be carried out according to an internationally-recognised standard. ISO 14046 is one of the of ISO 1404x series aiming to provide specific guidance on water use. (ISO, 2014).

It is recommended to include direct and indirect water use/consumption in the analysis for sites and for portions of the supply chain that are the most water-intensive. At the site/facility level, detailed monitoring systems are necessary to gain an accurate understanding – where possible, automatic meter readings will be used to reduce measurement errors. Software can be used to track water use against set indicators, and alarms will be raised if measurements fall outside of set ranges (WRAP Rippleffect, 2014). For example, Ford uses various software packages to track water use at each facility and generates monthly reports identifying successes and potential areas for improvement (Ford, 2012).

Step 2: Assess risks in local watershed and the supply chain

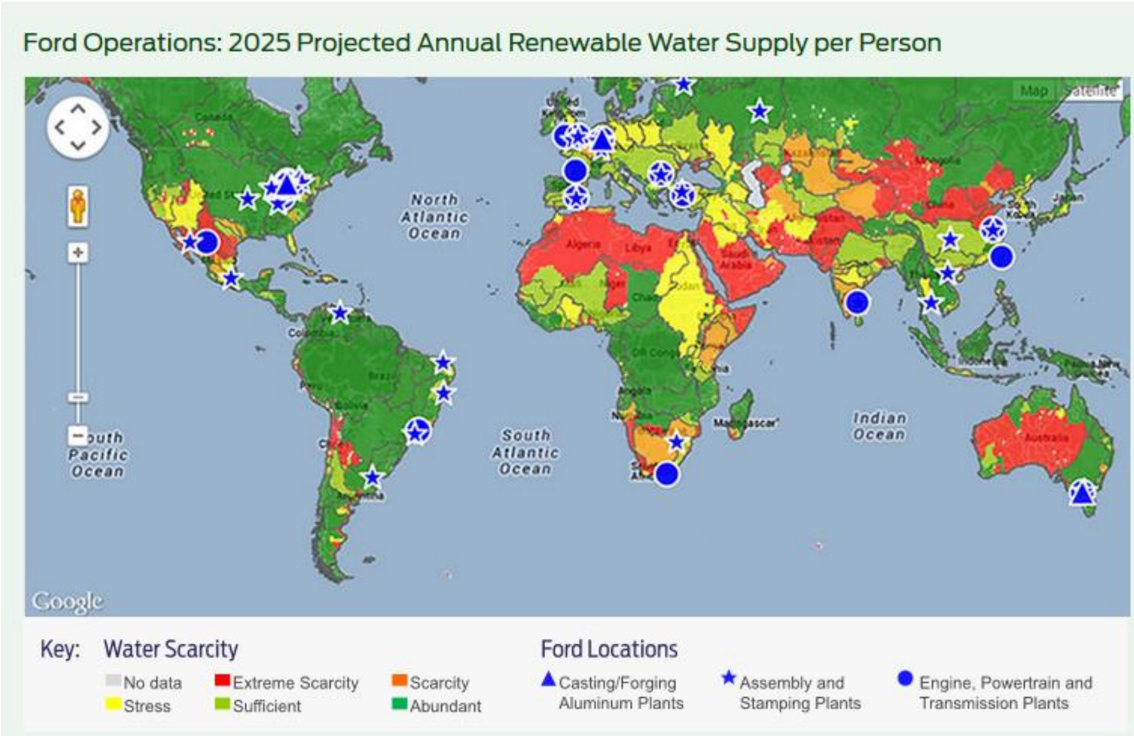
The results of a water footprint calculation will provide a better understanding of absolute volumetric needs. Ultimately, this information will be taken in context with other environmental impacts, as a water assessment by itself cannot provide a comprehensive solution. The information should therefore be used to assess the magnitude of potential environmental impact(s) related to water, as well as opportunities to reduce water related potential risks and impacts (ISO, 2014).

Automotive manufacturing is characterised by complex international supply chains and inputs from many different global regions. As such, local factors will play a role in determining and prioritising the water and effluent management actions that can be taken.

Free tools are available to support this analysis. For example The Global Water Tool is provided by the World Business Council on Sustainable Development

(WBCSD, 2007). This allows organisations to map their water use and assess risks relative to their global operations and supply chains. Ford has used this tool to evaluate which of their operations are projected to be in water-scarce regions by 2025 – see **Figure 27** (Ford, 2015). According to the analysis, approximately a quarter of Ford's operations are projected to be in such regions. The location of the most water-stressed regions is outside of Europe, highlighting the importance of taking the supply chain into account.

Figure 27: Results from the Global Water Tool



Source: (Ford, 2015).

The WBCSD Global Water Tool does not provide specific guidance on local situations. This requires more in-depth systematic analysis at the plant level. Companies can employ the Global Water Tool to identify and prioritise high risk sites in their portfolios. Companies can then employ the **Global Environmental Management Initiative (GEMI) Local Water Tool™** (GEMI, 2014) to further evaluate the high risk locations and identify actions to manage the risks. This is another free tool for companies and organisations to evaluate external impacts, business risks, opportunities and management plans related to water use and discharge at a specific site or operation.

Besides, in the last few years several efforts have been made by the LCA database suppliers to provide an update of the current software with regionalised data for the calculation of Water Footprint. Important examples are:

- the first Water Footprint database, produced by consulting company Quantis. The aim of this "water database" is to fill this gap and provide water footprint practitioners with the data and structure they need to apply the latest methodologies. The project is supported by nine industrial partners (Danone, Kraft, L'Oréal, Molson Coors, Natura, Steelcase and Veolia Environnement) and by the Ecoinvent Centre, a life cycle inventory database provider. The project is based on Ecoinvent data and further developments have been done in order to enhance the information on water in this Database (Quantis, 2012).

- Thinkstep has recentely updated its GaBi version to make available regionalised data on water use[42].

Step 3: Create a plan on how to use water more efficiently and improve wastewater

A comprehensive strategy development can include many dimensions, such as establishing corporate governance and accountability mechanisms, setting goals, and defining water management philosophy (The CEO Water Mandate, 2012). This must be combined with continuous monitoring and improvement to ensure that improvements are sustained.

Ambitious targets for water pollutant levels are also necessary to ensure that reductions in water volumes do not lead to reductions in water quality. Best practice organisations aim to exceed the minimum legal requirements. For example, analysis conducted in 2015 on water discharged from FCA plants worldwide revealed levels of Biochemical Oxygen Demand (BOD) up to 96% below regulatory requirements, while levels of Chemical Oxygen Demand (COD) and Total Suspended Solids (TSS) were up to 89% and 97% below required limits, respectively (FCA Group, 2015).

A water management plan can include, for instance, building separate networks for different uses throughout the plant (sanitary, cooling, technical/process uses) fed by different grades of water (mains, treated on site, collected rainwater etc. – see following two BEMPs).

Step 4: Collaboration with the supply chain

In recent years more and more businesses have focused on issues and activities along their supply chains – recognising that many impacts are beyond their direct control. The degree of water use in the supply chain can be reduced by encouraging and facilitating actions with suppliers (see also *BEMP 3.6.1* SUPPLY CHAIN MANAGEMENT*).* To fully understand and address its external impact, a company must look outside the factory and have a firm understanding of the context in which it operates, including water stress, flooding, poor ambient water quality, regulatory uncertainty, and other factors. Local stakeholders, government and community organisations can also play a role in helping to protect and manage the area watershed (The CEO Water Mandate, 2012).

Step 5: Hold yourselves and others accountable

A company with the most advanced water management practices will look to engage externally to ensure long-term business continuity by contributing to the sustainable management of shared water resources on which the company relies (The CEO Water Mandate, 2012). This requires engagement among water users and other interest groups. Any deficiencies in the water governance, management, or infrastructure that allow water scarcity or conflict to emerge can create a risk to organisations. For example, Ford has been collaborating with a range of organisations such as UN Global Compact, the US State Department and the Global Water Challenge – to gain a better appreciation of outside stakeholder perspectives (Ford, 2012).

[42] http://www.gabi-software.com/spain/solutions/water-footprint/?gclid=Cj0KEQjw94-6BRDkk568hcyg3-YBEiQAnmuwkvZ3nz3RWxvDrpDbC2LB9jE7fYPulXxc_F1as2K3Mm4aAn4o8P8HAQ

Step 6: Communicate results

Current practice in corporate water disclosure (even among the most robust reporters) typically does not adequately capture the complex and location-specific nature of water resources. CEO Water Mandate's Corporate Water Disclosure Guidelines offer a common approach to disclosure (The CEO Water Mandate, 2012).

Applicability

The importance of water as a resource has become a prominent issue in light of increasing water scarcity (BSI, 2014). Water management is a highly localised issue: the same level of water consumption could put extreme strain on the available water resources in water-scarce regions, while presenting no issues in areas with abundant water supplies. The efforts put by companies in water management needs thus to be proportional to the local situation.

There are challenges associated with collecting sufficient data for a full water impact assessment. Therefore organisations will prioritise their efforts to focus on the most water-intensive processes, areas and products, as well as those in areas that are considered to be at high risk of water scarcity.

Economics

One of the challenges for water management is the collection of adequately detailed data, which requires monitoring water flows. Monitoring using sub-meters requires careful design analysis to suit the local situation. Capital costs vary depending on the type of water flow meter – an overview is provided in Table **42**.

Table 42: Cost of water sub-metering systems

Type of submeter	Pipe size (mm)	Cost (€)
Positive displacement	6 – 51	720 – 2,770
Turbine	3 – 203	200 – 1,440
Vortex shedding	6 – 102	340 – 1,550
Portable ultrasonic	6 – larger	920 – 4,520
Permanent ultrasonic	51 – 127	1,700 – 2,240

Notes: Assumed conversion factor of $ to € of 0.72.

Source: (US DoE, 2011)

Monitoring and sub-metering by themselves may have relatively little impact on overall water consumption; rather, it is a tool to understand and control usage. However, the investment costs required to more accurately meter water use are likely to be offset by the savings in water costs, depending on the actions taken. For example, Ford suggest that they are increasing usage of internal water metering to identify additional water saving opportunities at the department level (Ford, 2012).

Other aspects of a water management strategy at the site level are outlined in terms of the potential cost and payback in Table **43**.

Table 43: Water saving practices for industrial applications

Item	Description	Potential cost	Potential payback
Staff training	Increase staff awareness through training, workshops and seminars	Medium (a few €100s to a few €1,000s)	Medium (less than a year)
Water balance	Data collection through site-wide survey, bills and flow measurements	Medium	Short (months)
Monitoring	Flow meters	Medium	Short (months)
Leakage identification and elimination	Inspection and repair of equipment	Medium	Medium (less than a year)
Overflow identification and elimination	Using level controllers to avoid overviews and reduce risk of flooding or pollution incidents	Medium	Medium (less than a year)

Notes: Potential costs and paybacks are for guidance only. Actual costs and paybacks will vary due to project-specific details.

Source: (Zero Waste Scotland, 2012)

Driving force for implementation

There are a number of driving forces contributing to the implementation of better water management in the automotive industry. In particular:

- Increased awareness of water scarcity and the effects of climate change on water supplies within the supply chain, and directly on automotive plants;
- Corporate social responsibility (CSR);
- Legislative requirements for discharge of effluent and wastewater;
- Integration and increased customer requirement for Environmental Management Systems;
- Reduced costs.

Reference organisations

Many automotive manufacturers recognise the need to consider areas of water scarcity in their sustainability or water management plans. Examples of tools used by different manufacturers include:

- CDP Water Disclosure (Ford, 2012), (Volkswagen, 2013);
- The CEO Water Mandate (Ford, 2015), (Volkswagen, 2013);
- World Business Council of Sustainable Development Global Water Tools (Ford, 2012);
- World Resources Institute Annual Renewable Water Supply per person methodology (General Motors, 2013).

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3.4.2 Water-saving opportunities in automotive plants

<table>
<tr><td colspan="5">SUMMARY OVERVIEW:
BEMP is to minimise water use at all facilities, regularly review the implementation of water efficiency measures and ensure that the majority of practices and appliances are classified as highly efficient.
The potential of water saving throughout the plant[43] can be captured by:
• Avoiding water use:
- Dry sweep all areas before hosing
- Eliminate leaks
- Use alternatives to liquid ring pumps
• Reducing water use:
- Improve efficiency of operations
- Install flow restrictors on tap water supply line
- Use water efficient nozzles for spray rinsing/hosing
- Use timer rinse controls
- Install water efficient staff amenities
- Use ultrasonic cleaning processes
- Counter-flow rinsing
- Inter-stage rinsing</td></tr>
<tr><td colspan="5">Relevant life cycle stages</td></tr>
<tr><td>Management</td><td>Design</td><td>Supply chain</td><td>Manufacturing</td><td>End-of-life</td></tr>
<tr><td colspan="5">Main environmental benefits</td></tr>
<tr><td>Energy consumption</td><td>Resource use and waste</td><td>Water use & consumption</td><td>Emissions to air, water, soil</td><td>Ecosystems & biodiversity</td></tr>
<tr><td colspan="5">Environmental indicators</td></tr>
<tr><td colspan="5">• Water use per functional unit (m³/functional unit)
• Share of operations in existing sites retrofitted with water-saving devices and processes (% of operations)
• Share of new sites designed with water-saving devices and processes (% of new sites)</td></tr>
<tr><td colspan="5">Benchmarks of excellence</td></tr>
<tr><td colspan="5">• All new sites are designed with water-saving sanitary devices and retrofitting of water-saving devices is phased in across all existing sites</td></tr>
<tr><td colspan="5">Cross references</td></tr>
<tr><td>Prerequisites</td><td colspan="4">• Water use strategy and management</td></tr>
<tr><td>Related BEMPS</td><td colspan="4">• Water recycling and rainwater harvesting</td></tr>
</table>

[43] this BEMP does not specifically address paint shops (where significant water savings can be realised), as existing guidance is available in the relevant BREFs (STS, STM).

Description

Production processes (other than the paint shop) and sanitary uses can be a significant water-consuming aspect of an industrial site; therefore, they should not be overlooked as an important part of an overall water-saving strategy.

In automotive production, water is needed for many processes such as cooling machines, in air conditioning systems and in the paint shop. Due to the importance of the painting processes in contributing to overall manufacturing water use, dedicated guidance has been developed to help organisations reduce water use in car painting. Guidance on **Best Available Techniques Reference Document (BREF) for Surface Treatment Using Organic Solvents**, which covers environmental aspects related to the painting of car bodies and components[44].

Outside of the painting process, several other water saving options may exist throughout a plant. A thorough water use review could be conducted in order to identify these (see BEMP 3.4.1 on Water use strategy and management). For example, at BMW group most of the water used in car production is already optimised, but they have identified that there is still a considerable opportunity for savings in waste water from sanitary use (i.e. for taps, toilets and showers), which accounts for almost half of total water use at their manufacturing sites (BMW, 2012)[45]. Specific examples of water saving opportunities in the automotive sector are outlined below.

- Avoid
  - Dry sweep all areas before hosing
  - Eliminate leaks
  - Use alternatives to liquid ring pumps, vacuum pumps that require seal (gland) water
- Reduce
  - Improve efficiency of operations
  - Install flow restrictors on tap water supply line
  - Use water efficient nozzles for spray rinsing/hosing
  - Use timer rinse controls
  - Install water efficient staff amenities
  - Use ultrasonic cleaning processes
  - Counter-flow rinsing (water flows in opposite direction to material)
  - Inter-stage rinsing (uses overflow as an intermediate rinse stage immediately upstream)

Achieved environmental benefits

The main environmental benefit is water use reduction. For example, re-using condensed water from compressors at VW's Anchieta plant in Brazil reduces their water consumption by 270 m³ per year (Volkswagen, 2014). But co-benefits can also arise: for example with respect to reduced energy consumption since energy and water costs are very often linked, e.g. reducing hot water for cleaning saves heating costs as well. The use of rainwater harvesting can also contribute to a reduction in flooding.

[44] For the latest documents, please refer to the online repository: http://eippcb.jrc.ec.europa.eu/reference/

[45] Other significant end-uses being mainly evaporative cooling towers and the paint shop. The share varies depending on the site and the processes involved.

Table 44 outlines water-saving options specifically available for the automotive industry – however, the achieved water savings are only indicative due to the high variation between plants depending on the specific processes and equipment used.

Table 44: Estimated water saving from avoiding and reducing water use in the automotive industry

Type	Option	Approximate total water saving
Avoid	Dry sweep all areas before hosing	💧 - 💧💧
	Eliminate leaks	💧 - 💧💧
	Use alternatives to liquid ring pumps, vacuum pumps that require seal (gland) water	💧 - 💧💧
Reduce	Improve efficiency of operations	💧 - 💧💧
	Install flow restrictors on tap water supply line	💧 - 💧💧
	Use water efficient nozzles for spray rinsing/hosing	💧 - 💧💧
	Use timer rinse controls	💧💧
	Install water efficient staff amenities	💧
	Use ultrasonic cleaning processes	💧 - 💧💧💧
	Counter-flow rinsing (water flows in opposite direction to material)	💧 - 💧💧💧
	Inter-stage rinsing (uses overflow as an intermediate rinse stage immediately upstream)	💧 - 💧💧

Notes: 💧 *= <5% total water saving;* 💧💧 *= 5 – 10% total water saving;* 💧💧💧 *- over 10% total water saving*

Source: (Ai group, 2009)

Recycling of water- and oil-based coolants is also possible to a large extent in automotive manufacturing.

Appropriate environmental performance indicators

Organisations will monitor the uptake of practices and appliances that are considered to be water-efficient across their sites and processes. Results indicators for overall water consumption are likely to be dominated by the painting processes, so monitoring at the process level is recommended.

Useful indicators can include:

- Existing sites retrofitted with water-saving devices and processes (% of operations)
- New sites designed with water-saving devices and processes (% of new sites)

Cross-media effects

Cross-media effects can be considered positive, as waste water is reduced, along with energy requirements for treatment and pumping (European Commission, 2012). Specific cross-media effects to be considered in the automotive industry include (Ai group, 2009):

- Replacing an evaporative ("wet") cooling system with an air cooled ("dry") system can sometimes increase the facility's energy consumption;
- Reducing volumes of wastewater can increase the concentration of contaminants.

Operational data

See the **Sectoral Reference Document for Best Environmental Management Practices for the Construction Sector** for more detailed operational data on general building-related water saving devices (European Commission, 2012).

For aspects with significant staff involvement (such as sanitary fittings), instigating staff behaviour change programmes, or implementing simple low-cost devices can reduce water use by up to 30% (WRAP , 2014).

The example below from an ACEA member (source ACEA, 2016) illustrates a practical water-saving measure:

<table>
<tr><th>Manufacturer & site</th><th>System</th><th>Water savings</th><th>Source</th></tr>
<tr><td rowspan="2">[ACEA Member]</td><td rowspan="2">A deburring machine has been modified adding a drain point at the bottom of the tank in order to avoid the water being drained from the upper part of the tank during the cycle.

The project has been implemented in 2013-2014 and is still ongoing.

Provided that production processes can be adjusted, application to various deburring processes is applicable.

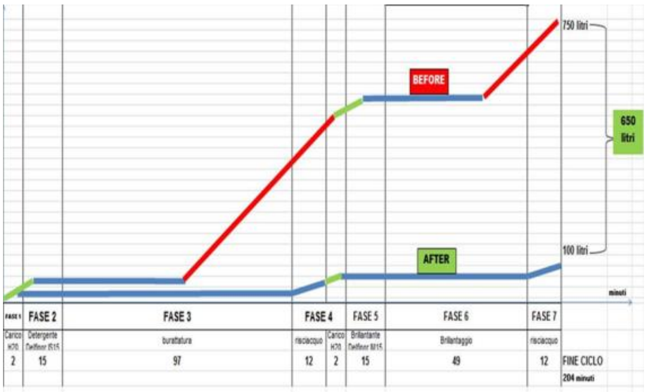
The project has been internally presented during an audit and is considered a best practice.</td><td>Used water sent to waste treatment has been reduced from 750L/day to 100L/day</td><td>ACEA, 2016</td></tr>
<tr><td colspan="2">
</td></tr>
</table>

Figure 28: Water use optimisation in deburring

Applicability

Water-saving devices are broadly applicable and do not compromise performance if chosen and installed correctly.

Economics

Economic information for buildings in general are provided in the **Sectoral Reference Document for Best Environmental Management Practices for the Construction Sector** (European Commission, 2012).

Table **45** indicates the range of expected costs for various water-saving options specifically available for the automotive industry. The costs are only indicative due to the high variation between plants.

Table 45: Estimated costs associated with options to avoid and reduce water use in the automotive industry

Type	Option	Approximate option cost
Avoid	Dry sweep all areas before hosing	Low
	Eliminate leaks	Low
	Use alternatives to liquid ring pumps, vacuum pumps that require seal (gland) water	Low – Medium
Reduce	Improve efficiency of operations	0 – High
	Install flow restrictors on tap water supply line	Low
	Use water efficient nozzles for spray rinsing/hosing	Low – Medium
	Use timer rinse controls	Low – Medium
	Install water efficient staff amenities	Low – Medium
	Use ultrasonic cleaning processes	Medium
	Counter-flow rinsing (water flows in opposite direction to material)	Low – High
	Inter-stage rinsing (uses overflow as an intermediate rinse stage immediately upstream)	Low – Medium

Notes: Low cost = up to €10k; Medium cost = between €10k to €100k; High cost = over €100k   Source: (Ai group, 2009)

Driving force for implementation

In many cases, the most significant driver will be cost savings, but customer and stakeholder requirements are also important (Zero Waste Scotland, 2012).

Reference organisations

The extent of take-up in the automotive sector is not extensively reported, but several manufacturers have highlighted their activities in this area – for example:

- BMW and Volkswagen are gradually replacing sanitary fittings with more efficient versions (BMW Group, 2012), (Volkswagen, 2013);
- Ford have highlighted their use of new cooling tower technologies such as electrolytic water softening to increase cooling tower cycles of concentration, thus lowering water consumption (Ford, 2012);
- BMW are gradually replacing open cooling towers with closed ones and using groundwater for cooling (BMW, 2013).

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3.4.3 Water recycling and rainwater harvesting

SUMMARY OVERVIEW:

BEMP is to avoid/eliminate the use of high-quality water in processes where this is not necessary, as well as increase reuse and recycling to meet remaining needs.

For many uses such as cooling water, toilet and urinal flushing, vehicle/component washing, and non-crop irrigation, it is possible to replace drinking- or high-quality water with recovered water from rain collection or water recycled from other uses. Installing these systems usually requires the following elements:

- for wastewater recycling systems: Pre-treatment tanks
  Treatment system
  Pumping
- for rainwater harvesting systems Catchment area
  Conveyance system
  Storage device
  Distribution system

Relevant life cycle stages

Management	Design	Supply chain	**Manufacturing**	End-of-life

Main environmental benefits

Energy consumption	Resource use and waste	**Water use & consumption**	Emissions to air, water, soil	Ecosystems & biodiversity

Environmental indicators

- Water use per functional unit (m^3)
- Installation of a wastewater recycling system (Y/N)
- Installation of a rainwater recycling system (Y/N)
- Yearly quantity of rainwater use and wastewater reused (m^3/yr)
- Percentage of total water use substituted with recycled rain- or wastewater (%).

Benchmarks of excellence

- **"Closed loop" water recycling implemented with recovery rate of at least 90% where feasible**
- **30% water needs met by harvested water (in regions with sufficient rainfall)**

Cross references

Prerequisites	• Water use strategy and management
Related BEMPS	• Water-saving opportunities in automotive plants

Description

The automotive industry is a large consumer of water, and therefore one of the key targets for wastewater reuse and recycling, as well as using alternative sources of water (i.e. rainwater).

After options to avoid and reduce water use in production have been exploited (see *Section 3.4.2* Water-saving opportunities in automotive plants*)*, the remaining needs can often be met to a large extent through combinations of waste water recycling and rainwater harvesting.

Wastewater recycling

Wastewater can be reused over and over in the same process (closed-loop) or in other processes. The treatment required depends on the quality of the incoming wastewater, and the required quality of the treated water. This in turn will depend on the quality required for the intended reuse activities.

Recycling of water- (and oil-) based coolants is also widely achievable – including emulsions from drilling oil, oil from presses, washing and degreasing water and bleeding from cooling systems and compressors (Gestamp, 2013).

Wastewater recycling systems vary greatly in their complexity, size and treatment processes. Systems typically consist of (Environment Agency, 2010):

- A pre-treatment tank to collect water from various processes;
- Some form of treatment system, with the sludge going to the foul drain and treated water to one or more treated water storage tanks;
- A pump to supply treated water to points of use.

Rainwater harvesting

Rainwater is collected and used in non-potable applications. Industrial and commercial premises generally have a greater demand for non-potable water. Since they typically have a large roof area, these buildings have the potential to recoup large amounts of rainwater. If it is correctly collected and stored it can be used for certain applications without further treatment – and typically presents fewer health risks compared to wastewater recycling (Zero Waste Scotland, 2012).

For rainwater harvesting systems, there are typically four main elements (European Commission, 2012):

- Catchment area, usually a roof surface or pavement;
- Conveyance system: piping and gutters transferring rainwater to the temporary water storage. Two different systems may be needed depending on the cleanliness of the catchment area;
- Storage device: usually a tank, which will be accessible and can be installed over the roof, within the building facilities or underground;
- Distribution system: this may consist of a container for the irrigation system, a piping system or water pumping devices.

Non-domestic waste water recycling and rainwater harvesting systems normally have bespoke specifications. The pumps and tank can be optimised to suit the building size, height, water demands, treatment options and pipework design (Environment Agency, 2010).

Water and wastewater mapping, as well as providing an indication of the required water quality by department or process, can allow organisations to match up wastewaters with reuse opportunities. This is therefore best used in combination with the installation of separate water networks of different grades adapted to the various uses throughout the facility (sanitary, process, cooling…),

In some cases, process water discharges can be used in other processes without any treatment provided the reused water does not impact quality and still complies with regulatory requirements. However, in most cases, wastewater requires some filtration and disinfection to prevent microbial growth and fouling of pipework (Zero Waste Scotland, 2012).

Suitable reuse applications in the car manufacturing sector include:

- **Cooling water.** The significant requirement for cooling water in the industrial production of automobiles means that there is also considerable potential for water savings in this area (Volkswagen, 2013). Water of potable quality is not required for the purpose of cooling. Treated wastewater (through a membrane bio-reactor and reverse osmosis purifier) can be recirculated from other areas, and combined with heat exchangers to minimise the water used in cooling towers;
- **Non-crop irrigation.** For example, watering green areas or in conjunction with green roofs (see *Section 3.4.4* Green roofs for stormwater management).
- **Toilet and urinal flushing**
- **Vehicle/component washing.** In this case the treatment and reuse of water in a closed loop (back to the washing process) can be investigated as it minimises the treatment steps required.

To ensure recycled and harvested rainwater is suitable for reuse, bacterial growth must be controlled. This can be dealt with using three main approaches (Zero Waste Scotland, 2012):

- Limit the time that the water is stored;
- Use chemical disinfectants such as chlorine or bromine to inhibit bacteria growth and extend the possible storage time;
- Treat water using traditional biological methods or newer membrane filtration technology (Membrane bioreactors or MBR), potentially in combination with reverse osmosis depending on the decontamination level pursued.

Most components of a rainwater harvesting system require annual checks (maintenance of the pump, cleaning the roof, gutters, etc.) and cleaning of the tank ("desludging") every three years (Environment Agency, 2010).

Additional general guidance is provided in the Best Practice Report for Environmental Management in the Construction Sector (European Commission, 2012).

Achieved environmental benefits

Providing an alternative source of water recovery and reuse can help reduce demand for mains water supply. In addition, it reduces the volume of water discharged into the sewerage system. Estimates of water savings from reuse, recycling and rainwater harvesting are shown in Table **46**.

Table 46: Estimated water savings from reuse, recycling and alternative sources in the automotive industry

Type	Option	Approximate total water saving
Re-use	Reuse water from a critical rinse stage in a less critical rinse stage	💧💧 - 💧💧💧
Recycle	Treat site wastewater and recycle internally	💧💧 - 💧💧💧
Alternative sources	Rainwater harvesting	💧 - 💧💧

Notes: 💧 *= <5% total water saving;* 💧💧 *= 5 – 10% total water saving;* 💧💧💧 *= over 10% total water saving*

Source: (Ai group, 2009)

The quantity of water that can be reused and/or recycled is dependent on the level of treatment, which is directly related to the characteristics of the site effluent and the application required for the treated water (Defra, Ricardo-AEA, 2014). An overview of some common wastewater recycling technologies in industrial processes is given in Table **47**.

Table 47: Typical water savings using different wastewater recycling technologies

Industrial application	Typical saving
Closed-loop recycling	90%
Closed-loop recycling with treatment	60%
Automatic shut-off	15%
Counter current rinsing	40%
Reuse of wash water	50%

Source: Adapted from (Zero Waste Scotland, 2012)

Appropriate environmental performance indicators

The most relevant indicators of water recycling implementation are (European Commission, 2012):

- Installation of a rainwater recycling system;
- Installation of a wastewater recycling system;
- Quantity of rainwater and grey water reused (m^3/yr);
- Percentage of annual potable water consumption substituted with recycled rain- or wastewater.

Since the performance of these systems depends on a number of important factors, the proposed benchmark is (European Commission, 2012):

- Installation of a rainwater recycling system that supplies **internal** water demand;

- Installation of a wastewater recycling system that supplies **internal or external** water demand (when connection to community networks is available).

Further environmental indictors are suggested in (European Commission, 2012).

Cross-media effects

While in general, cross-media effects will be limited if systems are implemented properly, it is worth noting potential issues.

Reused rain water can have a higher energy and carbon footprint than mains supply water due to the pumping requirements – i.e. electricity to run pumps and control systems – and embodied carbon in system materials (European Commission, 2012), (Environment Agency, 2010). Furthermore, rainwater reuse systems essentially bypass the natural water cycle. This could exacerbate water stress in regions where groundwater levels are locally declining and where water is supplied from a (nearby) area with greater water availability. However, such situations are rare (European Commission, 2012). Conversely, widespread rainwater harvesting could reduce flooding risk during high rainfall events (European Commission, 2012).

Moving from one treatment technology to another may have trade-offs. For example, BMW reports that by moving from an ion exchange technology to reverse osmosis to desalinate water, they increased their water use but reduced the chemicals required (BMW, 2012).

Operational data

Illustrative case study examples of the environmental achievements at automotive plants are described in

Table **48**.

Table 48: Case study examples of water reuse, recycling and rainwater harvesting at automotive plants

Manufacturer & site	System	Water savings	Source
Ford Maraimalai Nagar (India)	Wastewater from the assembly and engine plants are each pre-treated then mixed with sanitary and cafeteria wastewaters. After biological treatment, the combined stream is filtered through active carbon and then ultrafiltration. The final stream is then sent to a three-stage reverse osmosis system, which leaves a large volume of salt-free water as well as a small volume of concentrated brine. The final part of the process sees the water in the brine boiled, condensed and reused in the plant, with only a solid salt remaining	According to Ford, these activities mean that the plant has the lowest water requirement of any of its major global facilities – 1.16m^3 of water use per vehicle	(Brooks, 2012)

Manufacturer & site	System	Water savings	Source
GM San Luis Potosí plant (Mexico)	The wastewater contains high concentrations of dissolved metals, phosphates, free and emulsified oils, dissolved organics and silica. Veolia Water Solutions OPUS™ Technology was used, as well as a double-pass reverse osmosis to produce deionized water for the plant's paint operations	Zero liquid discharge – 90% of wastewater in the plant operations is cleaned and reused, thus minimising the volume of liquid waste (<10%) generated for evaporation in solar ponds. This significantly reduces the amount of groundwater used, saving around 1.2 m^3 water per vehicle built	(General Motors, 2013), (WaterWorld, 2014)
Volkswagen Salzgitter (Germany)	Recycled water is treated and used, for example, in the production of emulsions. Thus, in the engine plant, an evaporator system is used to extract most of the water from oily wastewater. Once separated, the condensate can be used in its entirety to produce new emulsions and detergents. The remaining oil concentrate is either used as lubricating oil, or thermally recycled in the site's power plant	The site treats all its industrial wastewater and recycles it completely. This has led to annual water savings of around 30,000 m^3	(Volkswagen, 2013).
Toyota Valenciennes (France)	Rainwater collection system built in 2008 with a capacity of 6,209m^3 After this, a second 10,385 m^3 tank was built in August 2012 Rainwater is collected as run-off from the impermeable parking lot for use in the manufacturing processes. TMMF achieved zero consumption of industrial water for a period of six months in 2013, however on average usage is: • 42% industrial water • 37% rainwater • 21% recycled water	Water savings of 36% of the plant's normal use from the first system. The second system aims to make Toyota fully autonomous in its industrial water supply	(Toyota, 2012a); (Toyota, 2012b) (Toyota – personal comm., 2014)

Manufacturer & site	System	Water savings	Source
Gestamp Navarra (Spain)	In 2013, a new wastewater treatment plant was implemented to tackle discharges from drilling/pressing, cooling systems and compressors. It treats 650m^3 water each year, of which 500m^3 are recovered and used for washing floors in the plant and 100m^3 of waste oils are sold to the waste management service provider and an economic return is obtained. It also produces 50 m^3 of oily sludge, from which 10 to 20% of concentrated waste can be obtained so that it can be removed by the authorised waste management service provider	The actual volume of hazardous discharges that must be treated via an authorised waste management service provider has decreased significantly. This has led to cost saving and a reduction in water footprint.	(Gestamp, 2013)

Applicability

Water recycling systems can be designed into all new buildings. Retrofitting to existing buildings is expensive and may be impractical unless the building is undergoing extensive renovation (European Commission, 2012). The economic feasibility of rainwater harvesting systems is also highly dependent on the climate (European Commission, 2012).

Systems are more effective where (WRAP, 2010):

- The quality of recycled water is appropriate to its use (so that treatment is minimised);
- The volume produced is similar to the volume used (to minimise issues with storage);
- The water distribution systems are compact with little horizontal distribution, e.g. multi-storey office buildings with vertically stacked washrooms;
- Rainwater systems are typically most cost-effective on buildings with large roof areas but relatively densely-packed service cores.

The potential for a rainwater harvesting system is also affected by the potential for storage in close proximity to the plant. The cost of implementation (including the cost of pumping and digging trenches) rises rapidly as the distance between the water reservoir and the manufacturing facility increases. Indeed, at Toyota's plant in Valenciennes, it was found to be cheaper to build a new reservoir near to the plant, than to use an existing reservoir just a few kilometres from the plant (Toyota – personal comm., 2014).

Water quality is also a significant factor. There must be a reasonably consistent use of water, as changes to processes inside and outside the manufacturing plant can lead to changes in water quality. Therefore it is critical to understand how new or modified processes (e.g. the introduction of a new sealant on the production line) impact water treatment decisions. For example, at Toyota's plant in Valenciennes the car park is used to collect rainwater. When salt was used to de-ice the tarmac, the wastewater treatment processes had to be adapted to cater for new chemical composition of the collected rainwater (Toyota – personal comm., 2014).

There are also legislative requirements which could increase the cost of construction. For instance, are separate piping systems required to separate water of varying qualities (Toyota – personal comm., 2014).

Finally it should be stressed that local conditions can facilitate different solutions which will achieve similar environmental benefits e.g. water recycling / harvesting directly on-site, outsourced externally or even centralised with other neighbouring sites.

Economics

Due to the variability of water recycling solutions, which are tailored to the specific needs of each site, the costs and savings are difficult to quantify. Approximate ranges are provided in Table **49**.

Table 49: Water saving options in the automotive industry

Type	Option	Approximate option cost
Re-use	Reuse water from a critical rinse stage in a less critical rinse stage	Medium – High
Recycle	Treat site wastewater and recycle internally	Medium – High
Alternative sources	Rainwater harvesting	Medium – High

Notes: Low cost = up to €10k; Medium cost = between €10k to €100k; High cost = over €100k

Source: (Ai group, 2009)

Water recycling systems can be installed at relatively low cost during construction, and at reasonable cost during major renovations; however they are expensive to retrofit (European Commission, 2012). The reuse of wastewater is more cost-effective for larger sites due to the economies of scale (Zero Waste Scotland, 2012).

For rainwater harvesting, where large collection areas can be exploited and only a low quality of water is required, commercial installations can pay back the investment cost in as little as two to three years (Zero Waste Scotland, 2012). It is more expensive to retrofit rainwater harvesting systems than to invest in technology when the site drainage system is under construction.

Case study: Toyota Valenciennes

As a concrete example of an application in the automotive industry, key cost and performance metrics from the rainwater collection system at Toyota France (TMMF Onnaing) are as follows (Toyota, 2012a):

- Water treatment costs (including labour, energy, chemicals and filters);
  - Recycled water (coming from rain water and wastewater treatment discharge water) are around 0.25 €/m^3;
  - Industrial water (coming from city network): around 0.75 €/m^3;

- Cost of rainwater collection system:
  - The cost of the first reservoir (6,209m^3) was €224,000, with an additional €23,000 contributed by the French Water Agency (Toyota – personal comm., 2014).
  - The cost of second reservoir (10,385m^3) was €157,000, with an additional €43,000 from the French Water Agency (Toyota – personal comm., 2014).
- Expected payback period: two years

Driving force for implementation

The two primary objectives for implementing water recycling schemes are to reduce water consumption and to reduce wastewater volume (European Commission, 2012). Increasingly, national regulations are encouraging the installation of water recycling systems and provide financial incentives for their installation. This includes international legislation – for example, in most Indian states, the relevant authorities require manufacturers to achieve zero liquid discharge in their operations – one of the key drivers for the high performance of the Ford Maraimalai Nagar plant (Brooks, 2012).

Reference organisations

Wastewater recycling systems are used in most plants to some extent. For example, many Volkswagen sites have treatment plants with membrane or evaporative reactors, allowing the bulk of process water to be reused. In these plants, more than 95% of the water remains in the cycle, or else is used for cooling, toilet flushing and irrigation (Volkswagen, 2013).

Gestamp, at the Navarra site (Spain) has achieved Zero discharge – Gestamp (2013)

Rainwater harvesting systems have been implemented by several manufacturers at selected sites, including:

- Toyota Onnaing (France) – (Toyota, 2012b).
- FCA group – Campo Largo, Brazil; Dundee, Michigan (USA); Cassino, Italy (Fiat, 2012, FCA, 2015);

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3.4.4 Green roofs for stormwater management

SUMMARY OVERVIEW:				
BEMP is to install or retrofit green roofs on industrial sites, particularly in environmentally sensitive areas where management of stormwater runoff is important. Installing green roofs where structurally possible can contribute to the following objectives: • Water attenuation especially from severe weather events; • Increased roof lifespan (reduced material consumption); • Insulating effect (reduce HVAC energy consumption); • Biodiversity conservation; • Improved water quality. This use of the roof has to be weighed against other environmentally beneficial uses such as the installation of solar (thermal/PV) energy systems and daylight inflow.				
Relevant life cycle stages				
Management	Design	Supply chain	**Manufacturing**	End-of-life
Main environmental benefits				
Energy consumption	Resource use and waste	Water use & consumption	**Emissions to air, water, soil**	**Ecosystems & biodiversity**
Environmental indicators				
• Percentage of sites that are suitable for green roofs (suitability depending on structural aspects, access to sunlight, moisture, waterproofing, and drainage or water storage systems), with green roofs installed (%) • Water holding capacity of the green roof: share of water retention (%), water run off (m^3); • Cooling effect: reduction in energy demand for HVAC (MJ); • Qualitative biodiversity indicators (e.g. number of species living in the roof), depending on local conditions.				
Benchmarks of excellence				
• N/D				
Cross references				
Prerequisites	**N/A**			
Related BEMPS	• Biodiversity management			

N.B. this chapter provides an overview of the technique applied to automotive sector companies. For further (non sector-specific) details on the implementation of green roofs, readers can refer to the Best Practice report on the Public Administration sector[46]

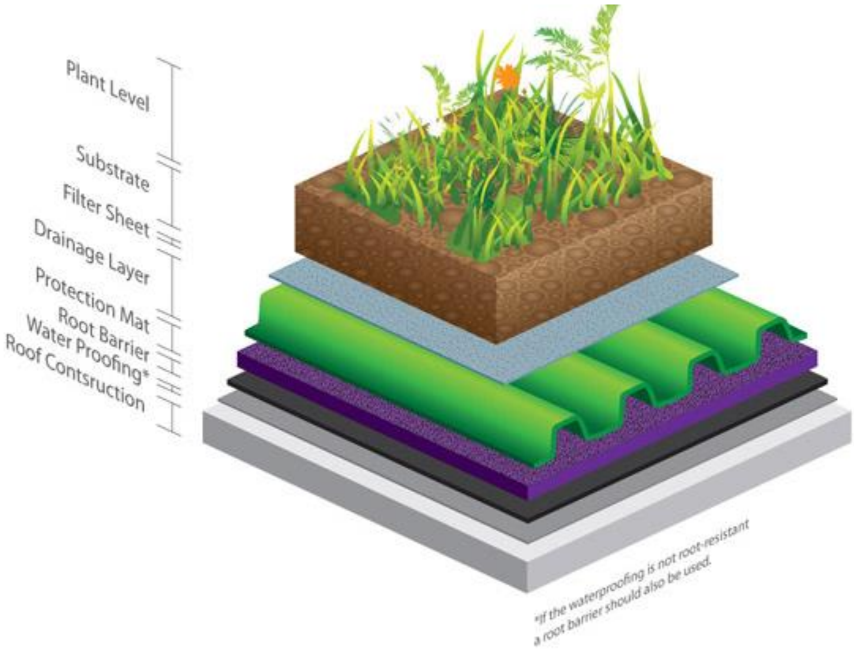
[46] available at http://susproc.jrc.ec.europa.eu/activities/emas/documents/PublicAdminBEMP.pdf , chapter 6.3 "Fostering the deployment of green roofs and integration with renewable energy generation" p.423

Description

"Green" or "living" roofs are layers of living vegetation installed on top of buildings. They can help to manage stormwater runoff, reducing the burden on the sewer network and lowering water treatment costs (GRO, 2011). In addition, water quality is improved due to retention and filtration through the plant's soil and root uptake. They can also help to insulate the building, reducing cooling and heating costs.

Figure 29 shows a common green roof structure. Sedums are the most widely-used plants for green roofs since they are drought-resistant and able to grow in shallow soil. However, the potential range of plants that could be used is very wide. It is important to consider selecting local plants which encourage local biodiversity directly and indirectly by also harbouring local species.

Figure 29: Typical green roof structure



Source: (Groundwork Sheffield, 2011)

An important aspect to consider is the opportunity cost of installing vegetation on the roof, rather than dedicating the space to other uses such as skylights for natural lighting, or installing solar thermal or solar PV systems. These can however be combined to some extent (see Applicability section below).

Achieved environmental benefits

The mitigation of stormwater runoff is often the primary environmental benefit, because rapid roof runoff in areas with impervious surfaces such as large automotive production sites can result in flooding. Each installation is unique, and the environmental performance varies by region, climate, building and roof design.

Table 50illustrates different environmental objectives possible, and the design features that can best contribute to each aim. The achievements of a specific example in the car manufacturing sector are also outlined. This is based on an extensive green roof that was retrofitted at Ford Motor Company's River Rouge Plant (USA). Around 42,000m^2 of assembly plant roofing has been covered with sedum and other succulent plants since 2003 (Priddle, 2013; Henry Ford, 2015).

Table 50: Suitable roof designs for desired environmental objectives

Environmental objective	Typical results	Automotive industry example (Ford River Rouge)	Suitable roof design features to optimise each objective
Water attenuation	Depending on the plants and depth of growing medium, green roofs retain 70-90% of the precipitation that falls on them; in winter they retain between 25-40%	The green roof has reduced runoff by 42%	Reservoir / drainage board with water holding capacity and unrestricted water escape from roof for excess water.
Increase roof lifespan (reduce material consumption)	On average, a green roof could prolong the life of a conventional roof by at least 20 years because the vegetation prevents the roof from being exposed to ultraviolet radiation and cold winds	The roof at Ford is over ten years old and nothing has needed replacing thus far	Double skin exposed waterproofing
Cooling effect (reduce HVAC energy consumption)	The temperature regulating properties of green roofs, can reduce heating and cooling demands. An extensive green roof can reduce the daily energy demand for air conditioning in the summer by over 75%	The roof at Ford insulates the building – providing an estimated temperature difference of up to +5°C in winter and -5°C in summer, and reducing heating and cooling costs by up to 5%	High level of vegetation coverage with varied types and heights of plants
Biodiversity	By providing food, habitat, nesting opportunities or resting places Different types of green roofs and different types of substrate and vegetation will support different habitats and species. Biodiverse roofs can be designed to mimic various habitats.	The roof is home to more than 35 species of insects, spiders and birds, including Canada geese	Varied depths of substrate, types and heights of plants, , and the inclusion of "natural features"
Improve water quality	Reduction in cadmium, copper and lead in runoff by over 95% compared to conventional roof systems. Zinc levels in runoff may also be reduced 16% compared to conventional roof systems	Water runoff contains 85% fewer suspended solids	Specific substrates and minerals can be used to filter out specific elements

Notes: In all cases, the substrate depth should be at least 80mm, and ideally deeper intensive systems with depths of greater than 200mm used where possible.

Source: Adapted from (Groundwork Sheffield, 2011), (GRO, 2011) , (Greenroofs.org, 2014), (Chicago, 2014) and (Priddle, 2013).

Appropriate environmental performance indicators

The potential level of uptake depends on the suitability of the facility – not all sites will necessarily benefit from green roofs. A suitable indicator will therefore be measured relative to the number of suitable sites with green roofs (% coverage).

Systems can be monitored in terms of their performance depending on the design objectives. For example:

- Water holding: % retention, water run off (m^3);
- Water quality: pH, temperature, total suspended solids (TSS), total dissolved solids (TDS), dissolved oxygen (DO), chemical oxygen demand (COD), and nutrients (ammonia, nitrite, nitrate, phosphate, and total phosphorus);
- Cooling effect: reduction in energy demand for HVAC (MJ);
- Qualitative biodiversity indicators (e.g. number of species living in the roof), depending on local conditions.

Cross-media effects

For green roofs, there may be competition in terms of available roof space with other uses that could be usefully made of the surface such as: opening up skylights for natural lighting, or installing solar thermal or solar PV systems for renewable energy capture. As described above these effects can be mitigated by combining two systems.

The key objective of reducing storm-water runoff requires high vegetation cover on the roof, supported by a fertile soil. This can lead to nitrate leaching which compromises water quality in the runoff that flows from the roof.

Finally, specific measures designed to benefit biodiversity may affect the appearance of the roof, or could change the performance of the roof in terms of rainwater attenuation or cooling (Groundwork Sheffield, 2011).

Operational data

Key considerations for implementing green roofs include the structural and load-bearing capacity of the building, access to sunlight, moisture, waterproofing, and drainage or water storage systems. Most extensive roofs, and many intensive green roofs, are supplied as complete systems, which include all components for green roof construction from the insulation and waterproofing membrane to specialist soil mixes and vegetation (Groundwork Sheffield, 2011). Detailed engineering guidance is available in (GRO, 2011).

There are a wide range of choices with respect to vegetation, but the most common are sedum mats – for further design information, please refer to (GRO, 2011).

Extensive systems (<100mm) typically do not require much maintenance after establishment. Irrigation should not be required, fertilisation is only needed on an annual basis, removal of weeds and other undesirable plant species is needed only once or twice a year (GRO, 2011). Conversely, extensive systems require regular irrigation, fertilisation and management (GRO, 2011).

Applicability

Green roofs are applicable to many existing and new building designs, but in practice, few locations will be eligible for a wide-scale deployment of the solution. Limitations include:

- Benefits of stormwater management: Areas with low or no risk of these weather events will have lower incentives to implement the solution;

- Structural constraints on the building: the load-bearing capacity of existing roofs must be taken into account when retrofitting systems (Chicago, 2014). Green roofs are most suitable for flat roofs, as there are additional costs associated with erosion control for sloped roofs (Groundwork Sheffield, 2011). Limitations may apply in cases where the roof shape of existing installations is not suitable, and in some cases due to local climate/weather conditions (Fiat, now FCA Group – personal comm., 2014).

- Existing roof systems: Limitations may also apply in instances where production sites have systems with pipes that are installed under the roof, such as a sprinkler system or central coolant system, as well as possible installations on the roof for ventialation or cooling (Schleicher – personal comm., 2014). In all cases, a structural assessment should be conducted.

- Competition with other environmentally beneficial solutions: Both solar thermal and solar photovoltaic (PV) panels can be combined effectively with green roofs. Indeed, the cooling effect of a green roof can lead to performance improvements from a PV system mounted on A-frames, as the cells work at a higher efficiency. The area under any panels will be shaded from sun and will not be naturally watered – the effect will be to create a different microclimate and attract different (especially shade-loving) plants (Groundwork Sheffield, 2011).

- Collected rainwater management: Storm-water runoff from a green roof is reduced compared to a traditional roof. However, rainwater can still be collected and used for any non-potable applications. In this case, fertilisers should not be used as high nutrient levels in water can lead to problems with algae blooms (Groundwork Sheffield, 2011).

Economics

Initial capital costs are higher compared to traditional roofing materials, but the higher capital costs are often offset by the lower maintenance, replacement and utility costs (Chicago, 2014). Typically the costs per m^2 for applications in the automotive industry will be toward the lower end of these estimates due to economies of scale across large production sites (Priddle, 2013). However, for retrofitting green roofs on existing sites, the increased weight of the roof may lead to higher overall costs for the building (Schleicher – personal comm., 2014).

Table 51: Typical installation and maintenance costs for green roofs

	€/m²
Installation	60 to 115
Maintenance	0.4 to 4

Notes: Assumed conversion factor of $ to € of 0.72.

Source: (Priddle, 2013).

Where green roofs are used on a new development, it is sometimes possible for cost savings made on the drainage package to be used to offset the additional cost of the green roof installation (Groundwork Sheffield, 2011). Retrofitted systems can be costly if the additional weight requires extra roof support.

Driving force for implementation

Many green roofs are built to collect and filter rainfall in order to comply with regulations and government fees with respect to stormwater runoff management.

Reference organisations

Ford Motor Company's River Rouge Plant (USA) has a sedum planted roof based on a thin, four-layer, mat-like system instead of loose soil, in order to reduce the weight (Priddle, 2013).

A new-build extensive system installed at Rolls-Royce (BMW) Goodwood Plant (UK) covers an area of 32,000 m^2 to help it blend in with its countryside surroundings (AutoX, 2012).

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3.5 BIODIVERSITY MANAGEMENT

3.5.1 Review and strategy of ecosystems and biodiversity management throughout the value chain

SUMMARY OVERVIEW:

BEMP is to conduct an ecosystem management review so that the impacts of ecosystem services throughout the value chain can be clearly understood, and to work with relevant stakeholders to minimise any issues.

Organisations can follow methodologies such as the Corporate Ecosystem Services Review (developed by the World Resources Institute with the WBCSD), which consists of five steps:

1. Select the scope;
2. Identify priority ecosystem services (qualitative);
3. Analyse trends in priority services;
4. Identify business risks and opportunities;
5. Develop strategies.

Relevant life cycle stages				
Management	Design	**Supply chain**	**Manufacturing**	End-of-life
Main environmental benefits				
Energy consumption	Resource use and waste	Water use & consumption	Emissions to air, water, soil	**Ecosystems & biodiversity**

Environmental indicators

- Application of methodologies to assess ecosystem services to the value chain (Y/N or % coverage);
- Coverage of relevant scope, as determined by prioritisation (Y/N or % coverage).

Benchmarks of excellence

- **A high-level ecosystem review is conducted across the value chain, followed by a more detailed ecosystem review in identified high risk areas**
- **Strategies to mitigate issues in the identified priority areas of the supply chain are developed, in collaboration with local stakeholders and experts**

Cross references	
Prerequisites	• Implementing an advanced environmental management system;
Related BEMPS	• Biodiversity management at site level • Integrating environmental criteria into supply chain management

Description

An ecosystem is a dynamic complex of plant, animal, and microorganism communities and the non-living environment interacting as a functional unit. The Millennium Ecosystem Assessment, organised by the United Nations, defined four "ecosystem service" categories as follows (Millennium Ecosystem Assessment, 2005):

(1) Provisioning services, or goods and products obtained from ecosystems, such as food, freshwater, timber;

(2) Regulating services, or benefits from the ecosystem's natural regulating processes involving climate, disease, soil erosion, water flows, and pollination, as well as protection from natural hazards;

(3) Cultural services, or the spiritual and aesthetic enjoyment derived from nature;

(4) Supporting services, or such natural processes as nutrient cycling and primary production that maintains other services.

Biodiversity is not considered an "ecosystem service", but rather it underpins the supply of all ecosystem services – that is, biodiversity conservation tends to support a broader range of ecosystem services and to enhance their productivity and resilience.

The automotive industry impacts on ecosystems through resource consumption, pollution, land conversion, and other activities. The most significant potential impacts from car manufacturing are indirect, occurring through the extraction of raw materials, habitat fragmentation due to road construction, local pollution from vehicle use and the potential impacts of climate change (Ford, 2012). Indirect biodiversity impacts occur in the supply chains or during the in-use phase, and will be considered as part of strategies at a higher level. Since many important biodiversity impacts occur in the supply chains, considering this aspect during procurement is an important measure although few automotive manufacturers currently include any specific biodiversity requirements (Global Nature Fund, 2013).

The automotive industry is directly and indirectly dependent on biodiversity, intact ecosystems and their services. This is evident in the provision of certain renewable resources that are currently used in vehicle components, for example:

- Natural rubber. The cultivation of the tree is land-intensive, and usually occurs in regions of high biodiversity, in competition with the natural ecosystems (Global Nature Fund, 2013).
- Leather: has the potential to cause significant disruptive impacts on biodiversity. The manufacture of leather requires large quantities of chemicals, and waste from the production process must be dealt with in an environmentally responsible way (Global Nature Fund, 2013).
- Filling materials such as coconut fibre or visually appealing woods for fittings (Global Nature Fund, 2013). However, the relative proportion of such materials in contemporary vehicles is low.

All of these materials grow in nature, and a sound ecosystem is required to support them.

In addition, the impact of transport on biodiversity can be important, especially related to shipping. The introduction of non-native species is one of the five drivers for biodiversity loss and considered to be a serious risk for society (Hörmann, personal comm., 2014). Ballast water discharged from ships is one of the pathways for the introduction and spread of aquatic nuisance/invasive species ranging from pants, animals, bacteria, and pathogens. They may displace native species, degrade native habitats and disrupt human social and economic activities that depend on water resources. Companies can request from their carriers a Ballast Water and Sediments Management Plan in Shipments which avoids an introduction on invasive species (Hörmann, personal comm., 2014).

As a consequence, it is considered best practice to conduct an ecosystem management review so that the impacts of ecosystem services throughout the value chain can be clearly understood, and to work with relevant stakeholders to minimise any issues[47].

Achieved environmental benefits

The primary environmental benefit is the conservation of natural resources, and the associated ecosystem service provision. While sometimes the consequences of depletion and degradation of ecosystem services can be mitigated (for example, water treatment facilities can sometimes substitute for the role of watersheds and wetlands in water purification), in other cases it is either more costly or impossible to do so.

Appropriate environmental performance indicators

The development of widely accepted indicators for ecosystem services is challenging and work in this area is ongoing. Therefore the approaches detailed in this section are binary indicators that relate to the level of uptake and scope of the approaches used:

- Methodology in place to assess the corporate impacts on ecosystem services (Yes/No – or % coverage of the value chain)
- Methodology covers relevant scope, as determined by prioritisation (Yes/No – or % coverage of the value chain).

Cross-media effects

There are often trade-offs between ecosystem services (e.g. relating to carbon, water, food, landscape, etc.). Some strategies can result in increasing supply, quality or quantity of ecosystem services in certain regions of the world, while decreasing it in others (WBCSD, 2011). This aspect needs very careful consideration.

Evaluating trade-offs usually requires good, credible scientific information about the relationships, linkages and predicted environmental changes between the alternative scenarios – this often necessitates specialist expertise (WBCSD, 2011). It is not recommended that corporations attempt to value ecosystems services using in-house expertise alone – external expertise will almost always be required. Potential sources of technical expertise include universities, research institutions, governments, non-governmental organisations and consultants. Using external

[47] The operational guidance in this section focusses on ecosystem management – that is, it should be considered as a subset or complement to management of wider environmental issues such as emissions and effluents. However, the credibility of results is highly dependent on the approaches and assumptions used, which require a good understanding of the relationship between ecosystem change, ecosystem service provision, and economic or human wellbeing indicators. This almost always requires input from scientists and technical specialists (WBCSD, 2011).

expertise and involving stakeholders in the process will help to mitigate any controversies due to the fact that this is an evolving field.

Operational data

The interactions between human activities and ecosystems are highly complex and constantly evolving – consequently a vast range of modelling and assessment approaches have been developed to assess these linkages.

To help companies navigate this complexity the main approach presented is based on the **Corporate Ecosystem Services Review (ESR)** (WBCSD, 2012). This was selected as it is a comprehensive yet simple scheme that was designed specifically to meet the needs of businesses, and has been successfully applied in the automotive sector. It should be noted that there are a number of other existing guidance documents that can inform good and best practice in ecosystem management (see section on *Applicability*).

The Corporate Ecosystem Services Review was developed by the World Resources Institute with support from the World Business Council for Sustainable Development and the Meridian Institute. The methodology consists of five steps, as shown in **Table 52**.

Table 52: Overview of the Corporate Ecosystem Services Review methodology

1. Select the scope;
2. Identify priority ecosystem services (qualitative);
3. Analyse trends in priority services;
4. Identify business risks and opportunities;
5. Develop strategies.

Source: (WBCSD, 2012).

A detailed case study implementation of each of the steps involved in the Corporate Ecosystem Services Review is presented below, based on (Nissan, 2010).

Step 1: Select the scope

The scoping stage may focus on one product or project to begin with, and subsequently be expanded to other areas. An alternative approach is to do a high-level review to help target more detailed studies (WBCSD, 2011).

Implementation at Nissan defined the scope to cover 10 areas of the value chain, including:

- **Upstream analysis**, including mineral mining, fossil fuel sourcing, biofuel sourcing, and materials sourcing of metals and chemicals. The scoping exercise will identify which part of the supply chain is critical or of major relevance, i.e. direct suppliers or above;
- **Company operations**, including manufacturing (fabrication, painting, thin-coating, assembly), logistics, and Nissan's office usage;
- **Downstream**: Customer use of Nissan automobiles, road construction and maintenance, and the recycling, disposal, and exports of scrapped cars.

Step 2: Identify priority ecosystem services

This is a screening exercise to evaluate the company's dependence and impact on more than 20 ecosystem services to help identify priority services, both in terms of whether the company depends on a service or impacts on it.

— **Dependence:** If the company is dependent on a particular ecosystem service, the company could face business risks, such as higher input costs or disruption to its operations. To evaluate this aspect, Nissan assessed two key questions:
  - Does the ecosystem service serve as an input or does it enable or enhance conditions for successful company performance?
  - If yes, does this ecosystem service have cost-effective substitutes?

— **Impacts:** If a company impacts an ecosystem service—either negatively by depleting or degrading it or positively by supplying or enhancing it. Nissan assessed two key questions:
  - Does the company affect the quantity or quality of this ecosystem service in a positive or negative way?
  - Does the company's impact limit or enhance the ability of others to benefit from this ecosystem service?

Nissan managers and external experts conducted a *rapid assessment* to determine the level of dependence and impact on each ecosystem. The results of this qualitative analysis are shown in Table **53**.

Table 53: Ecosystem Services Dependence and Impact Matrix

Ecosystem services		Upstream (suppliers)		Manufacturing		Downstream	
		Dependence	Impact	Dependence	Impact	Dependence	Impact
Provisioning	Food		●				
	Fibre		●				
	Biomass fuel		●			●	
	Freshwater	●	●	●	●	●	●
	Genetic resources		●				
	Biochemicals		●				
Regulating	Air quality		●		●		●
	Climate		●		●		●
	Water		●				
	Erosion		●			●	
	Water purification & waste treatment	●	●		●	●	●
	Disease		●				●
	Pest regulation		●				●
	Pollination		●				
	Natural hazards				●		●
Culture	Recreation and Ecotourism		●		●		●
	Ethical values		●		●		●
Supporting	Nutrient cycling		●				
	Primary production						
	Water cycling						

Source: (Nissan, 2010).

It is likely that these findings can be used to inform a starting point for evaluations conducted by other automotive companies, although it is emphasised that this exercise was carried out as a rapid screening exercise and not a comprehensive review. The analysis was conducted in collaboration with Nissan managers and various external experts, including consultants from the United Nations Institute of Advanced Studies, to provide perspectives and lead the ESR-related analysis.

Step 3: Analyse priority services

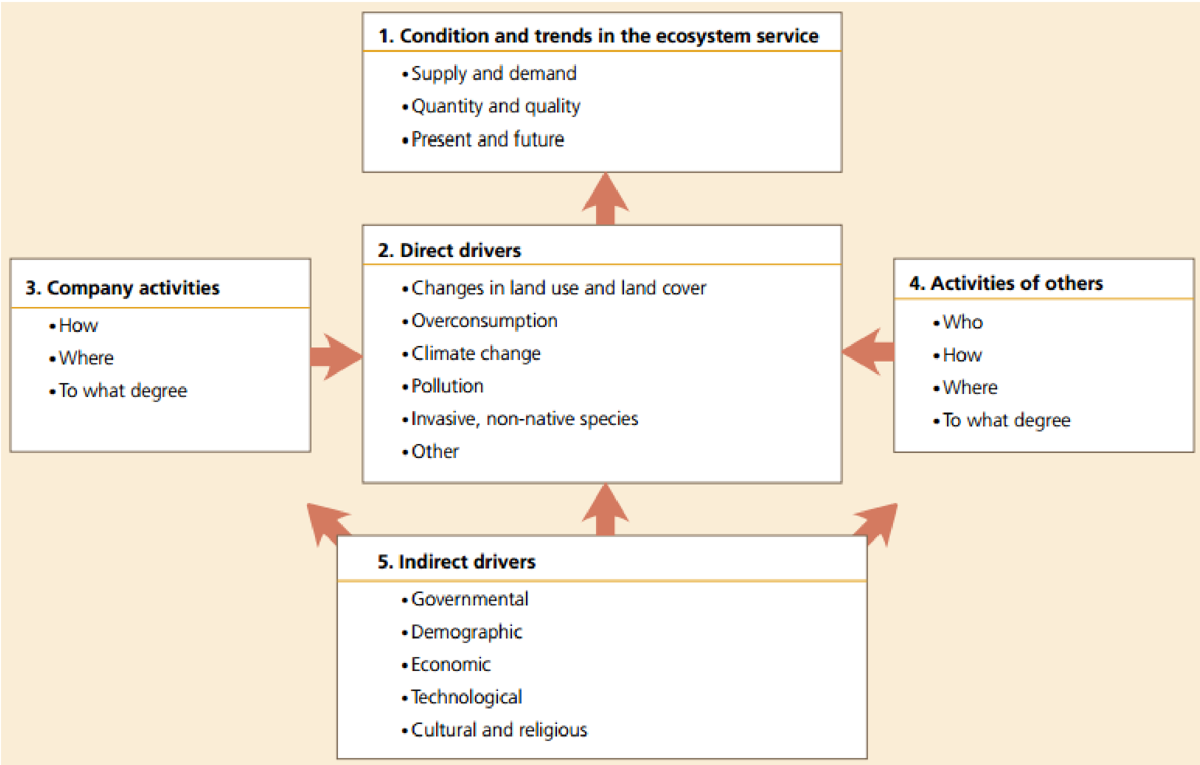
After completing the simple dependence and impact assessment table, the priority ecosystem services can be selected — those judged most likely to be sources of business risk and opportunity. Experts in the area of ecosystem services, including high profile university professors and NGOs offered detailed information on the conditions and trends of ecosystem services. Though not explicitly mentioned in these seven ecosystem services, changes in ecosystems have an impact on the biodiversity inherent in these ecosystems (Nissan, 2010).

For the trends analysis, research will be conducted to answer the following five questions:

1. What are the conditions and trends in the supply and demand of the ecosystem service?
2. What direct drivers underlie these trends?
3. What is the company's contribution to these drivers?
4. What is the contribution of others to these drivers?
5. What indirect drivers underlie these trends?

These five questions can provide a comprehensive understanding of the important trends for priority ecosystem services. A framework for the analysis is shown in Figure 30.

Figure 30: Ecosystem service trends and drivers framework



Source: (WBCSD, 2011)

Based on this assessment, key areas selected as priorities for Nissan and the broader automotive sector were (Nissan, 2010):

1. **Freshwater**: From "well to wheel," the automotive sector significantly depends upon access to water. This can deplete the quantity of freshwater available;
2. **Air quality regulation**: The automotive sector strongly impacts ecosystem air quality regulation services along the entire value chain, from fossil fuel sourcing to manufacturing, logistics, and finally (outside the current scope) customer automobile use;
3. **Climate regulation**: Greenhouse gases and aerosols emitted into the atmosphere largely through fossil fuels, biofuels, and material sourcing, as well as through company operations and customer automobile use;
4. **Water regulation**: Mineral mining and fossil fuel sourcing impact the water storage potential in an ecosystem or landscape;
5. **Erosion regulation**: Fossil fuel, biofuel, and material sourcing and mineral mining all significantly negatively impact vegetation and soil retention. Customer automobile use and road construction indirectly impact erosion regulation through infrastructure development;
6. **Water purification and treatment:** The automotive sector is highly dependent on freshwater and thus naturally dependent on the ability of ecosystems to filter and decompose organic wastes and pollutants in water;
7. **Natural hazard regulation**: The ability to regulate natural hazards can be highly impacted by society's infrastructure development choices. For example, filling in coastal wetlands to develop scenic ocean-view roads may make the area and those depending on this infrastructure vulnerable to coastal hazards.

Step 4: Identify business risks and opportunities

There are five main categories of business risks and opportunities associated with the degradation and enhancement of ecosystem services:

1. **Operational risks** relate to a company's day-to-day activities, expenditures and processes;
2. **Regulatory and legal risks** include government policies, laws, and court actions;
3. **Reputational risks** affect a company's brand, image, "goodwill" and relationships with their customers and other stakeholders;
4. **Market and product risks** relate to product and service offerings, consumer preferences, and other market factors that affect corporate performance;
5. **Financing risks** affect the cost and availability of capital to companies. CEV can be used to identify cost-effective "no net loss" scenarios for major developments.

There are many ways to identify possible business risks and opportunities. One method that proved useful in case study examples was to begin by holding a structured brainstorming session (WBCSD, 2011). Desk-based research can also supplement the results. Expert consultation or further research may also be needed, as well as commissioning original analysis.

As a starting point, the case study implementation example, Nissan focussed specifically on assessing the main business areas affected by them, namely (Nissan, 2010):

1. Energy sourcing;
2. Mineral and material sourcing;
3. Water usage.

Step 5: Develop strategies

The fifth step is to develop and prioritise strategies for minimising the risks and maximising the opportunities identified during step 4. Similar techniques to those described in the previous step are also useful here (i.e. brainstorming, research and stakeholder collaboration).

In addition, reviewing actions taken by other companies facing similar issues can help to trigger additional ideas – see for example,

Table **54**. Further guidance on strategies to mitigate specific impacts is also referenced where provided elsewhere in this document.

Table 54: Nissan case study: Impacts and strategies for the automotive sector

Impacts	Strategies	Further guidance in this document
Energy sourcing		
Many of the major impacts are during the use phase of the vehicle	Production of more fuel-efficient vehicles was highlighted as a priority	This aspect is outside the scope of this document and covered under other policies, such as the car CO_2 Regulation
Impact on global warming from fossil-fuel based electricity generation	The use of fossil fuels in electricity generation can be significantly reduced, such as by expanding solar and wind power generation	See *Section 3.2.3 on* Renewable and alternative energy use
Mineral and material sourcing		
The development of mineral resources may involve stripping away the topsoil or cutting down forests on a large scale.	Metals account for approximately 80% by weight of the materials used to build a vehicle, making automobiles highly dependent on mineral resources. Other raw materials are also derived from agricultural products from regions where biodiversity is threatened, such as rubber trees for tyres. Strategies will aim to conserve resources and to promote recycling in order to reduce the quantities of virgin mineral resources needed.	

Impacts	Strategies	Further guidance in this document
The impact of the extraction of mineral resources on various ecosystems is one risk factor for the automotive sector in the procurement of necessary resources	Efforts, at the time of procurement, to select resources having minimal impact on ecosystem. It is important for the automotive sector to promote materials stewardship and to give precedence to the procurement of resources that take into account the minimisation of the impact on ecosystems	See *Section 3.6.1on* Promoting environmental improvements along the supply chain
Water usage		
Water stress is defined as a ratio (critical ratio) of the volume of water withdrawn annually to that which is potentially available or renewable. Due to the rise in water consumption, some two-thirds of the world's population are expected to live in regions with water stress by 2025.	It is important for the automotive sector to promote materials stewardship together with the mining sector and to give precedence to the procurement of resources that take into account the minimisation of the impact on ecosystems. Water-use assessments were carried out at all plants. The highest-risk plants were given water reduction targets	See *Section 3.4.1 on* Water use strategy and management

Source: Adapted from (Nissan, 2010).

<u>**Examples of initiatives**</u>

- For the last ten years, **Michelin** has worked closely with local farmers, government and local biodiversity groups to protect 3,000 hectares of primeval Atlantic forest linked by ecological corridors, near its experimental farm in Bahia, an unmatched biodiversity reserve. The Group has also set aside an ecological reserve with 35,000 plants grown from native seeds representing 100 different species, and created a Biodiversity Research Center that can host around 30 researchers. It currently helps finance around 20 biodiversity studies every year.

- Based on the assessment carried out under the Ecosystem Services Review, **Nissan** has presented a prioritisation plan for the on-site and off-site activities it will lead to address the hotspots identified in the review (Nissan, 2010). The top three priorities are: energy sourcing, mineral material sourcing and water usage, which now orient Nissan's future efforts on biodiversity.

Applicability

The approaches outlined consist in mainstreaming biodiversity management in the (environmental) management plan of the organisation, and can therefore readily link with many other existing company processes and analytical techniques, such as life cycle assessments, land management plans, economic impact assessments, company reporting, and sustainability appraisals (WBCSD, 2012).

A growing number of other tools and approaches are available, which can make it challenging to select the most appropriate for each organisation. A decision tree to help organisations choose what scale of assessment and what tools would best support decision-making has been developed by the WBSCD[48].

The Corporate Ecosystem Services Review (ESR) is an example of a tool which represents a credible and proven low-cost tool to help companies when they first start to assess their interactions with ecosystem services. The ESR can serve as a management-level guide to help identify, prioritise and respond to the risks and opportunities of ecosystem services. It is one of the few tools that are suitable for immediate and widespread use in a corporate setting (Bagstad et al, 2013). For many activities in the automotive sector, simple screening and assessment tools are likely to offer the best trade-off between cost-effectiveness and added value. Other tools may become appropriate as companies develop and refine their strategies, although the complexity and cost of these tools also increases.

Economics

In most cases, ecosystem service valuation does not need to be lengthy or expensive (WBCSD, 2011), although the cost and effort involved scales with the complexity of the tools used. Some illustrative figures suggest that:

- At least ten hours is needed to conduct an initial qualitative review of ecosystem services (such as the suggested Corporate Ecosystem Review methodology) or to use simple spreadsheet models (Bagstad et al, 2013). However, the time taken depends significantly on the scope and level of detail, and involvement of stakeholders and conducting workshops will add to this time requirement;
- Application of spatially explicit modelling tools requires hundreds of hours of work by an experienced analysis (Bagstad et al, 2013). Therefore such assessments will only be conducted where there is a strong need for insights and where the added value is clear. In practice, there are unlikely to be many applications in the automotive industry for which this level of analysis is required.

Direct cost and benefit information is difficult to present, as it is highly dependent on specific business operations and approaches. Broadly, better management of ecosystems is expected to lead to better risk management, thereby increasing revenue, saving costs, boosting asset values and potentially share prices (WBCSD, 2011).

Driving force for implementation

There is increasing evidence that ecosystem degradation has a material impact on companies through undermining performance, profits, their license to operate and access to new markets (WBCSD, 2011).

Mainstreaming ecosystem considerations into business is becoming increasingly important in order to deal with the challenges of a resource-constrained world (WBCSD, 2011).

In addition to materials, vehicle manufacturing is often reliant on biodiversity and intact ecosystems to supply a local water supply (of sufficient quality and quantity) for production processes (Global Nature Fund, 2013). Finally, ecosystems serve as a sink for emissions from production processes. Companies must also anticipate that ecosystem valuation will be more consistently incorporated into public policies, regulations, and political decisions. For example, in 2011 the European Union

[48] available at: http://www.wbcsd.org/Clusters/Natural-Capital-and-Ecosystems/Resources/Guidelines-for-identifying-business-risks-and-opportunities-arising-from-ecosystem-change

adopted the Biodiversity Strategy to 2020. The strategy aims to halt biodiversity loss in the EU, restore ecosystems where possible, and step up efforts to avert global biodiversity loss.

Reference organisations

An analysis of the sustainability reporting of some major automobile manufacturers (BMW, Daimler, Fiat (now FCA Group), Ford, GM, Honda, Mitsubishi Motors, Nissan, Toyota, Volkswagen) shows that the issue of biodiversity has been established in company targets, albeit to varying degrees of importance (Global Nature Fund, 2013). However, approaches to ecosystem services and management are heterogeneous, and mainly focus on the established topics of climate change, resource scarcity and water (Global Nature Fund, 2013). These aspects play an important role in reducing the progressive loss of biodiversity.

The main guidance described is based on the Corporate Ecosystem Services Review (WBCSD, 2012), with a case study implementation adapted from (Nissan, 2010).

Michelin, a major Tier 1 (tyre) supplier, also carries out extensive initiatives on biodiversity.

Reference literature

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3.5.2 Biodiversity management at site level

<table>
<tr><td colspan="5">SUMMARY OVERVIEW:
BEMP is to improve direct impacts on biodiversity on company premises by measuring, managing and reporting on biodiversity efforts, working with local stakeholders.

Three key steps are essential in improving biodiversity impacts on site:
• <u>Measuring</u> biodiversity to track an organisation's positive and negative impacts on biodiversity, e.g. focussing on land use, environmental impacts and protectable species. Best practice includes e.g. location-based biodiversity or risk screenings, including assessment of the surrounding areas, and measurement according to indicators and species inventories.
• <u>Management and collaboration with stakeholders:</u> Managing the site to promote and maintain biodiversity, and conducting ecological compensation measures, while working with specialist organisations involved in biodiversity and educating staff and contractors.
• <u>Reporting:</u> sharing information with stakeholders about an organisation's activities, impacts, and performance in relation to biodiversity.</td></tr>
<tr><td colspan="5">Relevant life cycle stages</td></tr>
<tr><td>Management</td><td>Design</td><td>Supply chain</td><td>Manufacturing</td><td>End-of-life</td></tr>
<tr><td colspan="5">Main environmental benefits</td></tr>
<tr><td>Energy consumption</td><td>Resource use and waste</td><td>Water use & consumption</td><td>Emissions to air, water, soil</td><td>Ecosystems & biodiversity</td></tr>
<tr><td colspan="5">Environmental indicators</td></tr>
<tr><td colspan="5">• Number of projects or collaborations with stakeholders to address biodiversity issues.
• Procedure /instruments in place to analyse biodiversity related feedback from customers, stakeholder, suppliers (quality indicator).
• Inventory of land or other areas, owned, leased or managed by the company in or adjacent to protected areas or areas of high biodiversity value (area, m^2).
• Plan for biodiversity friendly gardening in place for premises or other areas, owned, leased or managed by the company (Y/N).
• Biodiversity Index (to be developed according to local conditions)</td></tr>
<tr><td colspan="5">Benchmarks of excellence</td></tr>
<tr><td colspan="5">• Implement a comprehensive biodiversity plan to ensure systematic incorporation through measurement, monitoring and reporting
• Cooperation with experts and local stakeholders</td></tr>
<tr><td colspan="5">Cross references</td></tr>
<tr><td>Prerequisites</td><td colspan="4">• Review and strategy of ecosystems and biodiversity management throughout the value chain</td></tr>
<tr><td>Related BEMPS</td><td colspan="4">• Green roofs for stormwater management</td></tr>
</table>

Description

Comprehensive approaches for biodiversity management are not common in the automotive sector, where the current focus is typically on more established topics such as climate change, resource scarcity, energy efficiency and water (Global Nature Fund, 2013). However, these aspects also play an important role in biodiversity. Biodiversity relates to the variability among living organisms from all sources, and diversity within and between species and diversity of ecosystems. Biodiversity is not an "ecosystem service", but rather it underpins the supply of all ecosystem services – that is, biodiversity conservation tends to support a broader range of ecosystem services and to enhance their productivity and resilience.

There is extensive literature documenting good and best practice measures with respect to biodiversity protection at the general level. The guidance in this section has been tailored to make it more relevant, and the guidance in this section is based on evidence from actions that are specific to the automotive sector. Site-specific aspects include:

- **Measurement:** Measuring biodiversity first requires an understanding of how an organisation creates positive and negative impacts on biodiversity. A foundation of accurate information about land take, environmental impacts and protectable species is required for individual manufacturing locations before actions can be planned and taken. Best practice organisations have introduced extensive measurement activities at all of their sites using location-based biodiversity or risk screenings, including assessment of the surrounding areas, and measurement according to indicators and species inventories (Global Nature Fund, 2013).
- **Management and collaboration with stakeholders:** Managing the site to promote and maintain biodiversity, and conducting ecological compensation measures to minimise impacts. In addition, working in partnership with specialist organisations involved in biodiversity and educating staff and contractors in the importance of protecting and enhancing biodiversity;
- **Reporting:** sharing information with stakeholders about an organisation's activities, impacts, and performance in relation to biodiversity.

This section focusses on local, site-specific measures to protect biodiversity and ecosystems at the site level. The focus of this section is therefore on direct impacts, i.e. where companies can directly affect biodiversity on their premises. Direct effects can occur through soil and water contamination, pollution from manufacturing or landscape changes.

Achieved environmental benefits

Achieved environmental benefits must be considered in terms of their ability to reduce direct impacts on biodiversity, thereby increasing the conservation of natural resources, and associated biodiversity and ecosystem service provision.

Daimler list the following benefits to the environment following from comprehensive and systematic documentation and environmental assessment of land around a production site (Daimler, 2011)

- Hazardous waste sites and natural habitats are accurately documented.
- Degraded areas are systematically restored and upgraded in order to improve the food supply for native species.
- Biodiversity is promoted in areas suitable for use as habitats (e.g. temporary hives for non-domesticated bees, dry stone walls etc.) as well as by nesting and colonization aids (peregrine falcon nest boxes, noise attractors for common swifts, bat boxes etc.).
- The sustainable nature of the measures is ensured by monitoring systems.

In addition there is documented evidence of the effects of on-site biodiversity areas on staff well-being as e.g. measured by reported workers' satisfaction and a reduction in absenteeism (source: major Japanese Tier 1 supplier).

Appropriate environmental performance indicators

The following set of basic key indicators are applicable for all companies. They are based on suggestions from the European Business Biodiversity Campaign, which aimed to establish indicators compatible with the requirements of EMAS and ISO14001 so that biodiversity can be more easily incorporated into existing management systems (Business Biodiversity, 2013):

- General indicators:
    - Number of projects / collaborations with stakeholders to address biodiversity issues.
    - Procedure /instruments in place to analyse biodiversity related feedback from customers, stakeholder, suppliers (quality indicator).
- Site-specific indicators:
    - Inventory of land or other areas, owned, leased or managed by the company in or adjacent to protected areas or areas of high biodiversity value (area, m^2).
    - Plan for biodiversity friendly gardening in place for premises or other areas, owned, leased or managed by the company (yes/no).
    - If located in or adjacent to protected areas: Size of areas under biodiversity friendly management in comparison to total area of company sites (%).

In addition, the company could use more tailored indicators, such as: Total size of restored habitats and/or areas to compensate for damages[49] to biodiversity caused by the company (m^2) in comparison to land used by the company (m^2). Depending on the local conditions, this could include both on-site and off-site measures.

Relevant indicators for biodiversity are an active area of research and hence organisations will check for the latest available guidance. The core set of indicators for biodiversity developed by Business Biodiversity are rather extensive and are available online[50].

As another example, one ACEA member developed a simplified **Biodiversity Index** to facilitate the widespread use of biodiversity management and to increase biodiversity on industrial production sites:

A tool to simply assess the status and potential of open land spots was needed to effectively start biodiversity enhancement activities. A tool providing 6 classes of ecological relevance from 0=no ecological relevance (i.e. sealed surface without any vegetation); 1=very low , 2=low, 3=medium, 4=high, 5= very high ecological relevance was developed with each class characterized by defined criteria. For example, a tree is credited depending on the radius of its crown, domestic or non-domestic origin, etc. These credits are then accumulated on the piece of land together with other contributing factors. No specific botanical professional background is required and after a short training, a site can be assessed and results automatically illustrated. After pilot implementation at some European sites, the method was presented in 2013 to sites in

[49] if necessary, the definitions of Directive 2004/35/EC on environmental liability can be used
[50] http://www.business-biodiversity.eu/default.asp?Menue=233

North and South America, Africa as well as Asia. In the aftermath, strategic and effective biodiversity improvement projects were launched.

The method requires data like:

- total site area
- size of non-built-up areas
- sizes of plots to be evaluated
- information of, for example, mowing frequencies and gardening

Classification of the plots needs data like

- kind of plants present (exotic, endemic, rare, endangered species)
- human influence/impact (strong: regularIwing, annual planting activities,... ; low: extensive cultivation, infrequent mowing)
- estimate on number of plants or animal species present

Going through the exercise not only enables transparency and benchmarking of biodiversity for defined areas at the site, but also helps identify measures for improvement.

At the sites, environmental staff do most of the assessment (frequently using internships of university students as support). and initiate consultations with site planners and management to define and implement biodiversity revaluation measures.

Class I – very low ecological relevance
- ➢ Low biodiversity
- ➢ High human influence (frequent mowing activities)

Class II – low ecological relevance
- ➢ Strong human influence (annual planting)
- ➢ Low biodiversity
- ➢ No rare/endangered species
- ➢ Mainly non-domestic species

Class III – medium ecological relevance
- ➢ Some rare species
- ➢ Recently planted but now undisturbed
- ➢ Medium biodiversity

Class IV – High ecological relevance
- ➢ Rare ecosystem
- ➢ Potential habitat for species with special ecological needs
- ➢ High biodiversity

Cross-media effects

Measures to protect biodiversity in this context are rarely associated with significant cross-media effects. However, zoning to protect high nature value areas may lead to more concentrated development that can have additional environmental benefits in relation to efficient service provision, but that may give rise to localised pressures (noise, air quality, etc.) (European Commission, 2013).

Operational data

Measurement – operational data

The key focus is on direct drivers of biodiversity change. There are various drivers, but the ones most relevant for the automotive industry include (GRI, 2007) (Global Nature Fund, 2013):

- **Conversion or destruction of habitats. ,** e.g. land conversion resulting from site development
- **Pollution:** Soil and water are particularly at risk due to the pollutants used in production. Leakages of nitrogen-or sulphur-containing pollutants can cause acidification, whilst hazardous substances (including heavy metal compounds) can be detrimental to wildlife.
- **Invasive species.** Organisations can unintentionally introduce species (e.g., insects that have nested in cargo containers or aquatic organisms in shipping ballast) into habitats;
- **Overexploitation of resources**: that are available in finite quantities with different renewal cycle;
- **Climate change,** e.g. human activities contributing to global warming such as deforestation and use of fossil fuels;

Initial screening of the biodiversity linkages and performance of a company can be achieved by can be achieved by following existing guidelines. For example, **biodiversity checks** are offered as part of European Business and Biodiversity Campaign[51]. They provides a first overview on biodiversity opportunities, impacts and risks to a company according to the procedure of environmental management systems EMAS III and ISO 14001 and based on the philosophy and objectives of the Convention on Biological Diversity (CBD)[52]. A few automotive manufacturers have opted to conduct biodiversity checks at their sites under this scheme. The Biodiversity Check examines the company's direct and indirect impacts on biodiversity in the areas of strategy, management, public relations, company premises, procurement, product development and production, logistics and transport, sales and marketing etc. (see the case study in Operational Data).

It is also increasingly common for manufacturers to cooperate with environmental specialists to establish their own ecological indicators for monitoring and evaluation, as well as species inventories and lists of priorities for further action (e.g. Fiat – now FCA Group, BMW and Daimler) (Global Nature Fund, 2013).

Further examples of biodiversity measurement carried out at automotive production plants are shown in Table **55**.

[51] http://www.business-biodiversity.eu/
[52] An international effort led by the United National Environment Programme: http://www.cbd.int/

Table 55: Examples of biodiversity measures at automotive production plants

Example measure	Case study implementation	Results	Reference
Measurement using the Biodiversity Check	To analyse biodiversity-related effects of production at the Sindelfingen plant, Daimler has performed the Biodiversity Check of the European Business and Biodiversity Campaign.	Daimler has established that ~16 hectares of viable green spaces at the location Sindelfingen could be protected through corresponding improvement.	**Daimler** **Germany** (Global Nature Fund, 2013); (Stöbener, 2012).
Measurement based on risk analysis	Since 2010, Volkswagen has teamed up with external partners in the scientific and insurance sectors to prepare risk analyses that identify the emission risks arising from the company's operations, such as exhaust air, wastewater, waste, noise or vibration. Volkswagen then sets them against the potential adverse effects on water, soil and biodiversity in the local environment and evaluates them.	This analysis has resulted in much better information about the ecological integration of the factories in their individual landscape settings, and also made improvements in efficiency and savings in costs.	**Volkswagen** **Germany** (Biodiversity in Good Company, 2011)
Collaboration with research institutions to develop measurement indicators	Fiat (now FCA Group) worked in collaboration with the Department for Animal and Human Biology at the University of Turin, to develop a FIAT Group Biodiversity Value Index and corresponding guidelines for its application. The index measures the biodiversity at and surrounding corporate locations based on recognized ecological indices and existing problems at the respective sites.	Two application studies have already been carried out, with an expansion planned for sites in or near areas with high biodiversity.	**Fiat** (now FCA Group), **Italy** (Global Nature Fund, 2013)

<u>**Management and collaboration with stakeholders – operational data**</u>

Many automotive companies carry out voluntary conservation measures, albeit to a varying extent. The range includes relatively simple actions such as environmental education and conservation projects (e.g. tree planting).

However, some frontrunner organisations have systems in place to ensure systemic collaboration with local stakeholders and NGOs in the areas of biodiversity and nature conservation. Further examples of biodiversity measurement carried out at automotive production plants are shown in Table **56**.

Table 56: Examples of management and collaboration with stakeholders

Example measure	Case study implementation	Results	Reference
Minimising land use	Daimler's production facilities cover a total area of about 4,000 hectares (10,000 acres), around 55% of which is covered by buildings, roads, and parking areas. Daimler use these surfaces as efficiently as possible – for example through multi-story buildings and high-density construction.	In cooperation with nature conservation organisations and public agencies, they are transforming open areas at the plants into species-rich meadows instead of lawns. Industrial architecture can also provide a habitat for threatened animal species. At Daimler's plant in Wörth, peregrine falcons nest on top of a chimney.	**Daimler** **Germany** (Daimler, 2011)
Attracting wildlife	At the Gaggenau plant, Daimler set up nest boxes and a noise attractor to encourage common swifts to colonize the area, built dry stone walls and created areas of nutrient-poor grassland, the facility is planning to attract certain plant species and set up various nesting and breeding aids, especially for assisting plant and animal species from Baden-Württemberg's list of 111 species that are particularly in need of help.	These measures are expected to facilitate a permanent improvement to local biodiversity with little effort.	**Daimler** **Germany** (Daimler, 2011)
Collaboration with conservation organisations	To date, GM has initiated habitat management programmes to increase the biodiversity at 21 locations worldwide. GM collaborates closely with the Wildlife Habitat Council, an association of nearly 100 large, generally global corporations and NGOs.	The habitat management programs will be certified by the Wildlife Habitat Council. GM are aiming to certify all of their properties worldwide by 2020.	**GM** **Global** (Global Nature Fund, 2013)

Example measure	Case study implementation	Results	Reference
Collaboration with suppliers	Volkswagen is a founding member of the German Biodiversity Initiative "Biodiversity in Good Company" (BIGC) and has committed to establishing corporate biodiversity management as well as to comply with and support the CBD objectives by signing the BIGC Leadership Declaration.	As part of its BIGC membership, Volkswagen has committed to inform its suppliers through the proprietary B2B platform of biodiversity objectives and to encourage the protection of biodiversity.	**Volkswagen Germany** (Global Nature Fund, 2013)
Set aside land for biodiversity and open for education	The site was set up in 2007 on a 10,000 square meter lot on-site that was previously fallow land, as a space for children to learn about and experience the environment. Employees, local citizens, a nonprofi t organization, civic group and elementary school students participated in the development of the facilities manually, which include an Ecotope and Eco-Farm The Eco-Center has also been set up to handle the recycling of complex waste that also cannot be done at ordinary recycling facilities.	As a result of the renewal, the number of species of living creatures increased at Ecotopia, which is at the center of the complex, including plants, fish and insects, providing more opportunities for school children to learn about the environment. There is even an orchard in one corner of the Eco-Farm producing mandarins and figs. Employee awareness is also raised and water, food, plastics and oils wastes are re-used on site.	**Major Tier 1 supplier (Japan)**

Reporting – operational data

Reporting is critical to making the most of the reputational benefits of implementing biodiversity measures, as well as sharing information to encourage environmental protection. For example, Volkswagen has committed to the preparation of ecological reports for its German sites, as well as meeting the requirements of the Global Reporting Initiative (GRI) (Volkswagen, 2012).

In order to ensure reporting is effective, automotive manufacturers will (GRI, 2007)**:**

- Incorporate stakeholders' values in combination with scientific assessments, to determine which ecosystem services are important in a given context, and which biodiversity impacts are considered acceptable;
- Communicate its understanding of how its activities affect biodiversity;
- Outline its approach and performance in the context of its perceived roles and responsibilities;

- Report the specific policies and management approaches that are put in place to guide day-to-day activities;
- Use indicators (e.g. the GRI Environmental Performance Indicators) which specify the common information to be reported, as well as organisation-specific biodiversity indicators.

For further details on what to report, how to report and what indicators to use when reporting on biodiversity, please refer to **Biodiversity a GRI Reporting Resource** (GRI, 2007). The indicators and reporting framework are part of ongoing efforts in this area, and so organisations should check online for the latest guidance.

Applicability

Most of the approaches can be introduced at any time during site operation. Existing sites may have little or no open space available for new development, although some solutions can make use of already constructed surfaces (see BEMP 3.4.4 on Green roofs for stormwater management).

One issue facing the organisations implementing these best practices is the threat that the areas dedicated to biodiversity may become protected, impending future use for e.g. planned long-term extensions.

On a more short-term level, it needs to be stressed that some measures to make the site more welcoming to biodiversity may also be in conflict with the operational management of the site. One example is the provision of favourable location for nesting areas in or near the site, where the increased frequentation of the site by fowl may cause increased soiling of the manufactured vehicles stockpiled in outdoor location and awaiting shipping. This can be mitigated by adequate covering of areas or vehicles.

Economics

Since biodiversity is a public good, the economic importance of intact nature is often overlooked or underestimated (Global Nature Fund, 2013). Direct cost and benefit information is difficult to present, as it is highly dependent on specific business operations and approaches. Broadly, better management of ecosystems and biodiversity is expected to lead to better risk management, thereby increasing revenue, saving costs, boosting asset values and potentially share prices (WBCSD, 2011)

Biodiversity checks, such as the one referenced in the Operations section, allow organisations to take targeted measures in order to avoid or mitigate negative impacts on biodiversity and ecosystems and in some cases can reduce costs. For example, in cases where a business is required to enlarge its site area for production, they may be obliged to implement compensatory measures. If these measures are taken in advance the cost to the company can be reduced (Business Biodiversity, 2011). Furthermore, timely assessment of impacts to biodiversity can reduce operational risks (e.g. reputational risks or penalties for damage to ecosystems), and heighten employee motivation (Stöbener, 2012). Businesses that address environmental impacts at an early stage gain a competitive advantage, and put themselves in a position to anticipate legal requirements (Stöbener, 2012).

Driving force for implementation

Companies may anticipate that biodiversity (and ecosystem) issues will be more consistently incorporated into public policies, regulations, and political decisions. For example, in 2011 the European Union adopted the Biodiversity Strategy to 2020. The strategy aims to halt biodiversity loss in the EU, restore ecosystems where possible, and step up efforts to avert global biodiversity loss.

Opportunities for the automotive sector also include (Business Biodiversity, 2011):

- Reputational benefits;
- Earned credits (currently applicable to Germany) that can be used for components in later construction projects;
- Securement of corporate production basis, e.g. by protection of water resources.

Reference organisations

Car manufacturers mentioned in this chapter include Daimler, Volkswagen, FCA, GM, and Toyota.

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3.6 SUPPLY CHAIN MANAGEMENT AND DESIGN

3.6.1 Promoting environmental improvements along the supply chain

SUMMARY OVERVIEW:

BEMP is to require all major suppliers to have certified environmental management systems, set targets for environmental criteria and conduct audits of high risk suppliers to ensure compliance. This is supported by training and collaboration with suppliers to ensure that their environmental performance improves.

Front runner organisations strive to improve environmental performance in their supply chain by:

- Tracking materials using the IMDS (International Material Data System);
- Requiring direct suppliers to have certified or verified environmental management systems;
- Setting environmental improvement goals and collaborating with Tier 1 suppliers[53] on how to achieve them, typically to
  - Reduce waste and increase recycling
  - Reduce energy consumption and CO_2 emissions
  - Increase the percentage of sustainable materials in purchased components
  - Improve biodiversity;
- Supporting suppliers to improve their environmental impact;
- Monitoring and enforcement.

Relevant life cycle stages				
Management	Design	**Supply chain**	Manufacturing	End-of-life
Main environmental benefits				
Energy consumption	**Resource use and waste**	**Water use & consumption**	**Emissions to air, water, soil**	**Ecosystems & biodiversity**

Environmental indicators

- Share of Tier 1 (direct) suppliers (by number or by purchasing budget/value) that comply with required standards according to internal or external audits (%);
- Self-assessment questionnaires are sent to direct high risk suppliers (Y/N)
- Direct supplier development and training is undertaken (Y/N)

Benchmarks of excellence

- **All major suppliers are required to have an environmental management system in order to qualify for purchasing agreements**
- **Environmental criteria are set across all environmental impact areas for purchasing agreements**
- **All direct suppliers are sent self-assessment questionnaires and high risk suppliers are audited by customers or third parties**
- **Direct supplier development and training is undertaken**
- **Enforcement procedures are defined for non-compliance**

Cross references

Prerequisites	**N/A**
Related BEMPS	• Implementing an advanced environmental management system; • Design for sustainability using Life Cycle Assessment

[53] for an overview of the meaning of different "tiers" in the industry please see section 0.

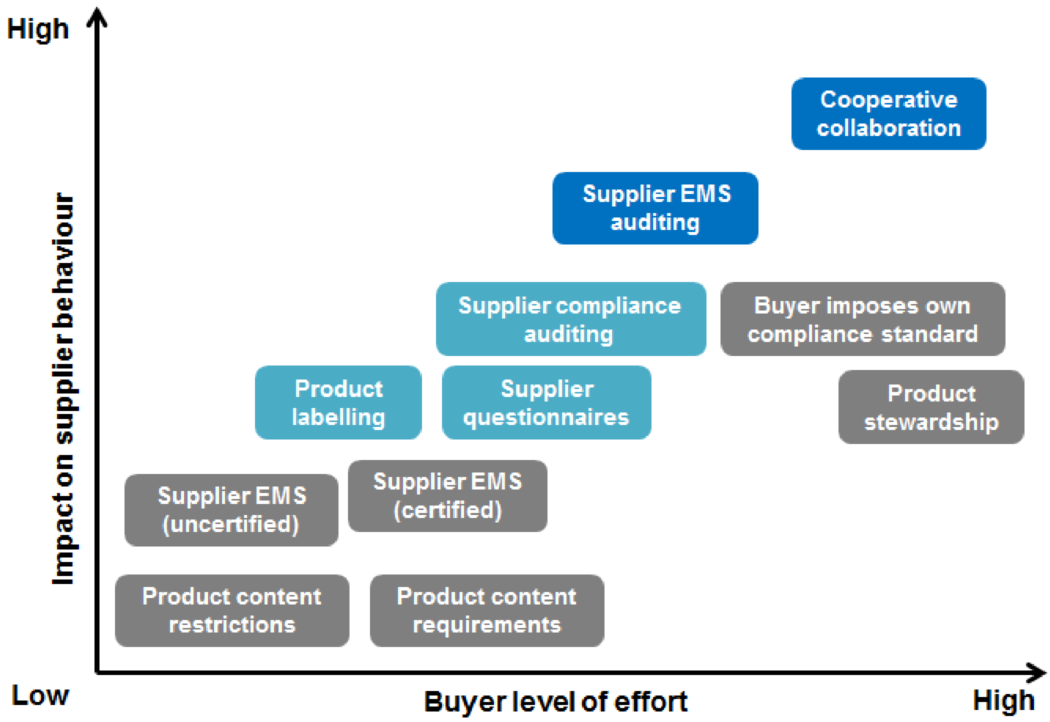
Description

An environmental quality scheme for direct suppliers can consist of several elements that complement each other, as illustrated in **Figure 31**. In general it can be seen that there is a correlation between the effort required by buyers and the environmental benefits (effect on suppliers). The very best results are obtained when:

- Direct suppliers are required to have an environmental management system (EMS), and this EMS is audited as part of the agreement;
- The schemes involve a high level of cooperation and collaboration with suppliers, which is also especially important to generate buy-in and ensure the success of the scheme.

Product labelling, supplier compliance auditing and supplier questionnaires are also useful supporting measures that require lower levels of buyer effort, and will be discussed where relevant. However, the main focus of this BEMP is on the aspects that have the highest impact on Tier 1 supplier performance.

Figure 31: Environmental quality standards – strategies for buyers



Source: Adapted from (Hamner, 2006)

The most ambitious strategies that have been implemented by major OEMs include the following aspects:

- The IMDS (International Material Data System) is the automobile industry's material data information system. Initially, it was a joint development of Audi, BMW, Daimler, EDS (after acquisition in 2008 part of HP, now Hewlett Packard Enterprise, HPE), Ford, Opel, Porsche, VW and Volvo. Further manufacturers have since joined the community and IMDS has become a global standard used by almost all the global OEMs. Talks are being held with additional manufacturers regarding their participation in IMDS.

In the IMDS, data on all materials present in finished automobile manufacturing are collected, maintained, analysed and archived. IMDS facilitates meeting the obligations placed on automobile manufacturers, and thus on their suppliers, by national and international standards, laws and regulations.

- **Requirement for direct suppliers to have certified environmental management systems:** Such as ISO 14001 and EMAS, in order to qualify for purchasing agreements (Daimler, 2012), (Ford, 2012), (Toyota, 2010), (Volkswagen, 2009). The requirement alone is not enough to guarantee environmental performance improvements, but is a first step that must be implemented and audited later on.
- **Set environmental improvement goals and collaborate with Tier 1 suppliers on how to achieve them:** Targets in various environmental areas are set or agreed in collaboration with the buyer – for example, some manufacturers clearly request their suppliers to consider how to:
    - **Reduce waste and increase recycling:**
        - Renault-Nissan demands that its direct suppliers comply with its standard on "design for recycling". This obliges the suppliers to propose recycled materials in the event of new applications of new materials or composite materials, and to back up the recyclability aspect of any products.
        - Toyota specifies that suppliers work to reduce the volume of waste generated in their business activities, and requires that all individual and logistics packaging used must be recyclable, and that the weight and use of packaging must be minimised (Toyota, 2010);
        - BMW Group increases systematically the use of secondary raw materials in its vehicles in the last years. Up to 20 % of the thermoplastic materials in its automobiles are already substituted by the recycled equivalent (2012: up to 15 %, 2013 and 2014: up to 20 %). These materials account for an average of 12 % of vehicle weight (BMW Group 2015)
    - **Reduce energy consumption and CO_2 emissions:**
        - Several manufacturers specify that suppliers work to reduce their own CO_2 emissions (Toyota, 2010), (Volkswagen, 2009). This aspect is also supported by requiring that suppliers implement an EMS;
    - **Increase the percentage of sustainable materials in purchased components:**
        - For example, at Ford, many commodity purchasing plans list recycled-content materials as a preferred material option, including those for battery trays, battery shields and wheel arch liners. In addition, the use of recycled plastics in required for underbody and aerodynamic shields, fender liners, splash shields, stone pecking cuffs and radiator air deflector shields manufactured in North America. (Ford, 2012);
    - **Improve biodiversity:**
        - Few automotive manufacturers currently include criteria to take into account biodiversity-relevant sustainability (e.g. participation in the development of sustainability labels, sourcing of metals from certified mining sites) The ecological impact of raw materials can be substantial, particularly for

resources such as leather, rubber, minerals and metals (Global Nature Fund, 2013)

- **Supplier development:** These supportive measures are important in order to encourage greater awareness and compliance, as well as to cultivate better direct supplier relations:
  - Tier 1 suppliers are typically required to complete a self-assessment questionnaire to determine their current status and are also required to communicate the standards to their own suppliers;
  - Training and support is provided either in face-to-face settings or via online portals;
  - Recognising supplier performance through environmental awards.
- **Monitoring and enforcement:** Auditing is an important part of the process, particularly for supplier EMS, but also for compliance with targets and other criteria. The most advanced schemes use third-party verification to monitor compliance. Requiring that suppliers report environmental data is also needed to maintain ongoing adherence to environmental quality standards, as well as to measure the impact. It may also be useful to identify potential problem areas and work with the supplier to resolve them.

Throughout the process the strategy has to be accompanied by an appropriate risk management process, whereby the risks to the environment, but also the risk to the company through an assessment of supplier risk, will be continuously evaluated.

Achieved environmental benefits

The environmental benefit of requiring suppliers to comply with certain standards depends on the stringency of the standards, the scope of suppliers covered and the resulting improvement in performance. Thus, requiring suppliers to report environmental data is necessary to precisely calculate the benefits. Of relevance here is the introduction of the new ISO 14001 standard (expected in 2015), which will significantly increase the requirements, particularly around reporting and robustness of data.

Examples of the environmental benefits achieved are outlined in **Table 57**:

Table 57: Examples of environmental benefits achieved in the supply chain

Environmental targets	Example achievement
Reducing waste and increasing recycling	A long-run partnership between Renault and their first tier suppliers has been established to ensure the economic viability of ELV and components recycling (de Medina et al, 2007). Recycled (secondary) materials are selected as a priority during vehicle design, including plastics and metals. In addition, the Renault-Nissan ECO_2 range of vehicles must contain over 7% of plastic obtained from recycling channels (Renault Nissan, 2011).

Environmental targets	Example achievement
Reducing energy consumption	Toyota has shared their energy treasure hunt process with 180 Tier-one suppliers since 2008. The process has helped to identify annual energy savings of over 43.5 million kilowatt-hours – equivalent to 15,200 tonnes of CO_2 per year (Toyota, 2013). Fiat (now FCA) estimate that their suppliers have reduced their CO_2-equivalent emissions by around 39 million tonnes in 2012, saving around €325 million (Fiat – personal comm., 2014).
Increasing the use of sustainable materials	In collaboration with their supplier partner Recycled Polymeric Materials (RPM), Ford launched a range of seals and gaskets that incorporate both 17% bio-renewable soybean oils and 25% post-consumer, recycled tyres. This material is currently used in 11 vehicle lines. In total, the seals and gaskets have removed more than 1,675 tonnes of weight from the vehicles. The use of post-consumer tyres in these gaskets and seals reportedly diverts 250,000 used tyres from landfills (Ford, 2012).

As suggested by the range of examples detailed above, there are many different environmental pressures within the supply chain. It is important to note that these may vary depending on the supplier, product/service or geographical location. Some aspects may require particular attention, support or monitoring – for example, biodiversity impacts are typically more challenging to measure and verify.

It is likely that there is still significant scope to improve environmental performance of suppliers, particularly those located in geographic regions that have less stringent environmental regulations. On the other hand, encouraging uptake and compliance in these regions is typically more challenging (Hamner, 2006). Additional environmental benefits may be achieved beyond those that are explicitly required or encouraged. Several buyers recognise innovative suppliers through industry awards and learning platforms to facilitate sharing of best practices. For example, Toyota's Green Supplier Guidelines "emphasise that Toyota expects its suppliers to be in compliance with applicable laws, regulations and social norms. Suppliers are also asked to go beyond legal and social requirements and to undertake activities that support Toyota's environmental goals" (Zafarzadeh et al, 2012).

Appropriate environmental performance indicators

General environmental indicators will be used to monitor the effectiveness of the scheme in terms of the general take-up among suppliers, for instance:

- Percentage of direct (Tier 1) suppliers (by number or by purchasing budget/value) that comply with required standards according to internal or external audits;
- Self-assessment questionnaires are sent to direct high risk suppliers (Y/N);
- Direct supplier development and training is undertaken (Y/N)

Specific performance improvements achieved in the supply chain will be defined according to the environmental objectives of the scheme (e.g. emissions/waste per unit of product sourced).

Cross-media effects

It is likely that a strong focus on only a limited number of environmental aspects will lead to trade-offs in other areas. Therefore, best practice supply chain management systems incorporate a broad range of environmental issues considered on a life cycle basis to mitigate against this risk.

For example, some manufacturers have started to encourage purchasing from more local suppliers in order to avoid long-distance transport and the associated environmental impacts, as well as to support the local economy. However, such decisions will be considered from a life cycle perspective (see *Section3.6.3 Design for sustainability using Life Cycle Assessment (LCA)*), since local production is not necessarily the most environmentally efficient option.

Operational data

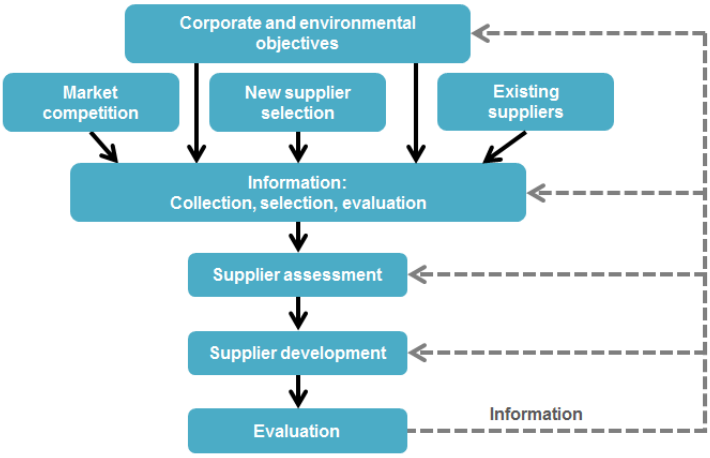
Figure 32 shows a framework for purchasers to implement environmental quality standards into supply chain management.

- The first step is to **develop environmental responsibility requirements** for suppliers and accompanying guidelines. These are typically based on corporate and environmental objectives, and may draw from internationally recognised initiatives such as ISO 14001 and the Global Reporting Initiative. The requirements may be introduced to the suppliers over time. For example, suppliers may initially be asked to comply on a voluntary basis, or the requirements may be introduced for contracts with new suppliers only. Eventually, the aim is for all suppliers to comply with the standards on a mandatory basis by incorporating them into contractual documents and purchasing decisions.
- **Supplier assessment** involves the measurement of the environmental practices of the supplier, such as ISO 14001 certification, involvement in pollution-prevention and waste-reduction programmes and meeting of environmental performance targets. As a first check, supplier self-assessment questionnaires are appropriate. An industry-developed questionnaire, covering environmental issues as well as wider societal aspects, has been developed by the European Automotive Group on Supply Chain Sustainability – available for download online[54] (CSR Europe, 2014).

  More detailed checks are recommended for high risk and significant suppliers. For instance, Renault carries out an additional level of checks for suppliers which are considered at risk or in high-risk countries. This takes the form of on-site audit with face-to-face interviews involving also a third party such as an environmental verifier.
- **Supplier development strategies** such as training are provided on an ongoing basis. Where suppliers do not satisfy the requirements, additional supplier development activities may be needed. Supplier performance problems can be technical or managerial, and suppliers will be invited to participate in the analysis of the problems so that a development plan can be implemented.
- The **evaluation** step is used to measure the results of the programme and to ensure continuous improvement.

[54] http://www.csreurope.org/sites/default/files/CSR%20SAQ%20automotive%20sector.pdf

Figure 32: Framework for implementing, selecting and developing environmental requirements into the supply chain



Source: Adapted from (Stroufe, 2006)

In general, it is recognised that developing a closer relationship with suppliers (e.g. through supplier development activities) is beneficial both for environmental outcomes of projects and as a facilitator for environmental objectives (Zafarzadeh et al, 2012). For the automotive industry in particular, this aspect is highly important – whereas many other industries can quickly improve supply chain sustainability by switching suppliers, many key components and materials used in automotive manufacturing are sourced from suppliers with whom long-term arrangements are set up, or from highly specialised organisations. An example of close cooperation between suppliers and manufacturers to achieve an environmental goal is outlined in **Table 58**.

Table 58: Case study: Sustainable Management of Supply Chain

The BMW Group aims to significantly increase transparency and resource efficiency in the supply chain by 2020. Examples of activities according to it are: • a comprehensive risk management system of its suppliers has been put in place to ensure that BMW sustainability standards are fulfilled at the production facilities of its direct suppliers. • Around 1,900 supplier locations were assessed for the first time based on an industry-specific sustainability questionnaire. Assessments were carried out at all nominated supplier locations as well as at potential and already active facilities. • Supplier locations that do not comply with the BMW Group's minimum requirements (e.g. in accordance with UN Global Compact criteria) must agree to develop and carry out a corrective action plan. In 2015, BMW's system logged corrective action plans with target deadlines for around 400 supplier locations. • Suppliers who joined the Supply Chain Programme of the CDP in 2015 reported an overall reduction of 35 million tonnes in CO_2 emissions (2014: 21 million t).

Source: (BMW Group, 2015)

In terms of enforcement, processes must be put in place to deal with Tier 1 suppliers that have violated the applicable sustainability criteria or are suspected of doing so. For example, Daimler requests the supplier to respond and to describe any measures that have been taken to remedy the situation (Daimler, 2012). In extreme cases, the partnership is terminated. Similar procedures have also been adopted by other OEMs such as Ford (Ford, 2012) and Renault (Renault, 2012).

Managing the supply chain towards greater sustainability can in practice be supported by existing tools already in use through the automotive supply chain. For instance, regarding materials data and substances monitoring, this includes the IMDS already mentioned, which also refers to substance lists such as the Global automotive declarable substance list (GADSL). This in turn will support greater transparency and wider diffusion of recognised tools in the wider supply chain.

Applicability

Many OEMs require all of their Tier 1 suppliers to agree to the same general environmental code of conduct that is integrated into purchasing agreements. More stringent standards generally apply to suppliers depending on their share of total purchasing budget and/or the specific types of products or services they supply (e.g. different requirements for component suppliers, raw materials, equipment, facility services and logistics.

Initially it may be beneficial to concentrate on Tier 1 suppliers that represent the largest share of total purchasing budget or those with high environmental impacts. Auditing of Tier 1 suppliers requires a significant effort that appears feasible only for larger organisations that already practice close inspection of supplier operations (Stroufe, 2006). In the longer term the requirements can be rolled out to more suppliers.

The effectiveness of such schemes tends to be enhanced in cases where the buyer has significant market power and/or close relationships with the suppliers in question (Stroufe, 2006).

Regarding the applicability of this best practice to Tier 1 supplier themselves rather than OEMs, these will take into account the leverage that the organisation is able to use in order to cascade up requirements to their own suppliers, in view of their own size / purchasing capability and relative weight in their own suppliers' portfolio.

Economics

Auditing and enforcing new environmental requirements, as well as carrying out supplier development activities is likely to incur costs – particularly since OEMs typically have thousands of individual suppliers. In the competitive automotive industry, the economic implications both to buyers (manufacturers) as well as their suppliers are relevant. **Table 59** gives an indication of costs to buyers and suppliers from activities related to environmental management in the supply chain.

Table 59: High level overview of costs to buyers and suppliers arising from environmental management in the supply chain

	Cost to buyers	Cost to suppliers
Requiring suppliers to have an environmental management system (EMS)	The cost to buyers of implementing environmental requirements is thought to be low, as they can introduce this requirement to suppliers based on existing accepted standards such as ISO 14001 or EMAS (Hamner, 2006)	The cost to suppliers varies depending on the size of the organisation and the standards of management already in place. In general, the cost is higher if they have to develop an environmental management system where they do not already have one (Stroufe, 2006) – for example, first year certification costs for EMAS range from €35,800 to €66,800 for manufacturing firms (Milieu et al, 2009).
Auditing supplier compliance	Costs for external audits depend on the size and complexity of the organisation – an expert estimates this to be around five to seven days for a senior auditor at consultancy rates of up to €1,150 (Drury – personal comm., 2014). External audits can combine wider aspects (health, safety, quality etc.) in order to reduce the overhead costs.	To ensure that they pass the audit, continued effort is required from suppliers to comply with the standards. For example, estimated annual costs for EMAS compliance range from €16,900 to €34,200 annually (although this cost may be offset by energy savings) (Milieu et al, 2009).
Supplier development	Costs to provide training to automotive suppliers can vary depending on the ambition of the scheme; for the best results it is important to embed the training in the day-to-day practices of the organisation, since one of the key challenges to improving environmental performance is staff engagement (Drury – personal comm., 2014)	Typically, supplier training is paid for by the buyer, but firms may also choose to invest in their own training and development.

Notes: actual costs will vary significantly depending on the scheme and the organisations involved.

These costs can be limited by:

- Focussing on high impact and high risk areas of the supply chain first;
- Conducting some audits using internal experts rather than third-party suppliers;
- Rotating audits so that suppliers are audited on a multi-year basis (e.g. every three years).

Driving force for implementation

Environmental practices are increasingly important throughout the supply chain due to the need to comply with regulatory pressures, economic advantages of reducing waste and its associated costs, and also in response to customer expectations with respect to reducing emissions and increasing recycling (Stroufe, 2006). Sustainability and social responsibility are increasingly recognised as ways to strengthen brand names or differentiate products (Zafarzadeh et al, 2012).

Reference organisations

Suppliers are often encouraged to adopt certified environmental management systems, but only a few manufacturers formally require suppliers to have them, including Ford (ISO 14001), Daimler and Toyota (ISO 14001 or EMAS).

The extent of monitoring and enforcement activities also varies considerably. Frontrunner organisations verify compliance for a major proportion of their suppliers, compared to many other manufacturers that do not conduct formal assessments. For example:

- Third-party assessments of management of supplier groups were conducted on 387 of Renault's suppliers in 2011, who represent an amount equivalent to 68% of Renault revenue (Renault, 2012);
- Volkswagen have verified (using internal staff) environmental certification for 44% of their suppliers (based on volume) and a further 40% have completed self-assessments – bringing the total to 84% (Volkswagen, 2013).

In terms of training, several manufacturers have partnered with the Automotive Industry Action Group (AIAG) to deliver training collaboratively with other OEMs, while others deliver training online. For example, Volkswagen provides online training in eight languages to its suppliers, and suppliers must complete a self-check before the module is "passed". At the end of 2013, 8,652 Tier-one suppliers had successfully completed the E-learning module, equating to 50% of procurement volume (Volkswagen, 2013).

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3.6.2 Collaborate with suppliers and customers to reduce packaging

SUMMARY OVERVIEW:

BEMP is to reduce and reuse packaging used for materials and components supply.

This best practice is based on the following principles:

1. reduce unnecessary packaging while ensuring adequate functionality (parts integrity, ease of access);
2. investigate alternative materials for packaging which are either less resource intensive, or easier to reuse / recycle;
3. develop reverse logistics for returning empty packaging to suppliers / recuperate from customers in a closed loop ;
4. investigate alternative uses for disposable packaging to divert from disposal (higher up in the "waste hierarchy"[55]).

Relevant life cycle stages				
Management	**Design**	**Supply chain**	**Manufacturing**	**End-of-life**

Main environmental benefits				
Energy consumption	**Resource use and waste**	Water use & consumption	Emissions to air, water, soil	Ecosystems & biodiversity

Environmental indicators

- Waste generation per functional unit (kg/functional unit)
- Packaging waste generation per functional unit (kg/functional unit)
- Packaging waste generation per site or maintenance group (kg/site, kg/maintenance group)

Benchmarks of excellence

N/D

Cross references	
Prerequisites	• Waste prevention and management
Related BEMPS	• Supply chain management

[55] as described in 3.3.1

Description

Automotive supply chains have become increasingly globalised, bringing together thousands of references for parts and components to the assembly lines and relying heavily on packaging to make the parts available and easily accessible for mounting at the assembly workstations.

Packaging for these parts is a B2B-only feature based on functionality (as opposed to aesthetics which is a key feature in most B2C applications). There are still ample opportunities to develop alternative solutions to one-way packaging by collaborating with suppliers on reducing the environmental impact of current solutions.

This best practice is therefore based on the following principles:

1. reduce unnecessary packaging while ensuring adequate functionality (parts integrity, ease of access)
2. investigate alternative materials for packaging which are either less resource efficient, or easier to reuse / recycle
3. develop reverse logistics for returning empty packaging to suppliers / recuperate from customers in a closed loop
4. investigate alternate uses for disposable packaging to divert from disposal (higher up in the "waste hierarchy")

These principles can be applied for all packaging in use in one site, to transport parts from one site to another, or for the supply of parts from suppliers or to customers in which case close collaboration with the supply chain is necessary.

In practice these principles can be implemented directly by the organisation, but also through outsourcing the management of packaging or in collaboration with external companies to improve the management of packaging logistics.

Meanwhile, as illustrated below, management or technical solutions to deliver the approach can vary, e.g. management systems of supplier collaboration and/or technical solutions based on a modular standard to improve reuse / recyclability.

Achieved environmental benefits

The benefits achieved will be centred on waste reduction and reduction of resource use. The indirect benefits also involve a reduction in energy consumption, carbon footprint and emissions.

Appropriate environmental performance indicators

The success of this BEMP can be monitored through waste indicators, typically:

- kg waste per functional unit

Closer monitoring can be put in place through dedicated monitoring of packaging waste:

- kg packaging waste per functional unit

or the monitoring of packaging waste at site or maintenance group level:

- kg packaging waste per site / maintenance group

Cross-media effects

Reverse logistics may actually involve an increase in shipments for the return of empty packaging, in case there is no opportunity to take advantage of empty return trips.

Operational data

This section highlights examples of the principles underlying the BEMP from OEMs and Tier 1 suppliers:

1. Reduce unnecessary packaging while ensuring adequate functionality

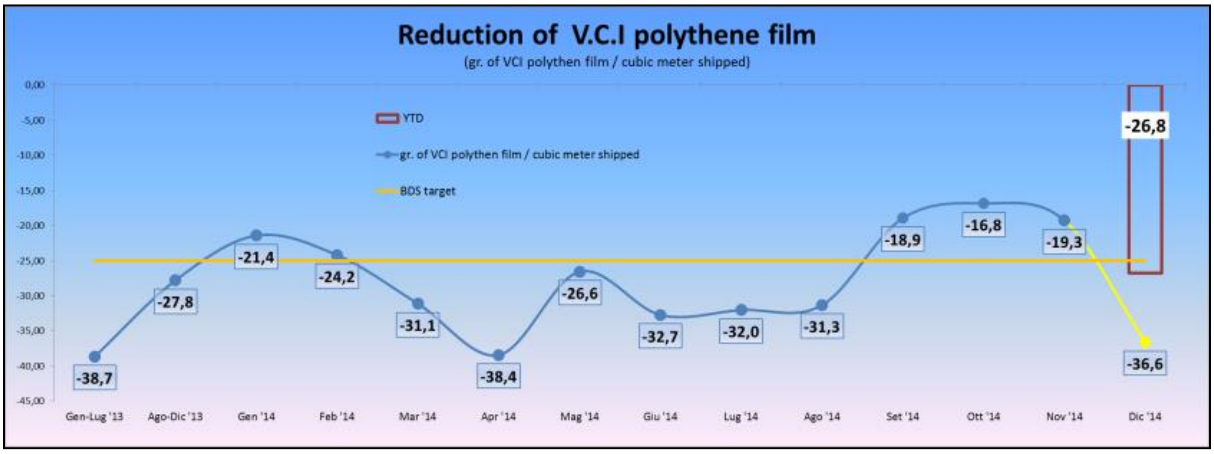
Reduction of vapour phase corrosion inhibitors (VCI) polythene film ([ACEA, 2016])

One ACEA member (ACEA 2016) searched for ways to reduce VCI polythene film utilisation, used to cover sensitive components in transit and prior to assembly. The solution consists of using a new generation product, which is both thinner and stronger than the previous one, with double face corrosion inhibition. After several shipment tests, a new product was found with the same chemical characteristics but thinner.

This allows reducing polythene film utilisation and eliminating VCI mobile emitters.

Year/ month of implementation: January 2014.

Figure 33: Example of decreases achieved in VCI film consumption (normalised by shipped volume), 24 month period



2. Investigate alternative materials for packaging which are either less resource efficient, or easier to reuse / recycle

Replacement of metallic rigid containers with plastic heavy load foldable containers

This best practice was implemented in 2014 and is still ongoing. All Assembly lines for new projects are set to use HDR containers instead of metallic racks. These are used for packaging for internal uses.

The table below illustrates the key decision factors in adopting the new technology:

Table 60: Metallic vs plastic containers

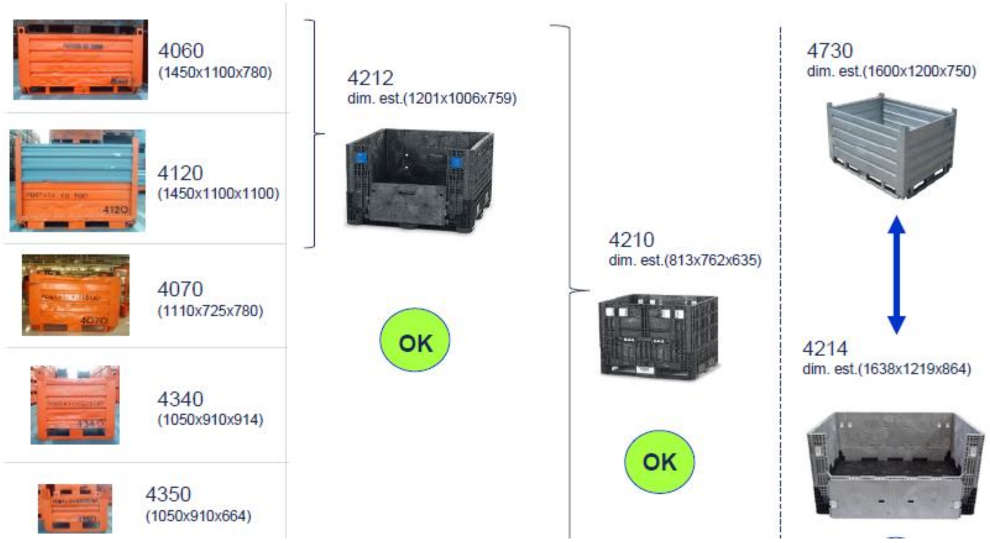
Pros	Cons
• 30% space optimisation at storage space for empty containers • 50% less weight to be carried (payload) • 30% less forklift truck utilisation (from assembly line to empty containers area to component storage) • 30% less trucks handled at docks • 100% containers have access doors on both long and short side	• Use of plastic containers instead of metal in historical manufacturing areas • Actual load capacity of metal containers is 1500kg as opposed to 900kg for plastic ones

The figure below illustrates the replacement of 7 types of metal containers by 3 types of plastic foldable containers:

Figure 34: Typology of containers used

The following figure illustrates the replacement pattern:

Figure 35: Replacement of metal container models by plastic subsitutes



<u>3. Develop reverse logistics for returning empty packaging to suppliers in a closed loop</u>

Returnable wooden crates

In an exemple from [ACEA member] (source: ACEA, 2016), wooden cages were used as a container material, with empty wooden cages scrapped at the destination plant resulting in a significant waste of wood. A project was undertaken to introduce returnable wood boxes instead of disposable ones. From May 2014 onwards, specific features were adapted to make wooden boxes returnable instead of disposable, with positive effects on cost reduction, safety improvement and environmental impacts

BEFORE **AFTER**

Figure 36: Design differences in adapting wooden crates for reuse

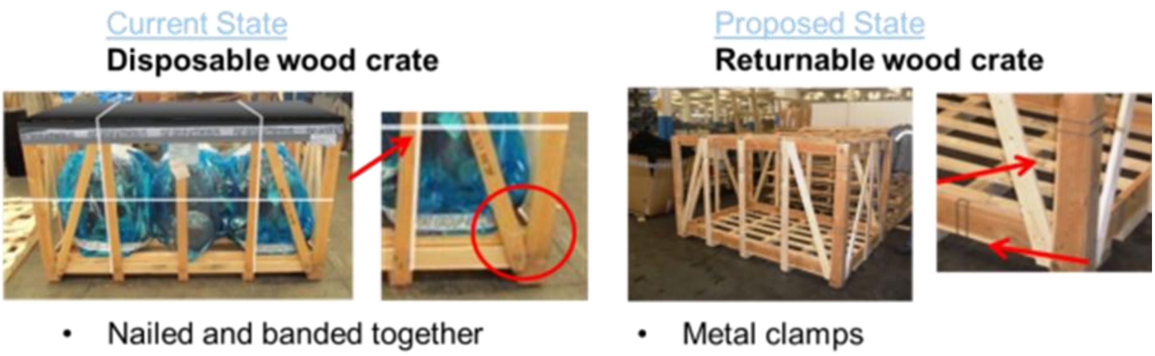
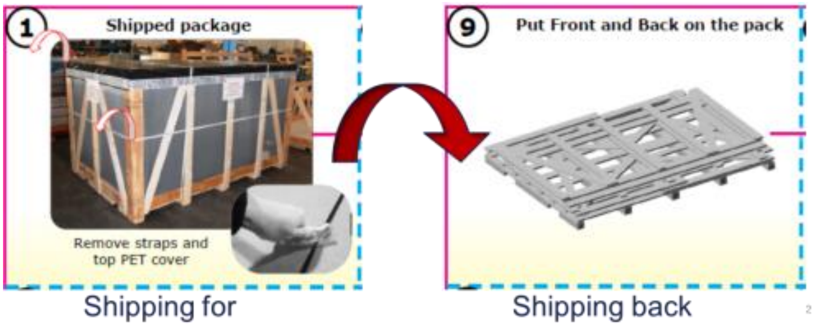


Figure 37: Preparing a used wooden crate for return logistics



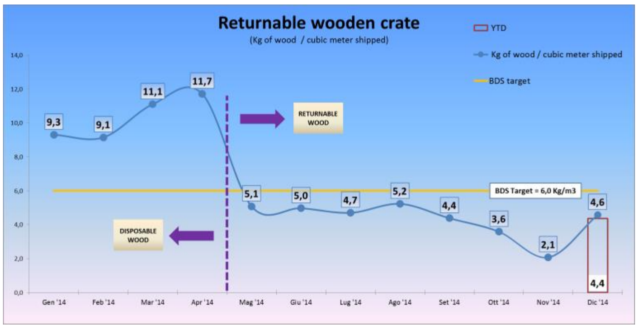
Quantified improvement:

Waste: 57% disposable packaging wood reduction vs 2013 value (from 10.1 kg/m3 to 4.4 kg/m3)

- 410 Tons of wood saved during 2014

- 130 Tons of CO_2 reduction due to wood production saving.

Figure 38: Wood packaging weight reduction achieved over 12 month period (normalised by shipped volume)



<u>4. Investigate alternate uses for disposable packaging to divert from disposal (higher up in the "waste hierarchy")</u>

DENSO Barcelona (DENSO 2016) receives certain temperature-sensitive components in refrigerated packaging. These are temperature controlled through the use of insulated boxes and thermal inertia elements (cold packs).

The cold packs were previously disposed of, and the opportunity of returning them to the supplier for reuse was investigated. However, the reverse logistics route for shipping back to Japan proved uneconomic.

DENSO investigated feasible alternative uses for the spent ice packs. They are now donated to a local charity and the packs are used for refrigeration in serving meals at local schools.

Applicability

These principles are broadly applicable to all packaging currently in use. The concrete feasibility of innovative solutions will be limited by the willingness of suppliers / customers

Economics

Developing a new technical solution might represent a small upfront investment, but with relatively rapid payback.

For the examples above, example 2 on the replacement of metallic rigid containers with plastic heavy load foldable containers, a RoI of 12% was achieved. Example 3 on returnable wooden crates achieved an RoI of 37%.

Driving force for implementation

- reduced landfilling costs
- reduced transport and logistics costs

Reference organisations

DENSO

ACEA Members, incl. FCA Group

Reference literature

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3.6.3 Design for sustainability using Life Cycle Assessment (LCA)

SUMMARY OVERVIEW:

Conducting life cycle assessment (LCA) helps to identify potential improvements and trade-offs between different environmental impacts, as well as helping to avoid shifting environmental burdens from one part of the product life cycle to another.

BEMP is to perform LCAs extensively during the design phase, to support the setting of specific goals for improvement in different environmental impacts and to ensure that these targets are met.

Best practice is to support decision making by using LCA tools in order to:

- Ensure sustainability of resources;
- Ensure minimal use of resources in production and transportation;
- Ensure minimal use of resources during the use phase;
- Ensure appropriate durability of the product and components;
- Enable disassembly, separation and purification;
- Enable comparisons among different kinds of mobility concepts.

Relevant life cycle stages				
Management	**Design**	**Supply chain**	**Manufacturing**	**End-of-life**

Main environmental benefits				
Energy consumption	**Resource use and waste**	**Water use & consumption**	**Emissions to air, water, soil**	Ecosystems & biodiversity

Environmental indicators

- Conducting LCA of the main product lines to support design and development decisions (Y/N)
- Improvements in environmental indicators (CO_2, energy consumption, pollution etc.) for new model designs in the main product lines compared to previous model designs (%)
- Conduct comparisons among different kinds of mobility concepts (Y/N)

Benchmarks of excellence

- **LCA is conducted for main product lines according to ISO 14040:2006 standards or equivalent**
- **Targets are set to ensure continuous improvements in the environmental impacts of new vehicle designs**

Cross references	
Prerequisites	**N/A**
Related BEMPS	Promoting environmental improvements along the supply chain

Description

Life cycle engineering is a framework for integrating environmental considerations into product development. While the majority of automotive manufacturers already use life cycle assessment (LCA) as a supporting tool for decision making, in practice the approach to using LCA data varies widely.

The main principles of best practice to use LCA results towards environmental sustainability are listed below (Telenko, 2008):

A. **Ensure sustainability of resources**: aims to address resource depletion by encouraging reuse of resources such as materials and components, and renewability of consumed resources such as energy. Of particular relevance to the automotive industry is the concept of using secondary material (such as recycled aluminium) , or recycled thermoplastic and a growing interest in using renewable resources to manufacture plastics. Decisions on system boundary and allocation approaches should prioritise methods that show the environmental benefit of maintaining value in materials.

B. **Ensure minimal use of resources in production and transportation:** this encourages designers to consider how to reduce material use in production and packaging. A particularly important aspect is the management of the supply chain (see separate guidance in *BEMP 3.6.1 on* Promoting environmental improvements along the supply chain*)* as well as design for optimally lightweight structures (see below). Targets are set to ensure continuous improvements in the environmental impacts of new vehicle designs compared to its previous one of the same product line;

C. **Ensure minimal use of resources during use phase:** this motivates a product design to ensure an efficient fuel consumption and to incorporate functions that guide the user to reduce environmental impacts, such as GHG emissions. While the use phase of vehicles is covered extensively under other legislation, it is nonetheless extremely important from a life cycle perspective;

D. **Ensure appropriate durability of the product and components**: appropriate durability of a product can avoid additional processing and transportation steps, as well as postponing waste, recycling and remanufacturing steps. This encompasses two main aspects – durability for long life, coupled with the ability to repair or upgrade the product to current best practices. In the automotive industry, excessively long-lived products may exclude cars from technological improvements in terms of performance, safety, emissions etc., as well as potentially having an excessive price – therefore this aspect needs to be balanced against other environmental and consumer needs (Ernst, 2013);

E. **Enable disassembly, separation and purification**: includes steps to facilitate remanufacturing, reuse, repair and upgrading by incorporating these features at the design phase (see for instance the concepts laid out in ISO TR 14062:2002 - *Environmental management -- Integrating environmental aspects into product design and development*).

Some manufacturers have also introduced concepts for evaluating the product's sustainability which go beyond environmental LCA to incorporate social and economic factors – see *the Emerging techniques* section below for more information on this aspect.

Material choice is one of the key elements in vehicle design in order to ensure that the environmental impacts along its life cycle as well as at the usage stage are minimised. However, this is a challenging task due to the complexity of the vehicle components, as well as the need to balance many factors such as performance, safety and recyclability. For example, the increasing fraction of plastics and aluminium in modern vehicles, the use of larger batteries, as well as the introduction of carbon fibre, are likely to move the environmental impacts from the use phase to manufacturing one. Yet the use of lightweight materials such as these will improve the fuel efficiency of vehicles during the use stage. These trade-offs are best managed using a life cycle approach, which will inform design management decisions in conjunction with broader inputs such as company policy and other technical choices.

Regarding the end of life of the vehicles, which still represents a small fraction of lifecycle impacts for most environmental dimensions, the current approach advocated by the automotive industry is based on "design for sustainability", which aims to encompass a holistic approach to environmental impacts. Several solutions can be implemented to deliver on this approach: some manufacturers have focussed on post-shredder technologies to achieve targets set in the ELV Directive, while others have chosen to prioritise higher levels of dismantling (de Medina et al, 2007). For the purposes of compliance with the ELV Directive, either technique is suitable. It appears that many European manufacturers prefer the post-shredder recycling option. Nevertheless, there are examples of positive results achieved through higher dismantling, particularly from Japanese manufacturers. For certain components, dismantling may be preferable to post-shredder treatment (unless the impact of long-distance transport of the recovered components outweighs the benefits of saved materials). In addition, the feasibility of actual closed-loop recycling[56] processes is only occasional at end of life, where the materials (on average over 15 years) may no longer correspond to market demand to substitute virgin materials.

Elements of best practice in the implementation of Life Cycle Assessments include the following:

- Use of internationally accepted standards;
- Integrating LCA into decisions at the earliest stages of design;
- Establishing cross-discipline teams;
- Establishing environmental improvement targets;
- Data for the complete value chain, including suppliers;
- Clear and transparent communication to the public, including underlying data and assumptions.

Achieved environmental benefits

Life-cycle assessments can prove very valuable tools to enable comparisons between the impacts of different lifecycle stages of products across a range of environmental aspects. However, it is essential to ensure the relevance of the LCA results by examining the sensitivity to various parameters which are critical when performing the LCA. In particular, LCA results can vary significantly according to the system assumptions (system boundaries), the data sources used (generic database or specific data reliably sourced from actors in the supply chain) and the methodology used (metrics, weighing factors, allocation approaches…).

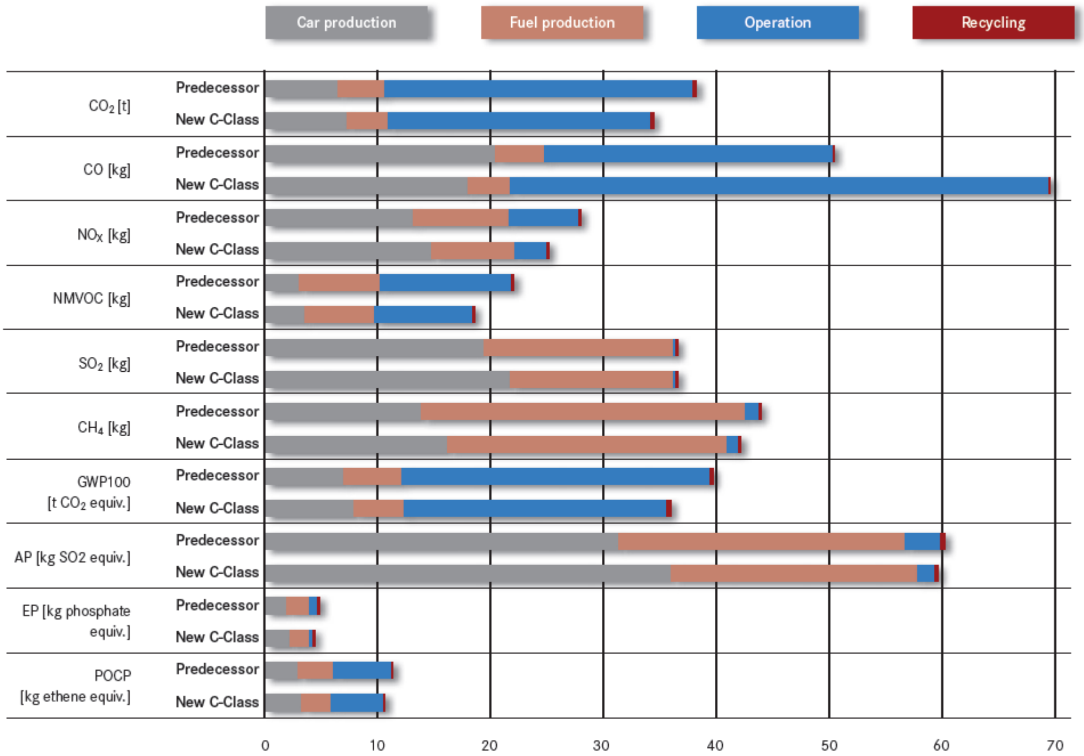
A major goal of using LCA tools is to avoid shifting environmental burdens from one part of the product life cycle to another. The analysis can be used for setting specific goals for the levels of different environmental impacts and ensure that company targets on the environmental impacts of new models of the same product

[56] closed-loop recycling is meant as a recycling of the material to substitute a virgin material of the same grade, as opposed to downcycling (recycling into lower specification materials). It does not necessarily imply cycling back to the manufacturer or even within the automotive industry.

line are met. Although it cannot be done for all new models, it is usually done for the leading model of each product line.

As an example, **Figure 39** shows environmental improvements for new C-Class Mercedes model compared to its predecessor (Mercedes-Benz, 2015). Reduction of environmental emissions and impacts across a range of categories were achieved, mainly due to increased fuel efficiency of the models (N.B. the use phase itself, while out of scope of this best practice document, is taken into account in the scope of LCA analyses themselves).

Figure 39: Environmental improvements achieved for the new C-Class Mercedes-Benz compared to its predecessor.



Notes: Assumed lifetime mileage of 200,000 kilometres.
Source: (Mercedes-Benz, 2015)

The key aim is to optimise environmental impact over the life cycle, paying attention to trade-offs between different life cycle stages. For example, reducing vehicle weight through the use of materials such as aluminium and carbon fibre will reduce energy consumption and carbon emissions during the use phase of the vehicle. However, these materials tend to increase energy consumption in the production phase. The use of LCA can help identify these trade-offs so that options with the lowest environmental impacts over the life cycle can be selected and the environmental credentials can be demonstrated to internal and external stakeholders.

Life cycle assessment results can vary considerably among studies due to differences in vehicle composition and processes, and also due to variations in the types of energy used by the plant (including the local electricity generation mix). Emission levels of sulphur dioxide and particles depend on the composition of fuels used in hot water boilers and burners, while emissions of Nox, carbon monoxide and hydrocarbons depend on the technical aspects of the combustion process (Volvo, 2013).

When looking at *single* environmental categories, it is relatively easy to identify the best option by minimising the impact across the whole life cycle. However, when considering impacts across *several* environmental categories, it is more challenging to compare decisions, especially where improvements in one category lead to trade-offs in another – see *section below* on *Cross-media effects* for more details on this issue.

Environmental indicators

At the implementation level, it is best practice to integrate LCA into all new design decisions (ISO 14062:2002). For example, Daimler and BMW Group indicate that the environmental aspects of design are considered long before the first prototype is developed in CAD software (Chanaron, 2007; Mercedes-Benz, 2015: BMW Group, 2015). Thus, LCA will be used to identify major tendencies rather than pinpoint details based on less significant data.

General indicators which can be defined for this BEMP include:

- Conducting LCA of the main product lines to support design and development decisions (% designs).
- Improvements in environmental indicators (CO_2, energy consumption, pollution etc) for new model designs in the main product lines compared to previous model designs (% improvement).
- Conduct comparisons among different kinds of mobility concepts. (cf. Renault, 2011).

Typically, the input and output considered in the life cycle inventory (ISO 14044:2006) include energy and raw material consumption; emissions to air, water and soil; and solid wastes (Chanaron, 2007). Common indicators for the impact assessment include:

- Global warming potential (tCO_2-eq).
- Acidification potential (kg SO_2-eq).
- Eutrophication potential (kg PO_4-eq).
- Photochemical pollution (kg C_2H_4).
- Water consumption/use (m^3).
- Primary energy demand (GJ).
- Material use rate (kg).
- Restricted material usage (kg).

These are measured for the chosen functional unit, such as a vehicle or component over its lifetime.

Cross-media effects

Trade-offs between different *life cycle stages* and *environmental impact categories* are often apparent when using LCA. For example, the LCA of the 2009 Mercedes S 400 Hybrid compared to the S 350 shows that the Hybrid variant consumes 45% more copper ore and 55% more rare earth materials, both connected to the manufacture of the hybrid components which in turn save fuel and reduce CO_2 emissions over the use phase of the vehicle (Daimler 2009).

Ideally, improvements in all areas can be achieved but in practice this is not always possible. Quantitative approaches attempt to rate different impact categories against each other, for example using a **single** overall metric of environmental impact. However, this approach is **not advised** in ISO 14044:2006 as it may compromise the objectivity of the assessment.

In LCA guiding principles it is often recommended to increase the lifetime of the product, and in many cases this is indeed a good strategy. However, for the automotive industry in particular, where the use phase is still the dominant aspect on most environmental impact dimensions, lifetime extension may sometimes increase environmental impacts – different products require different approaches. For instance, engines have continued to improve as emissions standards become more stringent. On the other hand, durable car bodies may provide a stable platform for a longer time, reducing the impacts associated with investments in tooling, pressing, etc. (Warren & Rhodes, 2006). Therefore, other methodologies for measuring environmental impact might provide a useful complement of information – for instance, looking at impact per km travelled.

The selection of materials has an impact at every stage of the life cycle of a vehicle and cannot be considered only in terms e.g. of the end-of-life of a vehicle. For example, if a recycled foam used in seat padding is heavier than that of virgin material, this could have an impact throughout the in-use phase of the vehicle. Focussing only on a narrow approach such as "Design for Recycling" would disregard other important factors, such as energy-efficiency considerations. Therefore, material selection factors should be considered as a subset of overall sustainable design.

Recycled material quality is highly influenced by the contamination rate. If materials that are not thermodynamically compatible cannot be separated through dismantling or in the shredder, they will be lost into one of the recyclate streams.

In all cases, the environmental benefits of dismantling will be compared to alternative end-of-life options such as post-shredder recovery.

Operational data

Examples of firms using best practice methods for conducting LCAs are outlined in **Table 61**.

Table 61: Examples of best practice implementation for each step

Step	Example
Use of internationally accepted standards	International standards for conducting LCA have been defined in ISO 14040 and 14044, which are widely accepted and generally applicable (Chanaron, 2007). BMW use the life cycle engineering approaches in accordance with ISO 14040-44 as well as the informative Technical Report ISO TR 14062 (BMW Group, 2015a,b)
Integrating LCA into decisions at the earliest stages of design	Daimler indicates that the environmental aspects of design are considered long before the first prototype is developed in CAD software (Chanaron, 2007) BMW take into account the environmental effects throughout the vehicle life cycle, from the selection of materials, product, use and recycling. The sustainability targets have the same significance as other criteria in the development of the vehicle, such as weight and cost (BMW, 2013) Toyota's Eco-vehicle assessment system is used to conduct LCA in the design stage. The software is linked to a database that holds information regarding all of Toyota's parts/materials. This allows the LCA impacts to be calculated automatically, when virtually adjusting the design (Toyota – personal comm., 2014).
Establishing cross-discipline teams	At Daimler, cross-discipline teams include experts in life cycle assessment, disassembly and recycling planning, materials and process engineering, design and production (Mercedes-Benz, 2015).
Establishing environmental improvement targets	At Volkswagen, each new model is required to consume less fuel and generate lower emissions than the current model. Its production must consume fewer raw materials and its components must be at least 95 percent recoverable (VW, 2010).
Data for the complete value chain, including suppliers	To gather data for the value chain, suppliers can be required to fill out a standardised template on materials, energy, emissions and transport distances. The supplier data collection approach for the association of German OEMs (VDA) aims for a minimum of 80% data completeness in 80% of the time provided within days or weeks (rather than months) (VDA, 2003). LCA models can also be drawn up on the basis of parts lists or material data sheets.
Clear and transparent communication to the public, including underlying data and assumptions	While some manufacturers feel that LCA data is commercially sensitive and are reluctant to publish their results, others make whole vehicle LCA reports publically accessible. For example, Volkswagen and Mercedes-Benz publish their LCA reports dealing with all stages of the life cycle, including assessing the environmental impacts in the supply chain (Mercedes-Benz, 2015; Chanaron, 2007).

While reliable databases for the automotive sector are increasingly becoming available, one of the key challenges may be to gather adequate data. Particular difficulties include:

— Location-specific data will be used where possible to ensure the data are representative, although it is not always available. In these cases, national data could be substituted. For example, Volkswagen uses data for Europe where possible as this is considered the appropriate geographical area, rather than German data. Assumptions on upstream supply chains for energy sources and materials are kept constant so that differences between models can be attributed more clearly to design/production decisions rather than fluctuations in raw material and energy supply chains (VW, 2014);

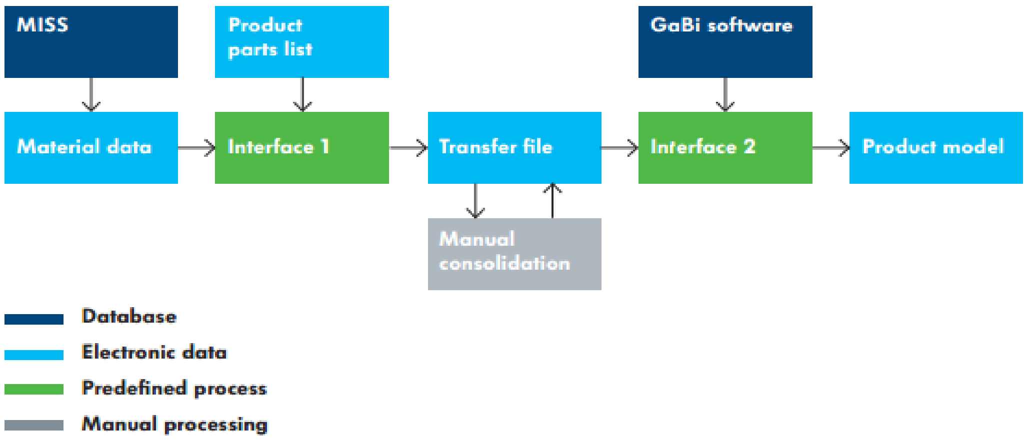
— Data on environmental impacts tend to be limited in the case of new supplier parts where the production process are unfamiliar, or when assessing technologies which are still in the early stages of development (VW, 2008). In such cases, an LCA with primary data from the supplier may be used to gain a high level insight into likely impacts until better data become available. See the example from BMW on LCA of carbon-fibre-reinforced plastic (CFRP) (BMW Group, 2015a).

— Calculations can be very time and resource-intensive. Where resources are constrained, greater effort will be more usefully directed towards the aspects that dominate the overall environmental impacts ("hot spots");

— Many materials used in the automotive industry are highly innovative and full data may not be available. The collection of primary data with the cooperation of the supply chain is highly recommended. On this note, a lot of efforts are currently made by the LCA database suppliers to update their data with an LCA of new materials and components.

To simplify the approach while still gaining similar insights, modelling processes can be used to fill data gaps. For example at VW as well as at Daimler and BMW Group in cooperation with LCA software supplier carried out an interface to model the energy-consuming processes and materials based by using LCA software (GaBi) – see Figure 40. The first interface assigns information from parts lists to relevant component information (part designations and quantities) to the relevant component information (materials and weights) from the Material Information System (MISS) and converts it into a transfer file that is then manually checked for quality. The second interface links to related data sets in the GaBi LCA software. This greatly reduces the time required to generate LCAs.

Figure 40: LCA modelling process used at VW



Source: (VW, 2009)

Material inputs, processing procedures and selection of data in GaBi are standardised as far as possible. **"Product data"** describes the product itself, including (VW, 2009):

- Information on parts, quantities, weights and materials;
- Information on fuel consumption and emissions during utilisation;
- Information on recycling volumes and processes.

"Process data" includes information on manufacturing and processing steps such as electricity provision, the production of materials and semi-finished goods, fabrication and the production of fuel and consumables. This information is either obtained from commercial databases or compiled by the automotive manufacturer as required.

With respect to materials, one option is using secondary materials that are coming from a recycling process.

Applicability

In principle, there are no limits to the applicability of LCA to inform design decisions at the level of the vehicle, as well as individual parts and materials. However, most SMEs lack the expertise and resources to address the requests for life cycle environmental performance information, and additional support may be needed (European Commission, 2013).

There are also limits to current LCA methodologies, as some impact categories are not well accounted for in LCA methodologies – for example, biodiversity loss and indirect effects due to displacement of agricultural production. Nevertheless, the transport sector does not have as large an influence on these last impact categories compared with those of Global Warming Potential or Acidification. For this reason few case studies are available on the Biodiversity aspect in the transport sector.

LCA can be an ineffective tool for comparison of vehicles inter-OEM, as the boundaries, parameters and data sets used can differ considerably, even when following ISO standard guidelines (Toyota – personal comm., 2014). Indeed it was not a goal of the tool when initially developed. However –as is the case for environmental management systems such as EMAS – LCA is very useful to measure the improvement that a company can achieve on the environmental performances of its products, typically the comparison of a vehicle with its own predecessor of the same product line (Mercedes-Benz, 2015).

Economics

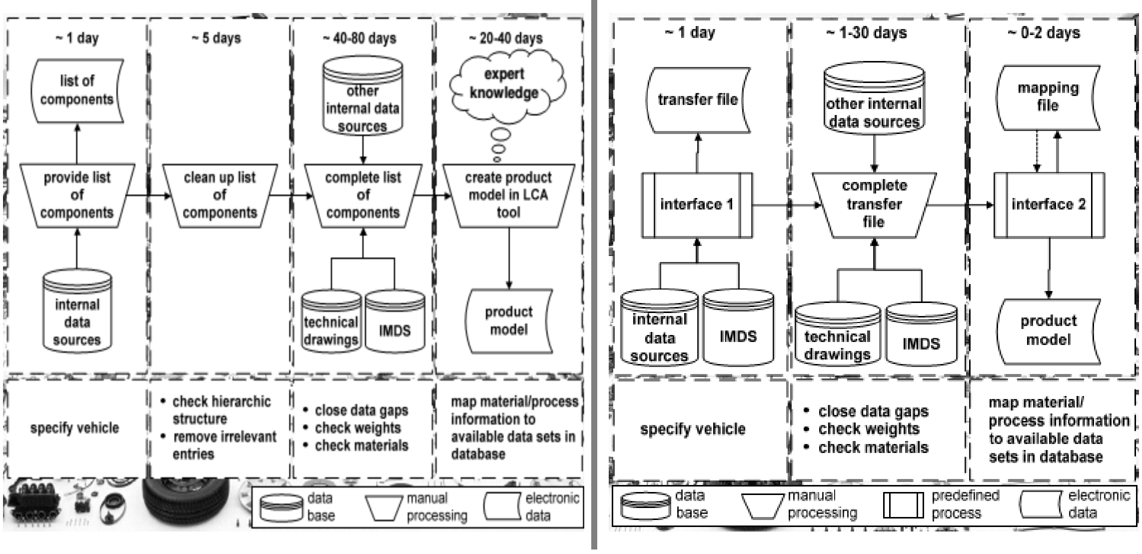
A detailed life cycle inventory analysis is a complex and data-intensive process due to the large number of parts and complex supply chains – a typical inventory includes more than 40,000 unit processes and more than 2,000 inputs and outputs (Finkbeiner, 2013). When first implemented, conducting LCAs to a high standard could require significant investment in the form of hiring and training staff, obtaining specialist software, working with suppliers, building a database, etc. For example, Fiat (now FCA Group) estimated that a full LCA on a vehicle can take between four and six months to complete (Fiat – personal comm., 2014); however, the time taken can be significantly reduced by using streamlined approaches in order to enable resources to be concentrated on the most important impacts – for instance, VW has reportedly reduced the time taken to less than a month (VW, 2008).

Procedures for a critical review of comparative LCAs are laid down in the ISO 14040 standard. This involves commissioning external experts for verification.

Initially, conducting a full LCA can be very time consuming, but significant improvements can be expected as manufacturers fill their databases and familiarise themselves with the procedures required. As shown by Figure 41, experience and software improvements have permitted OEMs to reduce the time for an LCA, e.g. Volkswagen reduced the time to carry out an LCA of its vehicle from around 65-125 days in the year 2000 to around 2-35 days in 2009. This was achieved by focussing on increasing automation of the manual processing steps through developing internal transfer files that contained pre-populated basic data on components. This also improved the consistency of LCA processes carried out within the company.

Figure 41: Procedure and time for conducting an LCA at Volkswagen in 2000 versus 2009

Time taken in 2000 (65-125 days) | ***Time taken in 2009 (2-35 days)***



Source: (Krinke, 2009)

Driving force for implementation

Since LCA is used by the OEMs both at the vehicle design stage (to set targets for environmental impacts and to identify ways of reducing the vehicle's environmental burden) and for communicating a vehicle's environmental credentials, it is likely that efforts to maintain a positive corporate image are driving forces for using LCA. To a lesser extent (since LCA is primarily used in corporate communication than product communication) it could also be used for advertising the better environmental performance of new models.

Increasing concern over the scarcity of raw materials is another incentive to focus on material selection within vehicles, in order to ensure that more secondary materials are used in the manufacturing phase.. Closing-the-loop, on material recovery, has been an important incentive for Toyota's development of TSOP (Toyota – personal comm., 2014).

Reference organisations

Organisations that provide a large amount of LCA information for their vehicle models include:

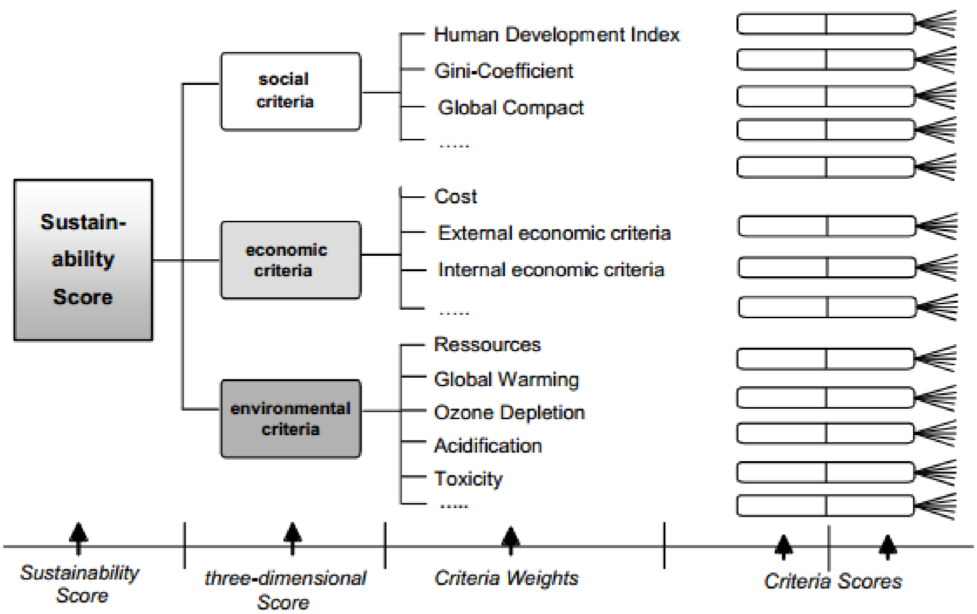
- Volkswagen – see for example (VW, 2008);
- Daimler – see for example (Mercedes-Benz, 2009, 2015)
- BMW Group - see for example (BMW Group, 2015b).
- FCA Group – see for example (FCA, 2015)
- Renault – see for example (Renault, 2011)

Emerging techniques

Recent developments in the field have shifted from a focus on pure LCA, which represents the state-of-the-art with respect to environmental impacts, towards including the economic and social aspects of sustainability. The economic dimension includes calculations of cost and performance, while the social aspects are mainly qualitative indicators that are in their infancy and hence selection of appropriate indicators is a challenge (Finkbeiner, 2010). The consideration of larger dimensions beyond LCA may lead to take into account broader trade-offs, e.g. for biomaterials.

An example of methodology for these dimensions is the Roundtable for Product Social Metrics[57], it is the first initiative that saw a group of companies such as BMW Group, BASF and Goodyear, led by PRé Sustainability, working together to develop an harmonized approach to assess social impact along a product life cycle. The Project is now at the third phase and Version 3 of the Handbook for Product Social Impact Assessment (PSIA) was published recently (Fontes et al. 2015). In the handbook, qualitative and quantitative methods to assess social impact along the product life cycle is described and on the website of the project further template and explanation are available to support new users of PSIA.

Figure 42: Life cycle Sustainability Assessment framework, addressing social, economic and environmental aspects



Source: (Finkbeiner et al., 2010)

[57] http://product-social-impact-assessment.com/roundtable-for-product-social-metrics/

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3.7 REMANUFACTURING

3.7.1 General best practices for remanufacturing components

SUMMARY OVERVIEW:				
Achieving greater levels of remanufacturing has a significant impact on the conservation of materials and energy savings. **BEMP is to increase the scale of remanufacturing activities, establishing procedures to ensure the high quality of remanufactured parts while reducing environmental impacts and scaling up activities to cover more components.**				
Relevant life cycle stages				
Management	**Design**	**Supply chain**	Manufacturing	**End-of-life**
Main environmental benefits				
Energy consumption	**Resource use and waste**	Water use & consumption	Emissions to air, water, soil	Ecosystems & biodiversity
Environmental indicators				
• Level of remanufacturing (weight per component (%)) • Overall remanufacturing levels (% of recovered components).				
Benchmarks of excellence				
N/D				
Cross references				
Prerequisites	• Design for sustainability using Life Cycle Assessment			
Related BEMPs	• Best practice ELV treatment for specific components			

Description

Components that are often economical to remanufacture include many mechanical and hydraulic parts, as well as a growing number of electrical/electronic parts. Examples include (Optimat, 2013):

- Air Conditioning Components
- Air brakes
- Alternators
- Brake Callipers
- Carburettors
- Clutches
- Cylinder heads
- Driveshafts
- Electrical units, Instrument Clusters & Controllers
- Engines and engine components
- Fan motors
- Heater blowers
- Front axles
- Fuel pumps
- Fuel injectors and ignition
- Generators
- Gearboxes
- Master cylinders
- Pumps (hydraulic, oil, water
- Rack and pinions
- Radiators
- Starters, alternators
- Steering units (manual, power)
- Turbochargers
- Torque convertors
- Transmissions

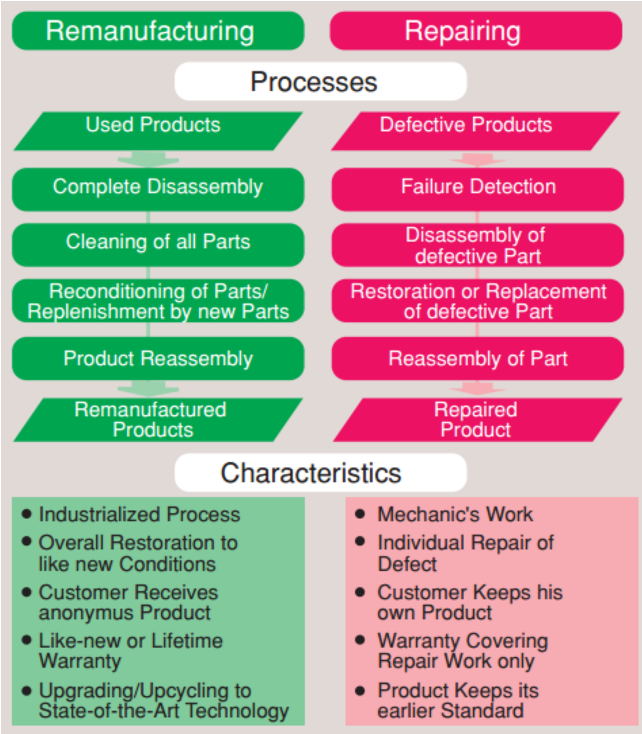
Remanufacturing involves dismantling and repairing used vehicle parts to restore their performance to a level comparable to new parts. Typically it involves:

1. Completely dismantling the used part;
2. Cleaning all components;
3. Checking these components, repairing or replacing defective components, replacing missing components;
4. Reassembling the part, readjusting as necessary and submitting it to a final test.

This process is outlined in **Figure 43** below, which also highlights the distinction between remanufacturing and recycling (see the introduction to Section 4 for definitions).

Figure 43: Remanufacturing process for automotive components compared to repair process

Source (Steinhilper, 2010)



Step 1: Completely dismantling the used part

Step 2: Cleaning all components

The cleaning step involves de-greasing, de-oiling, de-rusting and freeing the parts from old paint. Methods include washing in cleaning petrol, hot water jet or steam cleaning, chemical detergent spraying or chemical purifying baths, ultrasonic cleaning chambers, sand blasting, steel brushing, baking ovens and many more. This step can be made more environmentally friendly by moving to newer and more efficient cleaning technologies that do not generate hazardous wastes (Steinhilper, 2010). Best practice techniques:

- Do not involve the use of chemical detergents, replacing these instead with less harmful products such as water soluble detergent (Steinhilper, 2010);
- Use mechanical cleaning where possible, such as by glass bead or steel shot blasting (Steinhilper, 2010). These processes also help to harden the surface, thereby improving resistance against abrasion of the remanufactured product's parts (but may change the tolerances for bearings etc.).

Step 3: Checking these components, repairing or replacing defective components, replacing missing components

The third stage is to sort the disassembled materials. This process may be significantly helped by using tools such as screw gages to measure and compare screw dimensions instead of visual inspection, as well as greater standardisation efforts in the manufacturing industry (Steinhilper, 2010).

Some facilities also redesign components (such as gearboxes) to increase the reuse ratio and make sorting easier by standardising components (European Commission, 2012).

Step 4: Reassembling the part, readjusting as necessary and submitting it to a final test

Remanufacturing applies many of the same principles as original manufacturing, including experience with machine tools, assembly equipment and quality assurance. Equipment for reconditioning (such as lathes, milling and drilling machines) are similar to those used in manufacturing original equipment, undergo the same tests and often come with the same warrantee (Steinhilper, 2010).

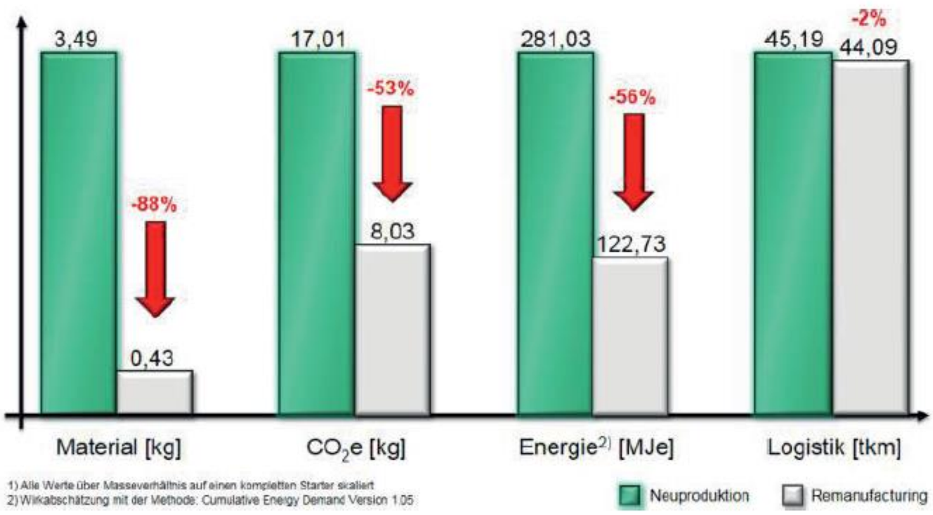
A further aspect that may improve overall environmental achievements is awareness-raising around the correct procedures to dismantle components. For example, many Diesel particulate filters that are initially sound are damaged during the removal and/or transportation process – according to one source this is assumed to be because the value of the cores is not recognised (Sundin & Dunbäck, 2013). The impact is increased scrap rates of cores that were originally suitable for remanufacturing (Sundin & Dunbäck, 2013).

Achieved environmental benefits

In all cases, the suitability of a part for remanufacturing versus other treatment will be assessed on a life cycle basis. These often include mechanical and hydraulic parts, where only parts of the component might fail, as well as a growing number of electrical/electronic parts.

The remanufacturing industry helps the environment through raw material conservation and energy reduction. The use of remanufactured parts and components can conserve up to 88% material and 56% energy use compared to new parts (APRA, 2015) – see **Figure 44**.

Figure 44: Material, CO_2 , energy and logistics savings from use of remanufactured parts



Source: (APRA, 2015)

Further environmental benefits can also be expected in terms of water consumption, chemical usage and waste. Renault estimates that their remanufacturing operations offer significant benefits in terms of the following (Ellen MacArthur Foundation, 2013):

- 88% less water is required compared to manufacturing products from new;
- 92% fewer chemical products are used;
- 70% less waste is generated.

Appropriate environmental performance indicators

In general, the less a product has to be changed, the quicker it can return to the market and the greater the savings in terms of energy and materials (and associated environmental impacts) (Optimat, 2013). Monitoring of this BEMP can be divided into the level of remanufacturing in terms of weight per component (%) as well as overall remanufacturing levels (% of recovered components).

Since a life cycle approach is recommended to evaluate the savings, the same indicators may be used (see *Section3.6.3* Design for sustainability using Life Cycle Assessment (LCA)*).*

Cross-media effects

No significant cross-media effects are expected. However, remanufacturing of parts may present logistical conditions which require delivery fleet vehicles to travel greater distances, resulting in higher GHG emissions; careful planning and logistics management can be used to negate some of the environmental impact of new and additional transport to and from remanufacturing sites (Toyota – personal comm., 2014).

Operational data

Remanufacturing is a clearly defined activity within the automotive sector[58].

Remanufacturing can have a significant impact on the conservation of materials, energy use, and emissions of GHGs. It has been taking place in Europe for decades, carried out by both independent remanufacturers and OEMs; however, general levels remain at a relatively small scale due to various challenges. Firstly, some components tend to have a relatively low value for the dismantler. For example, a brake calliper remanufacturer will be selective in which brake callipers it accepts and will pay little to get them, whereas it can be costly for a dismantler to remove and store the part (MVDA – personal comm., 2014).

Furthermore, there has traditionally been a poor linking of demand to supply. It is crucial that the correct cores in the right quality are available to the respective remanufacturing factory at the right time and in the right volume. This issue has been exacerbated by trends towards more variants and shorter model systems, making it more difficult to match parts to specific vehicles, as well as the difficulty of forecasting due to uncertainties over timing and quantities of returned products (Sundin & Dunbäck, 2013).

[58] According to the common definition of ACEA, APRA Europe, CLEPA and FIRM, a remanufactured part: fulfills a function which is at least equivalent compared to the Original part; it is restored from an existing part (CORE), using standardized industrial processes in line with specific technical specifications. A remanufactured part is given the same warranty as a new part and it clearly identifies the part as a remanufactured part and states the remanufacturer. A remanufactured part is different from a reused, repaired, rebuilt, refurbished, reworked or reconditioned part. [These categories are not subject to this definition and the process of remanufactured parts.].
Source APRA(2010)

Regarding parts harvested from end-of-life vehicles (ELVs), there is a specific challenge linked to the fact that many parts have already experienced an average 15 years of wear and tear, making remanufacturing more expensive and energy intensive, and that the market for the remanufactured part may be too small (see also **Figure 45**); in many cases the focus will instead be on parts from repair and maintenance.

In the face of the above challenges to building an efficient market, recent developments in ICT are empowering ATFs (including SMEs) to overcome these obstacles. Software in use by remanufacturing organisations such as Premier Components UK, allow ATFs to use a vehicle's license plate number to access a database revealing the demand for, and price of, relevant parts/components of the ELV in question (MVDA – personal comm., 2014). Systems such as this have led to increased rates of remanufacturing (MVDA – personal comm., 2014). Another example of an ICT system is the CoremanNet return system (Core-Management Network), which was specially developed to this purpose more than ten years ago, and is now an established network with sixteen collection and evaluation points in Europe, USA and China. According to the developers, CoremanNet enables a successful remanufacturing business and the resulting saving of 23,000 tons of CO_2 annually in comparison to the production of new automobile replacement parts (CoremanNet, 2014)

Whilst it is likely that there will continue to be a role for small businesses to participate in the remanufacturing economy, larger-scale remanufacturing services can achieve specialisation and economies of scale, which helps to overcome some of these key barriers.

Ensuring quality and consumer acceptance can be an issue in some cases, if the product is perceived to be inferior or unsafe. Industry standards and certification are a significant issue in this respect – although it is expected that the development of standards such as the British Standard for remanufacturing (BS 8887-220:2010) will help to overcome these issues (Optimat, 2013).

Applicability

Currently, remanufactured parts and components are mainly supplied to the aftermarket (i.e., for repairs and maintenance rather than new vehicles). However, there are examples of remanufacturing sites being established near new vehicle production sites for the purpose of supplying parts and components for use in new vehicles (at least in part) – such as Renault's facility at Choisy-Le-Roi (European Commission, 2012). The site has several hundred employees, who remanufacture engines, transmissions, injection pumps gearboxes and turbocompressors. Its output is still delivered primarily to the aftermarket division, but some components are supplied for new vehicles (European Commission, 2012). Renault works with its own distributor network to obtain cores, and supplements these with used parts purchased directly from end-of-life vehicle disassemblers, as well as with new parts where necessary (European Commission, 2012).

Typically, remanufacturing is viable for products with higher resale values, and markets for some components are already mature (e.g. starters, alternators etc.). Other areas are at an earlier stage of development (such as electrical and electronic components) where the complexity is much greater, and there is considerable potential for market growth in these areas (APRA Europe, n.d.). However, electronic parts may have higher residual values, meaning the economic case for reuse, repair, refurbishment and remanufacture improves against the alternative of material recycling.

Essential factors that influence the economic case for remanufacturing include (Steinhilper, 2010):

- Sales volumes of the vehicle model;
- Years of production of the vehicle model;
- Scrap rate of the vehicle;
- Vulnerability of the part.

All of these factors will influence the supply and demand of cores, and thus the feasibility of operations (see discussion of economic factors below). For example, shorter vehicle design cycles mean that the in-production phase also falls, so the population of models in circulation that are suitable for remanufactured parts is smaller (EGARA – personal comm., 2014).

Remanufacturing may also be helpful in situations where previous product generations are still in the marketplace and require maintenance, but are no longer in production (Steinhilper, 2010).

Economics

Since remanufacturing starts from the used parts, rather than raw materials, it is usually believed to be more economical (Steinhilper, 2010). Cost savings may be achieved through reductions in material and energy consumption – there are limited capital expenses required for machinery, and no cutting and machining of the products, resulting in no waste and a better materials yield. As noted previously, larger companies may be able to achieve greater economies of scale and remanufacture components more cost-effectively; however there are many examples of small firms operating profitably in the market as well (Sundin & Dunbäck, 2013).

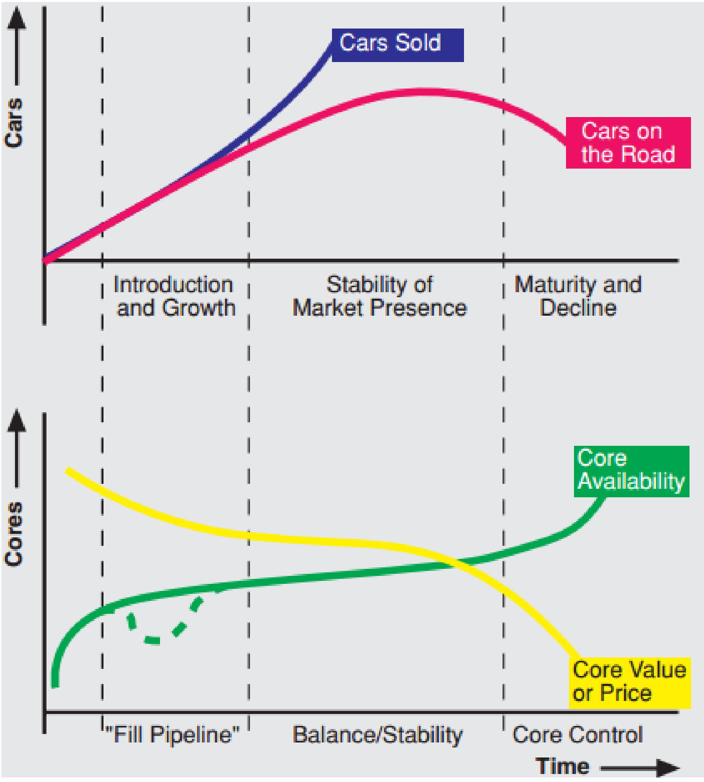
From the consumer's perspective, a remanufactured automotive part is the functional equivalent of a new part but costs typically 50-75% of a new unit and often carries the same warranty (APRA Europe, 2014). The price varies depending on the specific component, the process involved and the stage of the product life cycle.

From the remanufacturer's perspective, the main costs incurred are due to labour and purchasing of materials/parts (Steinhilper, 2010). Costs are also incurred for storage of parts and transportation. However, Renault's operations in Choisy-Le-Roi have found that in their particular case remanufacturing is only economical if carried out locally (i.e. shipping parts abroad would negate the savings (Ellen MacArthur Foundation, 2013).

Generally, complex mechanical units (such as automotive transmissions and engines) require significant effort at the parts reconditioning and new parts replenishments steps (Steinhilper, 2010). Assembly costs to carry out any required repairs/replacements are typically comparable to those of new manufacturing (Steinhilper, 2010).

The cost structure of materials is highly variable; prices of cores and the residual value of equipment could vary dramatically from year to year due to multiple supply and demand issues. When a new car model enters the market, there are very few cores available – these are typically sourced from cars involved in accidents or the first units that become defective and thus the cores can be rare (if available at all) and expensive). Later in the product cycle more ELVs are available and it becomes easier to source cores. Finally, in the last market phase an excess of cores may occur leading to declining prices (Steinhilper, 2010). **Figure 45** illustrates some of these issues. Although this is a rather simplified representation of the real world conditions, it helps to demonstrate the issues.

Figure 45: Core availability and value phases



Source: (Steinhilper, 2010).

Driving force for implementation

One of the main driving forces for the increase in central remanufacturing services is the End-of-Life Vehicle Directive (2000/53/EC).

However, remanufacturing operations can be profitable in their own right. For example, Toyota estimate that it will cost them less in the long-term if the vehicle parts are kept in Europe, as it facilitates local production and reduces the cost of importing parts manufactured outside the EU (Toyota – personal comm., 2014).

Renault's model has also been noted to create loyalty with clients in the brand's network, and also to facilitate the longevity of the exchange parts, at controlled costs, even for discontinued components (Ellen MacArthur Foundation, 2013). Similar rationales may apply to other OEM models.

Other drivers include: rising costs of raw materials and energy; costs or servicing aging cars and political focus (for example on job creation) (BORG Automotive, 2014).

Reference organisations

Data for some of the environmental aspects and operational information was based on Renault's Choisy-Le-Roi remanufacturing plant. There are many other actors in the remanufacturing sector, including other OEMs and independent operators.

Reference literature

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4 BEST ENVIRONMENTAL MANAGEMENT PRACTICES FOR THE HANDLING OF END-OF-LIFE VEHICLES

4.1 ELV COLLECTION

4.1.1 Component and material take-back networks

SUMMARY OVERVIEW:

BEMP is to deploy effective take-back networks to increase the rate of reuse, recycling and recovery that is economically achievable when treating ELVs. This involves extensive collaboration between different industry actors to recover components, consolidate with other waste streams where possible as well as training and support.

Front-runner authorised treatment facilities have implemented best practice through:

- Collaboration with industry actors: to coordinate the tracking, collection and transportation of components and materials and to ensure that the right incentives are in place for actors in the chain;
- Managing/incentivising product return;
- Consolidation with other waste streams, to reduce the administrative burdens and pool expertise;
- Providing technical support and awareness-raising.

Relevant life cycle stages				
Management	Design	Supply chain	Manufacturing	**End-of-life**
Main environmental benefits				
Energy consumption	**Resource use and waste**	Water use & consumption	Emissions to air, water, soil	Ecosystems & biodiversity
Environmental indicators				
• Recovery rate (%) for specific products or materials through ELV networks				
Benchmarks of excellence				
• **Collaboration and partnerships are in place with local/national organisations to implement take-back networks**				
Cross references				
Prerequisites	• Design for sustainability using Life Cycle Assessment			
Related BEMPs	• General best practices for remanufacturing components • Best practice ELV treatment for specific components			

Description

Effective collection networks are one of the most important mechanisms to enable full exploitation of recovery, reuse and recycling options[59]. Collection systems aim to take back specific components or ELVs and ensure they are properly treated.

The lack of an effective and economical take-back system for separate components is one of the main barriers for increased recycling and reuse. While in some cases post-shredder treatment can be the most environmentally benign option, the alternative of using better collection networks would improve the life cycle environmental impacts for some components (ADEME, 2008) (Farel et al, 2013).

For whole vehicles, take-back networks are a requirement under the End-of-Life Vehicle Directive, although the implementation method is not prescriptive. This BEMP explores the opportunities to develop take-back networks for components and materials from ELVs rather than for whole ELVs themselves. Indeed, the ELV Directive promotes an Extended Producer Responsibility (EPR) approach where manufacturers contribute to ELV processing through take-back schemes.

The guidance in this section provides an overview of best practices, taking into account that organisations may be working within the constraints of different national situations. The ELV collection systems put in place to comply with ELV requirements can be of two broad types:

- **Individual systems** in which each manufacturer is responsible for collection of their own brands through bi-lateral relationships and contracts.
- **Collective systems**, where different brands are collected through the same network. Although the End-of-Life Vehicle Directive requires that Member States establish collection systems for ELVs, there are several barriers to implementation including complex administrative requirements, lack of public awareness and additional costs.

The majority of Member States have both types of network. The dominant situation in each Member State varies due to different historical experiences, administrative arrangements and approaches to implementing the End-of-Life Vehicles Directive.

This general framework for best practice is primarily aimed at collection of components rather than whole vehicles, but is also generally applicable. It consists of the following stages:

- **Collaboration with industry actors**: In order to implement an integrated approach to material reuse, links must be established between those responsible for the design of products, their production and the management of waste once the product has reached the end of its life. This includes manufacturers and importers of vehicles, part manufacturers/suppliers, recycling plants, dismantling stations, shredders, car collection points and waste management firms (BIO Intelligence Service, 2013). This is vital to coordinate the tracking, collection and transportation of components and materials and to ensure that the right incentives are in place for actors in the chain.
- **Managing/incentivising product return**: In addition to collaborative efforts with industry actors, there are several possible business models that could encourage easier management of product return.
- **Consolidation with other waste streams**: Synergies with other (non-automotive) components can be exploited to reduce the administrative burdens and pool expertise.

[59] unless otherwise specified the words recovery, recycling and reuse follow the terminology defined in the ELV Directive (2000/53/EC) which also builds on the waste framework directive (75/442/EEC).

- **Providing technical support and awareness-raising**: Awareness-raising activities will be undertaken regularly, as lack of awareness is a key barrier to component recovery.

As an additional element the use of CoDs (Certificates of Destruction) as a proof of take-back by ATFs has had a positive impact where and when used to improve traceability and reduce illegal operations, enabling also higher standards of environmental management.

Achieved environmental benefits

The environmental benefits of establishing the collection systems are not directly quantifiable, as it depends on the subsequent treatment steps. Rather, this best practice is a prerequisite for unlocking higher reuse, remanufacturing, recovery and recycling potential by ensuring that the parts are collected effectively. Effective collection systems would also make it easier to avoid the black market dismantling sector, which can involve poor depollution practice and consequent soil and water pollution (MVDA – personal comm., 2014).

Appropriate environmental performance indicators

The monitoring of this BEMP will be specific to the circumstances of the ATFs aiming to implement the best practice. Therefore, metrics will be tailored to reflect performance in this specific context, e.g.:

- Recovery rate (%) for specific products or materials through ELV networks.

N.B. recovery encompasses recycling and other valorisation; although putting this BEMP in practice contributes to the overall achievement of the high-level objectives of the ELV directive, materials and components could be monitored at a finer level.

Cross-media effects

Systems will be designed so that the life cycle impacts are minimised (see also *Section3.6.3* Design for sustainability using Life Cycle Assessment (LCA)*)*. Improving the collection of components is likely to lead to higher emissions from transportation and energy consumption during any subsequent processing steps that are enabled.

In a scenario which results in the increased transportation of ELVs and their components, it will be critical to ensure that fluids are effectively removed from the ELVs, in order to minimise potential pollutant emissions to soil and water (ARN – personal comm., 2014).

Operational data

The best practice examples focus around increasing the rate of recovery of products (through improving product tracking, collaborative efforts and awareness-raising), as well as reducing costs by consolidating waste streams. Examples of best practice implementation include:

- **Collaboration with industry actors**: As an example of practices put in place by many OEMs, Renault works with recyclers and waste management companies—including INDRA (who manage distribution, treatment and recovery of ELVs). They have also formed a joint venture with a steel recycler to collect materials for recycling from their plants and other end-of-use parts. This gives them greater control of the material flow and allows them to ensure higher quality (World Economic Forum, 2014). On a pilot scale, Renault also initiated a LIFE project to provide the industry with new tools and outlets which not only help increase end-of-life vehicle recycling rates but also generate new income which justifies the proposed investments or implementation of new practices (ICARRE95, 2015).

- **Managing/incentivising product return**: The most appropriate model depends on the customer segment and the product involved, and may include the following examples (World Economic Forum, 2014):
    - **Trade-ins:** when selling a new product, the customer is offered a trade-in price for his redundant product. The trade-in price is often given as a discount on the new product sale. This may be appropriate for items such as worn or part-worn parts (such as gearboxes, brushes for electric motors etc.).
    - **Leasing business models:** where the product is leased to the consumer for a given period, after which the product is returned. This has been offered for management of vehicle fleet tyres for decades, but may also be applicable to other areas.
    - **Removal / disposal services:** for products that do not have a high residual value, removal services may be appropriate to recover redundant products. ELV take-back networks are a typical example.

  Crucial aspects to consider are the extent of product variety being returned and hence the extent to which the process can be automated, as well as the distances to be travelled.

- **Consolidation with other waste streams:** Synergies with other components such as batteries, tyres, electronics, airbags etc. can be exploited to reduce the administrative burdens and pool expertise. For example, reuse of components is typically only possible if they are replaced in the same vehicle model, except for some low-value components such as hose clips.
- **Providing technical support and awareness-raising:** Awareness-raising activities should be undertaken regularly to ensure that both consumers and firms are aware of the collection network. Technical support is particularly important for the ELV dismantling sector, which typically has many small actors with limited resources to keep up to date with current best practices or legislative changes (Optimat, 2013).

Applicability

The greatest potential environmental gains at the component level appear to be in collecting advanced technologies with limited service life (such as hybrid or electric vehicle batteries), as well as components/materials that are less financially attractive to dismantle (such as plastic and glass components) (Optimat, 2013).

Collection networks can apply to whole vehicles or specific components. With respect to managing/incentivising product return, the applicability of alternative business models (if at all) depends on local regulation, the customer base, the geographic dispersion and the type of product involved. However, the overriding factor is that the marketing of spare parts is an informal market, which typically depends on the dismantler's knowledge of which parts can be used in which vehicles, and whether there is a demand for those parts (ARN – personal comm., 2014).

There is currently a lack of information amongst ATFs, on how to appropriately deal with vehicle parts at end-of-life. Modern vehicles contain increasingly complicated technology and ATFs have relatively little information available directly from producers on how to deal with complex parts through reuse, remanufacturing or recycling (EGARA – personal comm., 2014). The International Dismantling Information System (IDIS) covers material information but does not, as yet, provide access to useful information on parts (in particular – part numbers for identification) (EGARA – personal comm., 2014), (MVDA – personal comm., 2014). In the case of some OEMs, this information (RMI – repair and maintenance information) can be purchased for a fee, but coverage is still not exhaustive.

Increasingly, software (such as online marketplaces) are becoming available for ATFs which are helpful to disseminate information about the market value (supply and demand) of specific parts, which allow ATFs to make more informed decisions about the economic rationale of harvesting for specific parts. This use of software also encourages higher rates of reuse and remanufacturing.

In some EU countries, take back schemes could be restricted by competition from the black market sector for dismantling of ELVs; a report on the effectiveness of the ELV directive for the European Commission (BIO, 2014) estimates that ~25% of ELVs arising in the EU do not end up in ATFs ("unknown whereabouts", although it is still unclear whether this discrepancy reflects a data gap or actual handling under illegal circumstances). Although OEMs can endeavour to select the most environmentally friendly dismantlers, the incentives for dismantlers to actually implement best practice are threatened by competition with black market dismantlers, which can dispose of vehicles more cheaply by avoiding even legislated environmental practices (Toyota – personal comm., 2014). The keystone of an efficient system for recovery and recycling of components is an efficient ELV recovery system (supported e.g. by a suitable deregistration system, linked to Certificates of Destruction), without which many vehicles risk exiting the system without recovery opportunities (ARN, personal communication, 2016).

Economics

In general, the cost of collection and treatment of ELVs is covered by the revenues from recycling (BIO Intelligence Service, 2013), sustaining the ELV handling business model. Additional fees may however be needed to cover data reporting, audits and communication/awareness-raising actions (BIO Intelligence Service, 2013).

Establishing recycling to a high material grade can also help to reduce risks due to increases in prices and volatility in raw materials (World Economic Forum, 2014).

The issue of creating and maintaining the right economic incentives for actors in the supply chain to choose the most environmentally friendly options is important, and one of the key factors that can determine the success of a scheme.

Driving force for implementation

An important driver for collection of whole vehicles is the ELV Directive. National legislation in the EU is based on this Directive, although national and regional incentive schemes and economic models implemented in addition may vary widely. At the manufacturer level, establishing recycling for their products is driven by increasing prices and volatility of raw materials (World Economic Forum, 2014).

Emerging issues

Since hybrid and electric vehicles are relatively new to the market, few have been processed as ELVs (MVDA – personal comm., 2014). However, there is currently a very high level of interest to recover as much value as possible from high voltage propulsion (traction) batteries, typically based on NiMH and Li-ion technologies.

Initial indication of best practice with respect to battery collection is shown in Table 62:

Table 62: Examples of best practice implementation

Best practice	Examples
Managing / incentivising product return	Renault became the first car maker to lease batteries for electric cars to help retain the residual value of electric vehicles (to encourage higher consumption) and make batteries fully traceable, ensuring a very high collection rate for closed-loop reengineering or recycling (World Economic Forum, 2014). For tyres, Michelin pioneered leasing for fleets.
Consolidation with other waste streams	Components that need to be replaced during a vehicle's lifetime are collected from retailers and workshops. Toyota consolidates collection of vehicle batteries with catalysts and returning delivery trucks of Toyota service parts (Toyota, 2013).
Providing technical support and awareness-raising	Toyota provides a 24-hour helpline to receive collection requests for its hybrid vehicle batteries (Toyota, 2013). Awareness-raising activities cover a range of different media in order to reach a wide audience, including radio, social media, internet, magazines and other publications. These are regularly carried out by ELV collection networks across Europe (BIO Intelligence Service, 2013).

In some countries there is no widespread commercial system for collecting hybrid batteries, and dismantlers are unsure how to dispose of them (MVDA – personal comm., 2014). Furthermore, the movement of electric vehicle batteries are governed by strict legislation under the European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR), which make the costs of collection excessively expensive when they are in compliance with ADR regulation (ARN – personal comm., 2014).

Reference organisations

See operational data for details: Toyota (Toyota, 2013) and Renault (World Economic Forum, 2014; ICARRE95, 2015).

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4.2 ELV TREATMENT

4.2.1 Enhanced depollution of vehicles

SUMMARY OVERVIEW:

BEMP is to carefully carry out the mandatory depollution of vehicles using specifically designed equipment where possible. Environmental considerations are relevant to contamination of soil and water, but also related to the potential for recovery of materials for reuse and recycling.

Best practice is to have in place effective depollution systems such as:

- Equipment which safely drills fuel tanks and hydraulically removes fuel
- Drainage/collection equipment for oils, hydraulic fluids etc.; and to remove oil from shock absorbers;
- Tools to remove the catalytic converter;
- Equipment for removal and safe storage of air conditioning gases;
- Equipment for airbag detonation and;
- Equipment for removal of seat tensioners,

or to use alternative methods to achieve the same levels of depollution.

Relevant life cycle stages				
Management	Design	Supply chain	Manufacturing	**End-of-life**

Main environmental benefits				
Energy consumption	**Resource use and waste**	Water use & consumption	**Emissions to air, water, soil**	Ecosystems & biodiversity

Environmental indicators

- Removal rate of components (%)
- Recycling rate of fluids (%)
- Installation of commercial depollution machine or equally performing equipment (Y/N)
- Use of mass balancing techniques to monitor depollution rates (Y/N)
- Adoption of a quality management system (Y/N)

Benchmark of excellence

A certified quality management system is in place in the organisation

Cross references	
Prerequisites	• N/A
Related BEMPs	• Best practices ELV treatment for specific components

Description

Since depollution is the first stage of the ELV process, it has impacts on the effectiveness of later stages such as recycling or even potential remanufacturing. Depollution refers to the removal or neutralisation of all hazardous materials from an ELV, including batteries, liquefied gas tanks, explosive components, (e.g. air bags), fuel oil, motor oil, transmission oil, gearbox oil, hydraulic oil, cooling liquids, antifreeze, brake fluids, air-conditioning system fluids and components identified as containing mercury. The ELV Directive sets minimum requirements for the depollution of ELVs.

Once fully depolluted, the ELV can be stored for future removal and sale of used spare parts.

In most countries, the majority of ATFs (Authorised Treatment Facilities) use similar tools, which vary from simple hand tools, to relatively complex tools. They include (Optimat, 2013):

- Equipment which safely drills fuel tanks and hydraulically removes fuel;
- Drainage/collection equipment for oils, hydraulic fluids etc.; and to remove oil from shock absorbers;
- Tools to remove the catalytic converter;
- Equipment for removal and safe storage of air conditioning gases;
- Equipment for airbag detonation and;
- Equipment for removal of seat tensioners

Best practice goes beyond the minimum requirements of depollution steps. The use of more complex equipment that has been specifically designed for carrying out the required depollution operations is generally considered to yield the best results as it ensures that a higher level of depollution can be achieved in a relatively short time-frame.

Achieved environmental benefits

The main environmental benefit achieved through the use of commercial depollution systems is an increase in the percentage of liquid removed from the vehicle (AEA Technology et al, 2011). This means that there is less hazardous substance left in the vehicle hulk, and therefore less potential to contaminate soil and water.

Appropriate environmental performance indicators

- Removal rate of components (%)
- The quantity of fluid removed (litres / %)
- Installation of commercial depollution machine or equally performing equipment (Y/N)
- Use of mass balancing techniques to monitor depollution rates (Y/N)
- A certified quality management system is in place in the organisation (Y/N)

N.B. The quantity of fluid removed is relevant if vehicle characteristics remain more or less constant, as if an ATF specialises in larger vehicles then they can expect to retrieve a large quantity of brake fluid etc, whereas if they specialise in smaller vehicles the quantities of material to remove are more limited (EGARA, personal comm., 2014).

Cross-media effects

Commercial systems require energy in order to create the suction for liquid removal. This results in increased emissions to the atmosphere, where the energy used is derived from fossil fuels.

Operational data

Depollution machines can be an effective tool to improve the environmental impact of depollution[60]. These machines remove more liquids from the vehicle (including brake fluid, coolant etc.) compared to other methods such as gravity draining of fluids (EGARA, personal comm., 2014). The majority of commercial depollution equipment is operated pneumatically; therefore the compressor used to power this equipment must have sufficient capacity for satisfactory operation (AEA Technology et al, 2011).

ATFs may decide to use alternative methods to achieve the same levels of depollution, but health and safety requirements should never be compromised (AEA Technology et al, 2011). An example sequence is shown in Table 63, developing through practical trials in order to find a sequence that maximises the time for gravity-draining of the engine oil (AEA Technology et al, 2011).

Table 63: Recommended sequence of depollution operations

Operation		Description
Above vehicle	Disconnect Battery and remove from vehicle.	The SLI (starting, lighting, ignition) battery must be removed, for health and safety reasons (prevention of possible electrical discharge igniting fuel), before the fuel tank is depolluted. The battery is easily removed with standard tools. Hybrid batteries should only be disassembled by suitable qualified personnel.
	Remove fuel, oil filler, coolant, washer, brake fluid and power steering caps.	This enables the fuel, oil and other fluids to be drained more easily.
	Set heater to maximum.	This ensures that coolant in the heater unit can be drained.
	Remove wheels and tyres and separate balance weights.	Removal of wheels and tyres is not in itself a depollution activity, but may allow for easier access to drain the brakes and shock absorbers, depending on the equipment being used.
	Check for and remove any items marked hazardous (e.g. mercury switches)	Some switches, such as tilt-based switches, may contain mercury. The ELV Directive requires switches which contain mercury to be removed.

[60] One of the most popular brands in Europe is SEDA, although there are many other less well-known brands that may be cheaper and provide the same performance.

Operation		Description
Put vehicle onto depollution frame or lifting device giving above & below access		
Below vehicle	Drain engine oil and remove oil filter for crushing or disposal	This will be done by using a suitable spanner/tool which does not puncture the oil filter during removal. The oil filter must be treated to remove residual oil. This can be achieved by crushing the filter and recovering the oil. Commercial equipment which performs this function is available. Alternatively, the oil filters can be sent to a suitable treatment facility using leak-proof transit packaging.
	Drain transmission oil, including rear differential if applicable	Transmission oil is contained in both manual and automatic gearboxes, and in the rear axle differential of rear wheel drive vehicles. If the gearbox has a drain plug, it can be gravity-drained. Gearboxes which do not have a drain plug must be drained by drilling or piercing a suitably sized hole in the bottom of the gearbox. Commercial equipment includes a suitable drill or punch, provides suction to assist in draining the gearbox, and collects the oil without the need for a container underneath the gearbox.
Above	De-gas air conditioning systems with specialist equipment	The refrigerant must be removed using specialist equipment into special canister
Below	Drain coolant	Coolant can be gravity drained by removing the bottom hose from the radiator and collecting the liquid in a suitable container. Commercial equipment enables the operator to make a hole in the bottom hose and suck the coolant out through this hole into a container. Either method can be used, but will only be able to achieve a high level of removal if the heater valve is set to maximum as part of the preliminary activities and the filler cap is removed.
	Drain brake fluid from brake lines and master cylinder	In order to achieve the required percentage of removal, brake fluid will be removed using equipment which uses suction and/or pressure on both the reservoir and the brake pipes and cylinders.
	Remove catalyst (if fitted)	Nearly all modern vehicles will have a catalytic conversion unit in the exhaust system. The catalyst unit can easily be removed by cutting through the exhaust pipe, both in front of, and behind, the catalyst unit. The use of the correct cutting equipment reduces the time which is required for this operation
Above	Drain washer bottle	Either commercially-available equipment or a simple pump can be used. If a simple pump is used, the reservoir must be inspected to determine that it has been completely emptied.
	Drain brake/clutch reservoir(s)	Virtually all modern cars have cable clutches and so do not contain any hydraulic clutch fluid.
	Drain power steering reservoir (if fitted)	If the ELV has power steering, fluid has to be extracted from both the reservoir and the connecting hose.

Operation		Description
Below	Drain fuel tank	Fuel can be removed by suction or siphoning it from the tank with a tube entering the tank through the fuel filling pipe, but this procedure is unlikely to achieve the required level of depollution. In order to ensure that the required level of depollution is achieved, a hole will be pierced or drilled into the lowest point of the fuel tank and suction is used to remove fuel. This ensures that no vapour is released during extraction
	Drain shock absorbers or remove suspension fluid	The recommended approach is to drain the fluid from the shock absorber without removing it from the ELV. Shock absorbers contain fluid, usually oil, in both an inner and an outer cylinder. Consequently, in order to achieve the required level of depollution, fluid/oil needs to be removed from both the inner and the outer cylinder. Shock absorber fluid/oil could be removed from an ELV by removing the shock absorbers, but the time required to conduct this operation may be considerable, and the shock absorbers would be classified as hazardous waste after they were removed from the ELV.
Replace drain plugs/fit plastic stoppers, r**emove vehicle from depollution frame or lifting device and place on concrete pad**		
Above	Deploy airbags and other pyrotechnics in-situ.	The majority of airbags are electrically deployed, either from a single direct connector or a Deployment Control Unit. If it is not possible to deploy the airbag within the vehicle, remove the airbag and deploy it immediately. Commercial equipment for the deployment of all electrical pyrotechnics is available but, as different air bags use different connections, a number of adapters will be required. Pre-tensioners may contain explosive or have stored mechanical energy (large spring) that is deployed mechanically or electrically. If they contain explosive devices, they need to be deployed as part of the depollution procedure.
	Remove air bags and other pyrotechnics	It is possible for undeployed air bags to be removed and stored. However, as they are classed as explosive devices, the storage facility would have to meet all relevant regulations and requirements for storage of explosive materials, including those relating to health and safety. Meanwhile, their resale and reuse as undeployed devices is not recommended by the industry as they are considered to pose safety issues.

Source: (AEA Technology et al, 2011)

All fluid types to be stored in separate containers in bonded storage area prior to specialist recovery/disposal. It is recommended that, where possible, air bags are deployed in situ using suitable equipment and that all persons deploying airbags attend a suitable training course (AEA Technology et al, 2011).

The Waste Oils Directive seeks to promote the regeneration of oils. Any mixing of fluids like oils may restrict the possibilities for recycling.

Applicability

Depollution rates will be affected by whether an ATF specialises in a certain type of vehicle. This will influence their consideration of whether it is economically worthwhile to remove the pollutant (e.g. vehicle size).

Certain other factors will also be required, alongside commercial depollution machines, to ensure depollution is non-hazardous to the environment. Sites for ELV treatment and storage (including temporary storage) of end-of-life vehicles prior to their treatment must have (AEA Technology et al, 2011):

- Impermeable surfaces for appropriate areas with appropriate spillage collection facilities.
- Equipment for the treatment of water, including rainwater.
- Appropriate storage for dismantled spare parts, including impermeable storage for oil-contaminated spare parts,
- Appropriate storage tanks for the segregated storage of end-of-life vehicle fluids.

Economics

The major barrier to dismantlers using more complex equipment is the investment cost, as well as the limited value of the hazardous products removed. In the Netherlands, ARN have tried to facilitate depollution by providing commercial units to ATFs on lease (ARN, personal comm., 2014).

Commercial depollution machines are relatively expensive to install which may prohibit their use in smaller ATFs, which process fewer ELVs, and do not have the capital cost to invest. [61]The cost will also depend on the equipment required (e.g. vehicle ramps, working platforms, tilting ramps, storage tanks, connection, compressors etc), which is in turn dictated by factors such as the number of vehicles processed per day and the space available to the ATF (SEDA, n.d.). The capital cost of such an installation will also depend on which other features are required (e.g. hydraulic frames, impermeable floors, size and location of tanks (i.e. underground) and initial ground remediation/preparation) (EGARA, personal comm., 2014).

The main benefit of using complex depollution systems is the saving made on time and therefore labour cost from vehicle draining (EGARA, personal comm., 2014). It is possible to connect a depollution system to the vehicle, and work on other parts of the car whilst the equipment is operating automatically.

Driving force for implementation

The ELV Directive sets minimum standards for adequate depollution (e.g. draining of fluids such as engine oil). According to Annex I of the legislation, the minimum technical requirements for treatment in accordance with Article 6(1) and (3) are:

- Removal of batteries and liquefied gas tanks,
- Removal or neutralisation of potential explosive components, (e.g. air bags),
- Removal and separate collection and storage of fuel, motor oil, transmission oil,
- Gearbox oil, hydraulic oil, cooling liquids, antifreeze, brake fluids, air-conditioning,
- System fluids and any other fluid contained in the end-of-life vehicle, unless they are necessary for the re-use of the parts concerned,
- Removal, as far as feasible, of all components identified as containing mercury.

[61] Costs are in the order of magnitude of €100,000 - €200,000, for the installation of the machine (EGARA, personal comm., 2014).

From July 2010, the minimum requirement for staff handling air conditioning systems must fulfil the European Union F-Gas Regulation 842/2006/EC.

Furthermore, the European Waste Catalogue and Hazardous Waste List form the basis for all national and international waste reporting obligations, such as those associated with waste licenses and permits, and the transport of waste.

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4.2.2 General best practices for plastic and composite parts

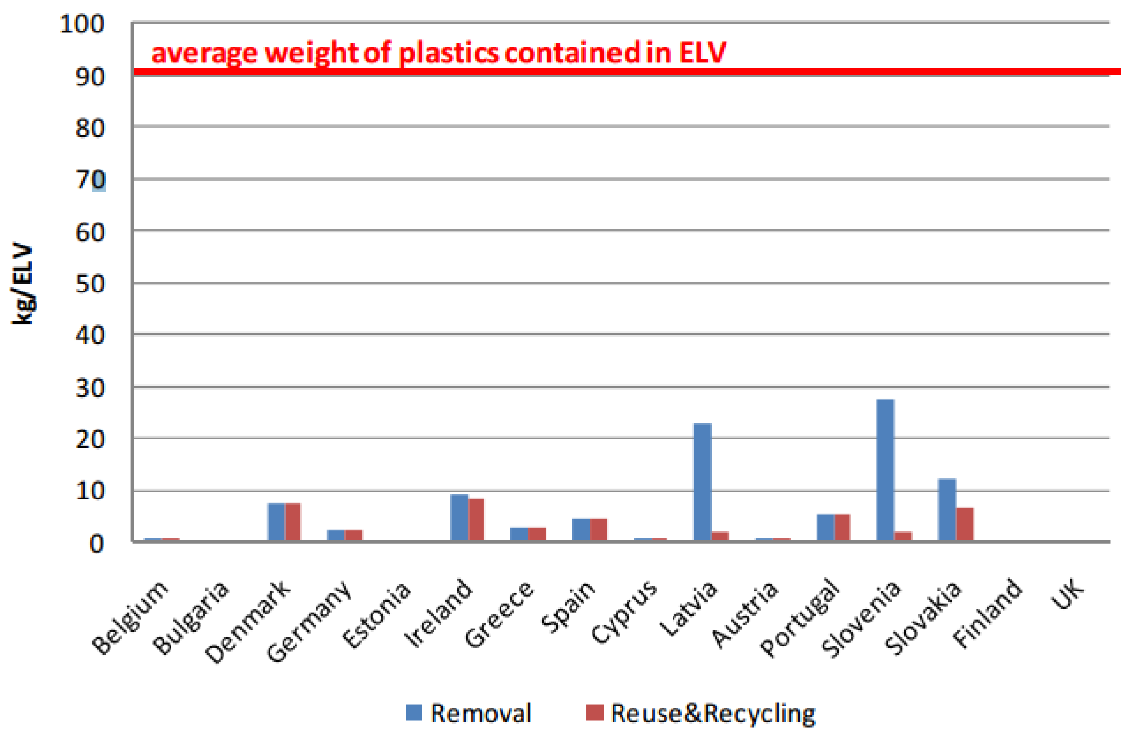
SUMMARY OVERVIEW:				
There are two main methods for treating plastic and composite parts – dismantling and recycling of components, and post-shredder recycling. The relative advantages and disadvantages of these methods depend largely on the availability and performance of ELV treatment technologies. **BEMP is therefore to evaluate the pros and cons based on specific information relevant to plastic and composite parts.**				
Relevant life cycle stages				
Management	Design	Supply chain	Manufacturing	**End-of-life**
Main environmental benefits				
Energy consumption	**Resource use and waste**	Water use & consumption	Emissions to air, water, soil	Ecosystems & biodiversity
Environmental indicators				
• Consideration of LCA studies to determine optimal material routes according to local factors (Y/N) • Share of components treated according to optimal LCA route (%)				
Benchmarks of excellence				
N/D				
Cross references				
Prerequisites	• Design for sustainability using Life Cycle Assessment			
Related BEMPS	• Component and material take-back networks			

Description

The average weight of plastic components in a vehicle is estimated to be around 12-15% of vehicle weight (150-250kg), with newer vehicles containing a higher quantity of plastic (Optimat, 2013 and PlasticsEurope, 2013). Many different polymers are used in cars – although polypropylene (PP) has the greatest share of around 30-40% in current ELVs (European Commission, 2007 and PlasticsEurope, 2013). Plastics have major applications in vehicles, including bumpers fuel tanks, body panels, battery housings, dashboards etc. The use of composite materials (such as carbon-fibre composites, polymer matrix composites etc.) is also growing very rapidly, for example in the construction of body interiors, chassis, bonnets and electrical components (Yang et al, 2012). Recovery routes for plastics may have different environmental benefits – using an LCA is helpful in determining whether recycling is preferable to other routes (see step 1 below).

Annex 1 of the End-of-Life Vehicle Directive requires that large plastic components (including the bumper, dashboard, fluid containers, etc.), be removed during the vehicle dismantling or shredding stage *if* these materials are not segregated in the shredding process in such a way that they can be effectively recycled as materials. However, compliance with these mandatory requirements appears to be poor. Monitoring data suggests that the amount of plastic removed from ELVs in Europe, prior to shredding, is small relative to the amount contained within the vehicle – see Figure 46. Typically plastic is left on the vehicle when it is sent for shredding, and processed into automobile shredder residue (ASR). The plastic fraction of the ASR is generally not recycled, but is more likely to be landfilled or incinerated to recover thermal energy (Schneider et al, 2010), which may not be the preferred route according to a specific LCA.

Figure 46: Weight of plastics removed from ELVs for reuse and recycling at ELV stage across Member States



Source: (Schneider et al, 2010)

Recycling of plastics and composites is particularly challenging due to the lack of clear and developed recycling routes (logistics, infrastructure and recycling technologies) relative to other material industries, the lack of clear end products/markets for recycled materials and lower quality of the recyclates compared to virgin materials (Yang et al, 2012), (Optimat, 2013). Yet the current waste management and environmental legislation in Europe increasingly requires these materials to be properly recovered and recycled from ELVs.

Long-term technology developments are still needed to optimise recycling of these materials; however there are still several key opportunities to realise best practice:

1. **Applying the principles of life cycle analysis (specific considerations);**
2. **Improving separation**
3. **Developing markets for recyclates**

Step 1) Applying the principles of life cycle analysis (specific considerations)

In general, plastics and composite materials are thought to have the most favourable environmental impacts where they allow for reduction of vehicle weight through direct substitution for other heavier materials or through parts consolidation.

There are often trade-offs with respect to different environmental aspects, and in all cases a LCA approach is recommended. Several important parameters that determine the outcomes of a LCA for plastic components will be considered in particular detail:

- **Inclusion of the whole life cycle:** it is typically the use-phase of plastic parts in cars that has the largest contribution to the environmental impacts; hence it is important not to optimise the part only for the end-of-life phase;
- **Assumptions on substitution factors:** the quality of the recycled material must be considered, as well as the application for which it will be used. For example, if the recycled plastic has inferior technical properties it may require additional material to achieve equivalent performance of the original part (depending on the application). The quality of the material may also be affected by the recycling technology – recent developments have resulted in higher quality recyclates that are indistinguishable from virgin materials (for example see Mazda's closed-loop recycling of bumpers – Operational data).
- **Using up-to-date information on recycling processes and technologies:** To date it has often been the case that separation of plastic parts (particularly large, mono-material parts such as bumpers) before the shredder with subsequent mechanical recycling is the most economical removal option, and this allows for higher-quality recycled materials to be produced. More recently, there has been significant investment in post-shredder technologies and in some cases (potentially increasingly over time) these may be preferable to pre-shredder separation. Thus the availability and performance of these technologies will have to be considered (Derichebourg, 2014; ARN, 2016).

Aside from these specific considerations, the general principles outlined in *Section 3.6.3* Design for sustainability using Life Cycle Assessment (LCA) continue to apply. In particular, product design is a key aspect in determining the opportunities for obtaining easily separable and recyclable polymers. For example, to facilitate recycling of plastic parts, vehicle design is increasingly moving towards use of fewer polymers in vehicles, lower use of PVC, greater use of PP and avoiding composite parts of incompatible materials (European Commission, 2007). Since traditional glass, talc or mica fillers used as reinforcements can hamper recycling and cause a loss in mechanical properties over time, there is growing interest in all-PP composites that use PP polymers filled with PP fibres (Delgado et al, 2007).

Step 2) Improving separation

There are many options for end-of-life treatment, ranging from reuse of parts, separation for mechanical recycling and post-shredder treatment. The separation of different materials is important to ensure high-quality recyclates. For example, recycled plastics mixes containing many different polymers have few uses since their physical properties are very rarely suitable for replacement of virgin plastic material for any application (European Commission, 2007).

The potential for these different options depends on the separation processes employed and the material/components involved. An overview is provided in Table 64

Table 64: Overview of options for separation at different stages of ELV treatment

Option	Description
Reuse / repair or refurbishing	There are options to reuse and refurbish plastic components, for example, a plastic wheel arch could be reused (as it is not safety critical) (Optimat, 2013). In practice, direct reuse may be limited by lack of standardisation in designs, problems associated with removing fixtures and damage sustained during the use phase. In some cases, repairs may be possible depending on the damage they have received. For example, holes and cracks in bumpers can be mended using a hot air plastic welder. The Urethane Supply Company provide information on how to identify the type of plastic used in the bumper (listed by make and model), as well as the method required to repair the part: • Identify the plastic – http://www.urethanesupply.com/bumperidstart.php • Identify the method and tools for repair http://www.urethanesupply.com/identify.php
Dismantling and separation before shredder	Dismantling and subsequent material recycling of plastics currently takes place at a very minor scale in Europe (Schneider et al, 2010). However, plastics removal for recycling is technically feasible and there are markets for segregated materials such as bumpers and fascia plastics – estimated at £60/tonne (€75/tonne) for baled material in 2013 (Optimat, 2013). Where waste plastics are mostly free of impurities, the recycling process itself can be relatively simple (European Commission, 2007). However, there is little incentive to segregate plastics when the scrap ELV hulk value is above the price available for individual products. Furthermore, developments of post-shredder technologies may make this option less important in future (see below).

Option	Description
Dismantling and separation post-shredder	There are some promising examples of post-shredder technologies that are able to produce high quality recyclates – for instance, in the Netherlands one ASR processing plant can produce a plastics pre-concentrate consisting of polypropylene, polyethylene, ABS and polystyrene a mixture that is processed by the company Galloo Plastics and returned in a closed-loop to automotive applications (Optimat, 2013). However, technological processes and the possibilities for recycling are different for different polymers and composite materials. The development of technology to improve separation and recycling of plastics and composites from shredder residue is essential, but proven technologies are not yet available in all Member States (Optimat, 2013).

In summary: the quality of plastic removed from ELVs at the dismantler stage is currently thought to be much higher than that recovered from ASR (which will be contaminated and a mix of polymer types) (Optimat, 2013). However, advances in technology now allow certain plastic pieces to be separated from shredder residue and thus the optimal solution may change as this technology becomes available. For example, although the Netherlands is known to remove bumpers and other large plastic parts, this practice may not continue in the future when more efficient post-shredder recovery is available (Optimat, 2013).

Step 3) Develop markets for recyclates

Vehicle and component designers are increasingly specifying plastic parts with a recycled content, which helps to stimulate a market for recycled plastics and thereby helps to improve the recycling rate for plastics in ELVs (National Composites Network, 2006).

Closed-loop recycling[62] – often seen as the gold standard in resource efficiency – is not easy for vehicle applications – the materials used in ELVs typically date from around 12-15 years before the recycling takes place, and significant changes have occurred since then (European Commission, 2007). For many components, very precise properties are needed. Thus, the recycled material would not necessarily be suitable for use in the same part in a new vehicle (European Commission, 2007).

Nevertheless there are many examples of recyclates being used in vehicle components where less specific properties are required, and thus there is more flexibility in the composition of the plastic used (see Nissan Leaf case study in the Operational data section). This is typically in parts that are not seen by the car-user (European Commission, 2007); however, best practice methods are emerging that also incorporate plastic recyclates in visible parts.

While closed loop recycling of all of the ELV materials is unlikely to be feasible, demand exists for any recyclates that can be used to substitute for virgin materials at cheaper cost while still meeting technical specifications (European Commission, 2007). Thus the previous steps of ensuring good design and separation are important to enable plastic and composite materials recovered from ELVs to be used in different markets.

[62] closed-loop recycling is meant as a recycling of the material to substitute a virgin material of the same grade, as opposed to downcycling (recycling into lower specification materials). It does not necessarily imply cycling back to the manufacturer or even within the automotive industry.

Achieved environmental benefits

The relative environmental impacts of plastics recovery largely depend on various factors such as the recovery method used and the type of substituted resources (European Commission, 2007).

Significant environmental benefits are generally expected from the recycling of individual (pure) polymers (Oko-Institut, 2003). However, numerous studies on the treatment of ELV plastics taken as a mixed whole indicate that the benefits of plastics recycling as compared to recovery are not always environmentally clear (European Commission, 2007).

As an example, the impacts of recycling bumpers are outlined below. On balance, significant environmental benefits are expected in terms of reducing energy consumption and GHG emissions compared to the current practice of landfill. Some trade-offs are also apparent in other areas – see cross-media effects for further information.

Table 65: Overview of environmental impacts of recycling PP/EPD bumpers compared to landfill

Recycling	Benefit / Harm per tonne	Unit
Energy consumption	5,680	MJ
Greenhouse gas emissions	992,000	gCO_2 equivalent
Air acidification	1,710	gSO_2 equivalent
Photochemical	720	G ethylene
Water pollution	(20)	m^3
Eutrophication	780	gPO_4 equivalent
Municipal waste	(20)	kg
Hazardous waste	8	kg

Source: (European Commission, 2007).

Appropriate environmental performance indicators

The level of implementation for each stage can be measured by:

- Taking into account LCA studies to determine optimal LCA routes according to local factors (%)
- Share of components treated according to optimal LCA route (%)

However, for innovative processes LCA data may be unavailable or unreliable, in which case qualitative indicators can also be used.

Cross-media effects

Depending on the specific material, separation processes and recyclate markets, the environmental impacts can differ substantially. An LCA would be required to establish specific cross-media effects.

As an example, if polyurethane foam (PUF) is recycled and used again in closed loops, the physical properties can affect the environmental outcomes:

- In auto seats, the physical properties of the recycled PUF are not as good as those of the virgin material. Therefore, an extra amount of PUF must be used to provide the required performance of the seat. For example, to make one seat cushion from PU, 1.5 times the amount of recycled PU must be used compared to virgin material, which means that the use of the recycled PU will cause negative environmental impacts compared to the use of virgin material. (European Commission, 2007).
- In auto carpet underlay, the physical properties of recycled PUF are more similar to the virgin material and it can replaced an equal amount of virgin PU – this application brings environmental benefits (European Commission, 2007).

A problem common to all large plastic parts is that storage can require a lot of space, and it may be necessary for the ATF to reduce their size using energy intensive processes such as shredding. If the parts are not shredded then there will likely be large amounts of unused space in the vehicles transporting the material (MVDA – personal comm., 2014).

Operational data

Operational data in this section is based on examples which demonstrate the successful application of the steps outlined above.

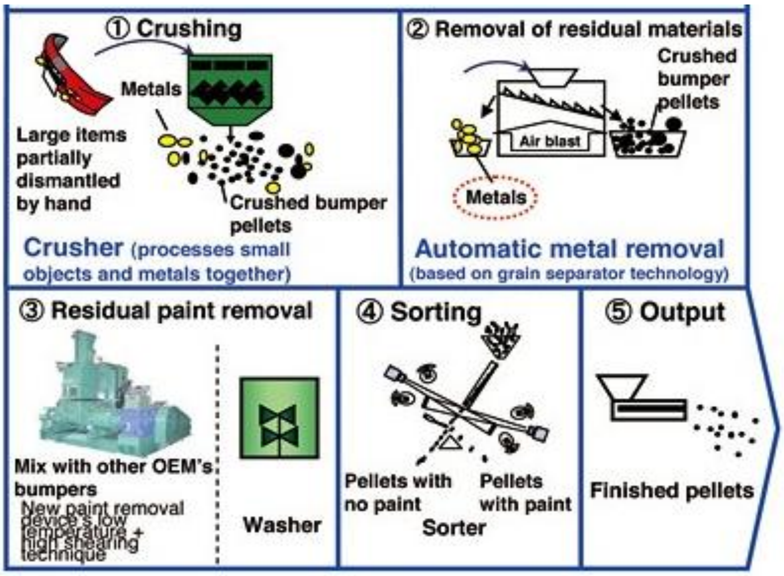
<u>Case study 1: Mazda – automated recycling for end-of-life vehicle bumpers</u>

Bumpers are a particularly interesting case study as they are the largest plastic component on a car and dismantling them is usually relatively easy – it has been common practice for dismantlers to remove bumpers when they block access to other parts, however they are rarely sent for recycling (Maudet and Bertoluci, 2007).

Using materials recycled from ELV bumpers is more technically challenging compared to reuse of damaged bumpers from newer vehicles, because the ELV bumpers are much older and vary in terms of their plastic composition, paint adhesive properties and use of metallic fastenings (Mazda, n.d.).

In Japan, Mazda developed a system to collect and recycle bumpers, achieving lower cost for the recycled material compared to using virgin material. In order to use the recycled material for new vehicle bumpers, a high degree of paint removal (99.85%) is required to ensure the recycled bumpers have the required surface quality and mechanical strength (Mazda, n.d.). An overview of the process is shown in **Figure 47** below.

Figure 47: Overview of closed loop bumper recycling



Source: (Mazda, 2009)

In the 1990s Mazda began designing bumpers to be easily recyclable: the bumper which can be swiftly removed, in one piece, during dismantling. A thin-walled construction is used for the bumper underside fastenings, so they can be easily removed manually when it is pulled hard. Bumper apertures have been strengthened so that bumpers can be pulled off in one piece without breaking (Mazda, 2009).

Crushed bumper pellets undergo a paint stripping process – this employs a kneading machine which is similar to those used for processing foodstuffs and chemicals including rubber and plastics. The machine applies a powerful shear force to the crushed bumper pellets, effectively stripping off the paint regardless of the plastic composition or paint properties, and without having to heat the plastic (PlastEurope, 2011).

The sorting stage used optical sorting to detect pellets with residual paint so that they can be removed using an air jet (Mazda, n.d.). The process allows up to 30% recycled material to be incorporated in new bumpers (Mazda, n.d.).

<u>Case study 2: Nissan – specifying high recycled material content</u>

The Nissan Leaf uses recycled materials in almost every part of the car, many of which are plastics:

- Insulation layers in the floor and skin fabric of headlining are made with fibres from recycled plastic (Visser, 2011).
- Fabric for the seats and armrests is made from recycled PET bottles (Visser, 2011).
- Rear and front bumpers are made from used or damaged recycled bumpers that have undergone a paint removal and recycling process (Visser, 2011).
- Back door trim: End of life vehicles are taken apart and plastic components are recycled into Back door trim and door pockets of the LEAF
- Recycled materials are also used for the roof trim and carpeting and a number of other interior pieces such as the door panels and centre console storage cover (Nissan, 2012).

Figure 48: Overview of recycled materials used in the Nissan Leaf

Source: (Nissan, 2014)

Further examples from other manufacturers include:

- Renault is committed to using 50kg of recycled plastics in all new vehicles vehicle by 2015 (equal to an average 20% of the plastic content of a modern Renault), and has already started to implement this on their existing range of vehicles. The proportion of recovered plastic used in components varies from between 7% and 13% for Renault models under their "ECO_2" range (Renault Nissan, 2011). Renault also participates in a pilot project to investigate increased recycling rate in short-loop partnership (ICARRE95, 2015).
- 100% recyclate parts are also used in vehicles, for example Ford have used 100% recyclate (from plastic bottles and other post-consumer waste) to create seat fabric in their REPREVE vehicle.
- Up to 15% recycled plastics are now incorporated into BMW vehicles across models (Zöbelein – personal comm., 2014).

Applicability

The quality of a plastic part at the end of its life will vary, which will affect its end-of-life treatment (MVDA – personal comm., 2014). In addition, before recycling plastic parts, unwanted materials such as metal attachments must be removed and the material must be sorted according to its recyclability. This may prohibit recycling where attachments are difficult to remove, and where the material is difficult to identify or consists of multiple, or rare polymers.

In the current context, it is seldom considered economically worthwhile for European ATFs to dismantle large plastic parts from vehicles, prior to shredding, due to factors such as logistical costs, space for storage, the variety of polymers in use, and the volume of materials required to make such an exercise profitable (ARN – personal comm., 2014).

Increasing use of composites in the future will have a considerable impact on end-of-life treatment of vehicles. There is little current knowledge of how composites will be dealt with in the shredding process (EGARA – personal comm., 2014), (MVDA – personal comm., 2014). Composites are usually not thermoplastics, and so cannot be recycled as granulate (ARN – personal comm., 2014). Therefore, if these plastic parts are not removed prior to shredding, then composites will become an additional contaminating element in the ASR (similar to PVC), as current post-shredder technology is not capable of isolating reinforced plastics (MVDA – personal comm., 2014), (ARN – personal comm., 2014). In addition, the metal fraction of the ASR will decrease in relation to the plastic fraction, which may affect the method of recovery for both materials (ARN – personal comm., 2014). In the current context, recycling of composites is limited due to the relatively small volumes of material in the vehicle fleet, issues concerning material identification, and the negligible value of recycled composite (MVDA – personal comm., 2014).Today, the application of recycled material in vehicles is usually limited to the non-visible areas, due to the quality of the surface finish. However, there are also applications where recyclates cannot be used from an engineering perspective. Typically, due to the varied content of recyclates, these materials have a wider range in properties, which can lead to process instabilities, in particular for critical parts with complex shapes, or those with thin walls (Schmidt & Gottselig, 2006). There is also the risk that the introduction of older plastic grades in new vehicles will not allow end-of-life recyclers to take advantage of state-of-the-art plastic processing technologies (Schmidt & Gottselig, 2006). Furthermore, typical plastics used by the automotive industry in the past may not be used in these applications in the future (i.e. recycling markets for these materials depend on the demand in other industries) (Schmidt & Gottselig, 2006). For example, historically bumpers were made from SMC or PC/PBT but there is little application for this material to be recycled today (Schmidt & Gottselig, 2006). Moreover, the contemporary fleet of vehicles only demand recycled plastics for niche applications; they cannot absorb the volumes put into the market in the past (Schmidt & Gottselig, 2006)

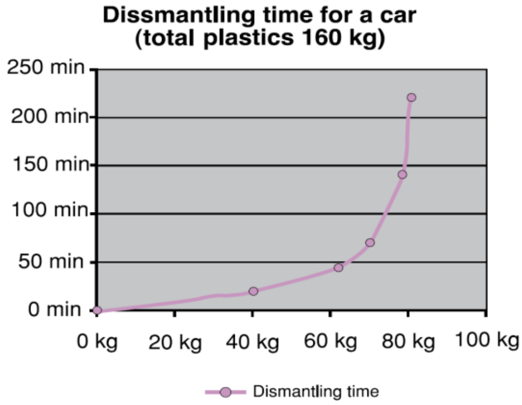
Economics

The removal of large plastic components from vehicles is sensitive to labour costs as well as the market price for recovered material (Optimat, 2013). In addition, the value of dismantled plastic will vary according to its quality and composition, and may be positive or negative. However, generally the costs of treatment of plastic are likely to be low compared to the cost of dismantling (GHK & Bio Intelligence Service, 2006).

There is a steep marginal cost curve associated with dismantling of plastic from ELVs. The first 70kg of plastic (i.e. large plastic parts) can be removed relatively cost-effectively, however there is a sharp increase in costs for the removal of smaller parts (

Figure 49) (Optimat, 2013). Existing studies suggest dismantling costs for plastics of €200-300/tonne for dismantling of 30-40kg of plastics from each ELV, with costs rising towards €1,000/tonne for dismantling much larger quantities (e.g. 70kg) (European Commission, 2007).

Figure 49: Dismantling time for a car (total plastics 160kg)



Overcoming these economic barriers is a key issue, but examples of economically viable alternatives exist, particularly where parts are large and more easily removed – for instance, Mazda's advanced closed-loop recycling technique makes closed loop recycling for bumpers cheaper than the cost of new material (PlastEurope, 2011)[63].

The development of a market for recyclate is also a key issue which is affected by the cost of virgin material relative to recyclate. The use of recycled material in components will be heavily influenced by the distance of the manufacture site from the source of supply; as the value per kg falls for a material, so it becomes uneconomic to move it very far.

Nevertheless, post-shredder advanced mechanical separation may provide a more cost effective recycling option, although quality of the recycled material may be lower.

Driving force for implementation

Regulatory factors are a key driver. The End-of-Life Vehicle Directive (2000/53/EC) set a target of 95% recovery by 2015 for vehicles below 3.5 tonnes, and therefore indirectly sets targets for large plastic parts. Furthermore, Annex I of the Directive specifies that certain materials must be removed from an ELV at the dismantling stage to promote recycling, including large plastic components, if these materials are not segregated in the shredding process.

There is also a competitive element to recycling: if a manufacturer can achieve closed-loop recycling then they stand to save money on virgin polymers used in the production process.

Reference organisations

The Japanese unit of Mazda has tested and achieved implementation of some of the recommendations relating to simplification of large plastic part design, removal and closed-loop recycling.

[63] Furthermore, in one specific case in the Netherlands, post-shredder treatment can cost as much money to run as it would cost to pay for pre-shredder dismantling (EGARA – personal comm., 2014).

Renault, through the ICARRE95 project, has attempted to demonstrate some of the principles at a prototype scale.

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4.3 Best practices for other automotive components and materials

Description

An ELV contains many other components that must be treated at the ELV stage to minimise overall environmental impacts. Due to the importance of these components, the reader is referred to guidance outlined in Table 66.

Table 66: Recommended guidance for best practice in end-of-life treatment of additional automotive components and materials

Additional guidance is provided in the Reference Document on the Best Available Techniques in the non-ferrous metals industries **(NFM-BREF)** (European Commission, 2001), which is relevant to the treatment of batteries and catalysts: • Recovery of lead, nickel, cadmium and other materials from batteries; • Recovery of precious metals from automotive catalysts; • Measures to reduce the environmental impact of battery breaking, including treatment of contaminated water, use of polypropylene from the crushed battery cases etc. At the time of writing, the guidance document on non-ferrous metal industries is currently under revision (draft in process). For the latest documents, please refer to the online repository[64]. General best practices are covered under guidance Reference Document on the Best Available Techniques for the Waste Treatment Industries **(WT-BREF)** (European Commission, 2006), which includes several aspects of particular relevance to the automotive industry: • Treatment of waste containing mercury (e.g. lamps, batteries); • Treatment of fluids (oil filters, steering, brake and transmission oils, antifreeze); At the time of writing, the guidance document on waste treatment industries is currently under revision (forthcoming). For the latest documents, please refer to the online repository[65].

Reference literature

European Commission. (2001). Reference Document on the Best Available Techniques in the non-ferrous metals industries. Available at: http://eippcb.jrc.ec.europa.eu/reference/BREF/nfm_bref_1201.pdf (accessed 18/06/2014).

European Commission. (2006). Reference Document on Best Available Techniques for the Waste Treatments Industries . Available at: http://eippcb.jrc.ec.europa.eu/reference/BREF/wt_bref_0806.pdf (accessed 21/06/2014).

[64] http://eippcb.jrc.ec.europa.eu/reference/
[65] http://susproc.jrc.ec.europa.eu/activities/emas/

5 Conclusions

This document identifies the most important environmental aspects, direct or indirect, relevant to the organisations or companies belonging to the Car Manufacturing Sector. The report presents some Best Environmental Management Practices for dealing with these identified aspects, including also sector-specific environmental indicators which allow the tracking of sustainability improvements. The following TABLE lists all the BEMPs presented in the document, including some details on their applicability, the environmental performance indicators applicable for each of them and, finally, also the benchmarks of excellence which were agreed by the Technical Working Group for this sector. As mentioned in the Preface of this document, the benchmarks of excellence represent the highest environmental standards that have been achieved by companies implementing each related BEMP; however, they are not targets for all organisations to reach but rather a measure of what can be achieved (under stated conditions) that companies can use to set priorities for action in the framework of continuous improvement of environmental performance.

Note: - **Environmental Performance Indicators** represent metrics that can be used by organisations in the sector to monitor either the implementation of the BEMPs described or, when possible, their environmental performance directly. For e.g. EMAS-registered organisations they can be used (or adapted) as a complement to the core indicators mentioned in the EMAS Regulation. Indicators are designed to be used for continuous improvement through time, or potentially across sites of the same organisation, but not to enable direct comparisons between organisations.

- **Benchmarks of Excellence** represent the highest environmental standards that have been achieved by companies implementing each related BEMP. These aim to allow all actors in the sector to understand the potential for environmental improvement at the process level. Benchmarks of excellence are **not targets** for all organisations to reach but rather a measure of what could be achieved (under specific conditions).

In many indicators presented below, the term 'functional unit' refers to a unit of output, of activity or resource use chosen by each organisation to reflect what is most relevant for its specific case (and can be adapted depending on the site, environmental aspect considered, etc…), as discussed in *Box 1*.

Some indicators or benchmarks can be relevant for several BEMPs, as may be the case below.

BEMP #	Title	Applicability	Environmental Performance Indicators	Benchmarks of Excellence
		Manufacturing		
3.1 Environmental management				
3.1.1	Implementing an advanced environmental management system	Generally applicable	- Sites with an advanced environmental management system (% of facilities/operations) - Number of environmental performance indicators that are in general use throughout the whole organisation and/or which are reported on in environmental statements; - Use of internal or external benchmarks to drive environmental performance (Y/N)	- An advanced environmental management system is implemented across all production sites globally

3.2 Energy management				
3.2.1	Implementing detailed energy monitoring and management systems	Generally applicable	- Number of facilities with adequate energy monitoring systems (# or % of facilities / operations); - Number of facilities with an energy management system certified ISO 50001 or integrated in EMAS (# or % of facilities / operations).	- Specific energy management plans are implemented across all sites (organisation level) - Detailed monitoring per process is implemented on-site (site level) - The plant implements energy management controls, e.g. to switch off areas of the plant during non-productive times for sites with detailed monitoring (site level)
3.2.2	Increasing the efficiency of energy-using processes	Generally applicable	- Implementation of regular reviews of systems, automation, repair, maintenance and upgrades (% of sites) - Overall energy use (kWh) per functional unit per year	N/D
3.2.3	Alternative energy sources – renewable energy generation	Generally applicable	- Share of production sites assessed for potential opportunities for use of renewable energy sources (%) - Share of site energy used met by renewable sources (%) - Energy consumption from fossil fuels (MWh or TJ) per functional unit	- All production sites are assessed for potential and opportunities for use of renewable energy sources - Energy use is reported, declaring the share of fossil and non-fossil energy - A policy is in place to drive an increase in renewable energy use
3.2.4	Optimisation of lighting in automotive manufacturing plants	Generally applicable	- Implementation of improved positioning, energy-efficient lighting (% of lighting areas within a site, % of total sites). - Implementation of lighting zonal strategies (% of lighting areas within a site, % of total sites).	- The most energy efficient lighting solutions appropriate to specific work place requirements are implemented at all sites - Zoning schemes are introduced in all sites according to best

			- Energy use of lighting equipment (if measured at detailed level), in kWh/year for a plant - Average efficacy of luminaires throughout plant (lm/W)	practice levels
3.2.5	Rational and efficient use of compressed air	Generally applicable	- Specific electricity use of the compressed air system (kWh/Nm³ of delivered compressed air, at the specified operating pressure of compressed air system)	- Energy Performance Indicator <0.11 kWh/m3 [for a compressed air system operation at a pressure of 6.5 bars effective, with volume flow normalised at 1013 mbar and 20°C, and pressure deviations not exceeding 0.2 bar effective]. - After all air consumers are switched off, the network pressure remains stable and the compressors (on standby) do not switch to load condition.
3.2.6	Optimisation of electric motor usage	Generally applicable	- Share of electric motors with VSD installed (% of total installed power or of total number) - Share of pumps with VSD installed (% of total installed power or of total number) - Average pump efficiency (%)	N/D
3.3 Waste management				
3.3.1	Waste prevention and management	Generally applicable	- Waste generation per functional unit (kg / functional unit) - Hazardous waste generation per functional unit (kg / functional unit) - Waste sent to specific streams, including recycling, energy recovery and landfill	- Waste management plans including monitoring introduced in all sites - Zero waste sent to landfill, achieved from all production and non-production activities/sites

			(kg/functional unit, % total waste). - Establishment and implementation of an overarching waste strategy with monitoring and targets for improvements has been (Y/N) - Number of sites with advanced waste management plans in place - Number of sites achieving target levels of waste management, such as zero waste to landfill	
3.4 Water management				
3.4.1	Water use strategy and management	Generally applicable	- Water use per functional unit (m^3 / functional unit) - Sites that have conducted a water strategy review (% of facilities/operations) - Sites that have monitoring for water use (%) - Sites that have separate water monitoring for production processes and sanitary use (%)	- Introduction of a water strategy according to a recognised tool, such as the CEO Water Mandate, integrating an assessment of water scarcity - Water use on-site is measured per site and per process, if appropriate using automated software
3.4.2	Water-saving opportunities in automotive plants	Generally applicable	- Water use per functional unit (m^3 / functional unit) - Share of operations in existing sites retrofitted with water-saving devices and processes (%) - Share of new sites designed with water-saving devices and processes (%)	- All new sites are designed with water-saving sanitary devices and retrofitting of water-saving devices is phased in across all sites
3.4.3	Water recycling and rainwater harvesting	Generally applicable	- Water use per functional unit (m^3 / functional unit) - Installation of a wastewater recycling	- Closed loop water recycling implemented with recovery rate of at least 90% where feasible

			system (Y/N) - Installation of a rainwater recycling system (Y/N) - Yearly quantity of rainwater use and wastewater reuse (m^3/yr) - Percentage of total water use met by recycled rain- or wastewater (%).	- 30% water needs met by harvested water, (in regions with sufficient rainfall)
3.4.4	Green roofs	Generally applicable	- Percentage of sites that are suitable for green roofs with green roofs installed (%) - Water holding capacity of the green roof: share of water retention (%), water run off (m^3); - Cooling effect: reduction in energy demand for HVAC (MJ); - Qualitative biodiversity indicators (e.g. number of species living in the roof).	N/D
3.5 Biodiversity				
3.5.1	Review and strategy of ecosystems and biodiversity management throughout the value chain	Generally applicable with a focus on large manufacturers	- Application of methodologies to assess ecosystem services to the value chain (Yes/No – or % coverage of the value chain) - Coverage of relevant scope, as determined by prioritisation (Yes/No – or % coverage of the value chain).	- A high-level ecosystem review is conducted across the value chain, followed by a more detailed ecosystem review in identified high risk areas - Strategies to mitigate issues are developed across the supply chain, in collaboration with local stakeholders and external experts
3.5.2	Biodiversity management at site level	Generally applicable	- Number of projects or collaborations with stakeholders to address biodiversity issues (#). - Procedure /instruments are in place to	- A comprehensive biodiversity plan is in place to ensure systematic incorporation through measurement, monitoring and reporting

			analyse biodiversity related feedback from customers, stakeholder, suppliers (Yes/No). - Inventory of land or other areas, owned, leased or managed by the company in or adjacent to protected areas or areas of high biodiversity value (area, m²). - Plan for biodiversity friendly gardening in place for premises or other areas, owned, leased or managed by the company (yes/no). - Total size of restored habitats and/or areas to compensate for damages to biodiversity caused by the company (m²) in comparison to land used by the company (m²). - Biodiversity Index (to be developed according to local conditions)	- Cooperation with experts and local stakeholders
3.6 Supply chain management, logistics and design				
3.6.1	Promoting environmental improvements along the supply chain	OEMs, Tier 1 suppliers	- Share of Tier 1 (direct) suppliers (by number or by purchasing budget/value) that comply with required standards according to internal or external audits (%); - Self-assessment questionnaires are sent to direct high risk suppliers (Y/N) - Direct supplier development and training is undertaken (Y/N)	- All major suppliers are required to have an environmental management system in order to qualify for purchasing agreements - Environmental criteria are set across all environmental impact areas for purchasing agreements - All direct suppliers are sent self-assessment questionnaires and high risk suppliers are audited by third parties - Direct supplier development and training is undertaken - Enforcement procedures are defined for non-compliance

3.6.2	Collaborate with suppliers and customers to reduce packaging	Generally applicable	- Waste generation per functional unit (kg / functional unit) - Packaging waste generation per functional unit (kg / functional unit) - Packaging waste generation per site or maintenance group (kg / site, kg / maintenance group)	N/D
3.6.3	Design for sustainability using Life Cycle Assessment (LCA)	OEMs	- Conducting LCA of the main product lines to support design and development decisions (Y/N) - Improvements in environmental indicators (CO_2, energy consumption, pollution etc) for new model designs in the main product lines compared to previous model designs (%) - Conduct comparisons among different kinds of mobility concepts (Y/N)	- LCA is conducted for main product lines according to ISO 14040 : 2006 standards or equivalent - Targets are set to ensure continuous improvements in the environmental impacts of new vehicle designs
3.7 Remanufacturing				
3.7.1	General best practices for remanufacturing components	Remanufacturers	- Level of remanufacturing (weight per component - %) - Overall remanufacturing levels (% of recovered components).	N/D
End-of-life vehicles				
4.1 ELV logistics				
4.1.1	Component and material take-back networks	ATFs, remanufacturers	- Recovery rate (%) for specific products or materials through ELV networks.	- Collaboration and partnerships in place with local/national organisations to implement take-back networks

4.2 ELV treatment				
4.2.1	Depollution of vehicles	ATFs	- Removal rate of components (%) - Recovery rate of fluids (%) - Installation of commercial depollution machine or equally performing equipment (Y/N) - Use of mass balancing techniques to monitor depollution rates (Y/N) - Adoption of a quality management system (Y/N)	- A certified quality management system is in place in the organisation
4.2.2	General best practices for plastic and composite parts	ATFs	- LCA studies are considered to determine optimal material routes according to local factors (Yes/No) - Share of components treated according to optimal LCA route (%)	N/D
4.3	Best practices for other automotive components and materials	ATFs	- Recycling rate (%) - Reduction in environmental impacts according to LCA criteria	N/D

N/D: Not Defined

N.B. note on applicability: the major target stakeholders for each group of BEMP is detailed in section 1.4.

"Generally applicable" in the table above refers to general BEMPs where, although written from e.g. a manufacturer's perspective, many elements can be of interest to all stakeholders, including manufacturers, tier1+ suppliers, remanufacturers and ATFs.

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LIST OF ABBREVIATIONS

ACEA	Association des Constructeurs Européens d' Automobiles (European carmakers' association)
ATF	Authorised Treatment Facility
BAT	Best Available Technique
BEMP	Best Environmental Management Practice
BPR	Best Practice Report
BREF	Best Available Technique Reference Document
ELV	End-of-Life Vehicle
EMAS	EU Eco-Management and Audit Scheme
EMS	Environmental Management System
EnMS	Energy Management System
EPI	Environmental Performance Indicator
FCA	Fiat Chrysler Automobiles
FMP	Ferrous Metals Processing [BREF]
GHG	Greenhouse Gas
HVAC	Heating, Ventilation and Air Conditioning
IED	Industrial Emissions Directive
ISO	International Standards Organisation
JRC	European Commission Joint Research Centre
LCA	Life Cycle Analysis
LED	Light Emitting Diode
N/D	Not Defined
PBDE	Polybrominated diphenyl ether
POP	Persistent organic pollutant
SF	Smitheries and Foundries [BREF]
SRD	Sectoral Reference Document
STM	Surface Treatment of Metals and Plastics [BREF]
STS	Surface Treatment Using Organic Solvents [BREF]
TWG	Technical Working Group
VCI	Vapour-phase Corrosion Inhibitor
VSD	Variable Speed Drive
VW	Volkswagen

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