ECOThink

Design for Sustainability

Educational Materials and Practical Worksheets for Designing Sustainable Products and Processes

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ACEEU LEVILO MITR

Project

ECOThink – Empowering Skills in Sustainable Design and Life Cycle Thinking

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Partners

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Summary

The handbook offers a structured and practice-oriented approach to the design of sustainable products and processes. It was developed as part of the ECOThink project as an educational and learning resource aimed at vocational education and training (VET) students, young entrepreneurs and sustainability professionals.

The content is divided into eleven chapters, which systematically guide the reader through the entire sustainable design process – from understanding the basics of sustainable development and thinking in life cycles, through assessing environmental, economic and social impacts, to developing and implementing concrete eco-innovation strategies. The manual includes theoretical explanations and practical worksheets supporting knowledge application in real-world design contexts.

The material promotes active learning and supports cross-sectoral cooperation and the development of green skills in eco-design, life-cycle thinking and reducing the carbon footprint. By combining knowledge and practical application, the manual enables users to design solutions aligned with market requirements and the SDGs.

The publication directly supports the mission of the ECOThink project: to strengthen green competences, increase employability and accelerate the transition to a sustainable economy through quality education and innovation.

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0 Introduction

0.1 Purpose and content of the manual

The Sustainability Planning Manual is designed as a practical, user-friendly and systematic tool for small and medium-sized enterprises (SMEs) and vocational schools and educational institutions (VET) that want to introduce sustainable design principles into the development of products and services.

When environmental and social challenges are becoming more pronounced today, companies and future professionals must think holistically at an early stage of development – considering environmental, social and economic aspects. Integrated sustainability thinking is also key in EU policies and global research frameworks (Bocken et al., 2014; ISO, 2020a; UNEP, 2020). Such an approach reduces negative impacts on the environment and society and increases innovation, market value and long-term resilience of companies. The handbook aims to present the key steps and tools for effectively implementing sustainable design principles in an understandable and structured way. Includes:

- modern methods such as sustainability planning, life cycle assessment (LCA) (ISO 14001:2015), eco-labelling and ESG (environmental, social and governance factors);
- circular economy and sustainable innovation approaches (European Commission, 2020),
- Practical worksheets, recommendations, and appropriate tools are accessible via the ECO-Think project web portal.

The manual is divided into eleven logically related chapters that guide the reader through the entire process – from setting up a team and analysing the existing situation to developing new solutions and evaluating the effects. Each chapter is directly linked to the corresponding worksheets, which allows immediate application of the acquired knowledge in practice.

The methodology is specifically tailored to SMEs, considering their specificities, limited resources and the need for flexibility. At the same time, it is also designed as a didactic material for the VET environment – to empower pupils, students and young professionals to become agents of change in sustainable development.

The most crucial factor for the successful implementation of sustainable design is intrinsic motivation – in companies, it often comes from the personal initiative of individuals such as engineers, designers, executives or environmental experts. In the educational environment, however, the key is to encourage critical thinking and integrating knowledge and creativity.

This guide offers a clear starting point and structured support, but the real power of change comes from commitment, collaboration, and a willingness to learn. We invite you to adapt your approach to your environment, find internal ambassadors and start creating products and services that will respond to future needs.

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Figure 0.1: Recommend following the planning steps for sustainability by displaying relevant chapters and worksheets.

0.2 Products and sustainability

It is becoming increasingly clear that the prevailing production and consumption patterns are no longer sustainable. Environmental crises, deepening social inequalities, and increasing pressures on limited natural resources are reminders of the need for holistic changes, including those in product design, manufacture, and use.

In a world marked by globalisation and digital intertwining, companies of all sizes – from micro and small enterprises to multinational corporations – are actively looking to operate more sustainably. Solutions based on the principles of sustainable development are coming to the fore (Ellen MacArthur Foundation, 2021; European Commission, 2020): integrating sustainable practices into supply chains, improving resource and energy efficiency, decarbonising business processes, using renewable resources, planning with circularity in mind, and reporting on environmental and social impacts in line with the latest frameworks such as CSRD, GRI, ESG and ISO 14001.

Design for Sustainability is an overarching approach that goes beyond the traditional boundaries of sustainability planning. It focuses on the entire system of products, services and related user behaviour. The focus is no longer just on optimising an individual product, but on finding the best solutions to meet user needs with a minimal environmental footprint, greater social responsibility and market performance.

Concepts such as sustainable planning, material-efficient design, circular design and design for the environment are now an integral part of the broader concept of design for sustainability. They are based on principles that simultaneously improve environmental performance, create social added value and increase economic competitiveness.

Designing for sustainability is not only a response to regulatory pressures, but is becoming a key strategic direction for modern businesses. It enables them to develop more innovative, responsible and resilient business models. It is linked to the trends of digitalisation, the development of the circular economy, ESG policies, sustainable markets and investor expectations (OECD, 2022).

At the heart of the design approach for sustainability are three fundamental pillars of sustainability:

- People,
- Planet (Planet),
- Profit (Profit).

These elements intertwine with each other to create a basis for product renewal that is only sustainable if it also takes into account:

- the carrying capacity of ecosystems;
- fair distribution of value in supply chains;
- diverse needs of stakeholders (customers, employees, communities, legislators and investors).

The design of sustainably oriented products and services requires companies to act in concert in the environmental, social and economic fields. This comprehensive approach is key to transitioning to a more sustainable, equitable and low-carbon future.

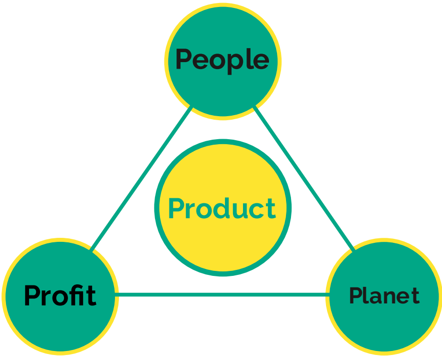


Figure 0.2: Correlation of products with three key aspects of durability (Goedkoop, 1995).

0.3 Examples of sustainability challenges in three dimensions

0.3.1 People – social aspects

- Improving working conditions, safety and quality of life of employees;
- Reducing unemployment and broader access to education and vocational training;
- Promoting gender equality and the inclusion of vulnerable social groups;
- Eliminating child and forced labour in supply chains;
- Provision of basic services: health care, clean drinking water and basic education;
- Enforcement of international labour law standards (e.g. International Labour Organisation – ILO conventions);
- Strengthening social cohesion and partnership cooperation with local communities.

Planet – environmental aspects

- Reducing the consumption of fossil fuels and switching to renewable energy sources;
- Increasing energy and material efficiency throughout the value chain;
- Reducing the use of hazardous substances and greenhouse gas emissions;
- Promoting circular design: design for dismantling, reuse and recycling;
- Conservation of biodiversity, natural habitats and protected areas;
- Reduction of industrial emissions and waste and remediation of polluted environments;
- Protecting water resources and reducing land use and degradation.

Profit – economic aspects

- Ensuring a fair distribution of benefits between businesses, customers and stakeholders;
- Developing sustainably oriented market niches and strengthening competitive advantage;
- Connecting small and medium-sized enterprises (SMEs) to global sustainable value chains;
- Establishing fair pricing models and long-term strategic partnerships;
- Reducing costs through more efficient resource management and optimisation of logistics;
- Strengthening the company's and brand's reputation and better access to ESG financing;
- Using innovation to develop new sustainable business models and products.

0.3.2 Products and environmental aspects – Planetary inclusion

In the early stages of environmental policy development, especially in the late 1980s and early 1990s, attention was paid primarily to managing emissions and final pollution streams. The focus was on so-called reactive technologies – wastewater treatment, emission capture and waste management. In the mid-1990s, however, the approach gradually shifted towards preventing environmental impacts at source – by introducing cleaner technologies, more efficient use of resources, and concepts such as *eco-efficiency* and *cleaner production*.

Further development has brought a broader systemic view that includes the entire product life cycle – from raw material extraction, production and distribution, to use and final treatment after use. This understanding has led to the development of methods such as *Life Cycle Assessment (LCA)* and the integration of environmental considerations into product design and design phases.

Modern design for sustainability builds on this approach and incorporates social and economic impacts, thus supporting the integrated implementation of the Sustainable Development Goals (Agenda 2030). In this way, the environmental aspect becomes part of a broader decision-making framework that treats the product as part of a complex system of interactions with the environment, society and the economy.

Environmental impacts associated with a product can be classified into three main categories:

- Ecological damage,
- Harm to human health,
- Depletion of natural resources.

These categories cover the range of environmental pressures that arise along the life cycle of a product. Understanding these impacts is key to improving the environmental performance of products and processes in large, small and medium-sized enterprises (SMEs).

Table 0.1: Types of environmental impacts.

Type of impact	Description
Ecological damage	
Global Warming/Climate Change	The result of greenhouse gas emissions from fossil fuels, industry and agriculture. They cause extreme weather events, rising sea levels, ecosystem changes, and health impacts.
Depletion of the ozone layer	Caused by emissions of CFCs and similar compounds. The consequences include increased UV radiation and adverse effects on humans, animals and flora.
Acidification (acidification)	The result of emissions of SO_2, NO_x and other gases that lead to acid rain and affect soil, water, organisms and infrastructure.
Eutrophication	Excessive nutrient uptake (e.g., nitrates, phosphates) into aquatic and terrestrial ecosystems leads to reduced water quality, algal blooms, and ecosystem degradation.
Land use and habitat degradation	Changes in the natural environment due to urbanisation, agriculture and infrastructure, resulting in biodiversity loss.
Ecotoxicity	Adverse effects of toxic substances on plants, animals and microorganisms in soil, water or air.
Harm to human health	
Smog and polluted air	Emissions of NO_x, particulate matter (PM), SO_2 and other pollutants cause respiratory problems, asthma, cardiovascular disease and premature mortality.
Substances harmful to health	Non-carcinogenic substances with irritant or hormonal effects (e.g. endocrine disruptors, allergens, growth inhibitors).
Carcinogens	Substances that have been proven to cause cancer in humans or animals (e.g. benzene, formaldehyde, certain metals).
Depletion of natural resources	
Fossil fuels	Oil, natural gas, and coal are consumed much faster than they can be naturally replenished.
Fresh water	Overuse of surface and groundwater resources leads to their depletion and scarcity.
Minerals	The exploitation of metal ores leads to a decrease in the quality of resources and a growing need for recycling.
Top layer of soil	Intensive agriculture and forestry are causing erosion that exceeds the rate of natural soil regeneration.

0.3.3 Products and social aspects – people's involvement

Over the past decade, the societal aspects of sustainability have gained much attention, and research shows that tools such as S-LCA can significantly contribute to fairer supply chains (ISO, 2020b; Pollok et al., 2021). The lack of fair working conditions, labour exploitation, human rights violations and unethical practices in supply chains – such as child labour, forced labour or unsafe working conditions – are increasingly the subject of research, campaigns and public pressure.

Many companies have begun incorporating social responsibility as an integral part of their business strategies. Thus, besides economic and environmental objectives, they are increasingly pursuing objectives related to improving social impacts. This applies to large corporations and SMEs, as stakeholders' expectations – investors, customers, employees, suppliers, NGOs and local communities – become increasingly geared towards sustainable and responsible action.

Products and production processes affect people at all stages of their life cycle. Societal impacts can occur in the extraction of raw materials, in the production, distribution, use, and even after the end of the product's use. It is essential for a company to understand the broader range of possible societal impacts and to manage risks and opportunities in this area actively.

Key societal impacts include:

- the health and safety of workers in the workplace;
- exposure to hazardous chemicals;
- opportunities for decent work and fair wages;
- protection of human rights in supply chains;
- social inclusion of vulnerable groups;
- the accessibility and safety of products for users;
- conflicts over natural resources (e.g. drinking water, food, land);
- impacts on local communities and cultural heritage.

Companies that understand the importance of these issues are better prepared to identify risks, improve their practices, and design products and services that enhance societal benefits. Incorporating social considerations into sustainability design processes enables the development of solutions that contribute to fairer and more inclusive economic models.

Tools such as:

Social Life Cycle Analysis (S-LCA) is also essential, complemented by modern approaches to assessing the impact on human rights, working conditions and gender equality (ISO, 2020b; Neugebauer et al., 2016).

- Social Life Cycle Analysis (S-LCA),
- OECD Guidelines for Responsible Business Conduct;
- standards such as ISO 26000 (social responsibility),
- and indicators within ESG reporting.
- With a holistic approach, companies can achieve more than just compliance with the law – they can become active actors of positive social change.

0.3.4 Products and financial aspects – inclusion of profits

In addition to the environmental and social benefits, design for sustainability can also have significant positive financial impacts. Incorporating sustainability considerations into product and process development can significantly contribute to a company's business performance. Such an approach not only brings about legislation compliance but also opens up many strategic opportunities for growth and increased competitiveness.

Sustainable improvements often involve optimising the use of raw materials and energy, which is confirmed in comparative analyses of sustainable business models in SMEs (De Padua Pieroni et al., 2019; OECD, 2022). Both material and energy-efficient production lead to direct financial savings, especially in SMEs, where each efficiency percentage significantly impacts the cost structure.

Greener and socially responsible products allow companies to enter new markets, especially where legislation or consumer preferences encourage sustainable choices. Such products often carry certificates or labels (e.g. EU Ecolabel) that increase customer visibility, trust and perceived value.

In addition, with a clear sustainability mindset, companies can gain greater loyalty from existing customers, improve their brand and secure a competitive advantage compared to providers that do not systematically address sustainability considerations. Buyers, especially the younger generation, increasingly evaluate products based on social and environmental criteria.

Including SMEs in global sustainable value chains is also essential to sustainable design. Such involvement opens the door to long-term partnerships with international companies, increases business resilience, and strengthens the company's position in the global market. At the same time, meeting ESG criteria and disclosures often leads to access to more advantageous financing or support schemes.

Integrated design for sustainability is no longer just an environmental or ethical choice; it is becoming a key business lever for the long-term success of companies, as well as in economic terms.

0.4 What is Design for Sustainability?

Design for sustainability is a holistic approach to developing products, services and systems, which considers environmental and social impacts in addition to classic criteria such as functionality, cost, quality and aesthetics. The goal is to comply with legal requirements and actively contribute to reducing environmental burdens, improving social justice, and improving long-term business performance.

Design for sustainability goes beyond just technical optimisation (UNEP, 2020). It integrates interdisciplinary knowledge and increasingly focuses on systems transformation, including user behaviour and business models (UNEP, 2020; Geissdoerfer et al., 2022. It considers the entire product life cycle, thus enabling better decision-making in the early stages of development, where the key characteristics of the product and its environmental profile are determined.

0.4.1 Defining Design for Sustainability

Design for sustainability (sometimes called eco-design) is a systematic process of product development that considers environmental and social impacts throughout the product's life cycle, in addition to traditional factors – such as cost, technical performance and usability (Goedkoop, 1995).

Figure 0.3 shows how the classic product development criteria are upgraded by incorporating environmental criteria without significantly changing the basic structure of the development. It is an extension of an approach that includes reflection on sustainability as an integral part of quality design.

Design for Sustainability aims to develop new products or improve existing ones to meet better sustainability requirements – not only in terms of functionality, but also in terms of their impact on people and the environment. Efficient is the re-design approach, where an existing product is adapted or optimised using environmental criteria. It is an evolutionary form of innovation that is financially and feasibly achievable for many companies, and less risky than radical innovations.

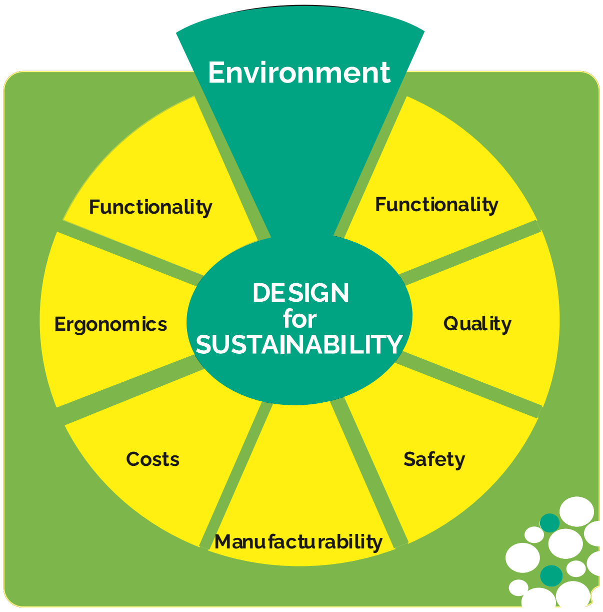


Figure 0.3: Product development criteria considering environmental criteria.

Replanning is particularly suitable as an initial step in implementing sustainability principles in a company. The market and production circumstances of the existing product are already known, and practical data – such as user experience, complaints and test results – allow for the rapid identification of potential improvements. Existing generation capacities are often already suitable for change, thus keeping investment risks low.

Because as much as 80% of environmental impacts are determined at the design stage of the product (UNEP, 2021) (Crul & Diehl, 2009), the developer plays a key role in shaping its sustainability profile. At this stage, decisions are made about the product's materials used, construction, functionality and service life. Therefore, environmental considerations must be systematically included in the early stages of the planning process.

Figure 0.4 illustrates how early design decisions determine many environmental consequences in the later stages of a product's life cycle.

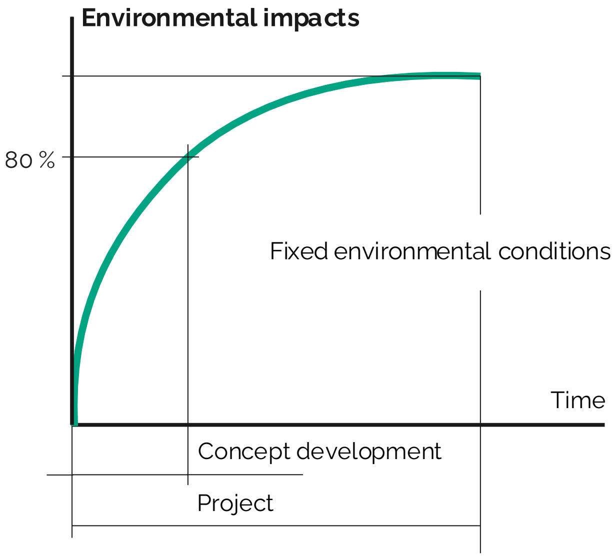


Figure 0.4: Around 80 % of the environmental profile of a product is determined at the conceptual development stage (McAloone & Bey, 2009).

0.4.2 Product life cycle

Design for sustainability aims to reduce a product's environmental and social impacts throughout its life cycle, which is supported by advances in LCA methods, including social and economic components (Klöpffer & Grahl, 2014). The life cycle includes several successive phases of the product system (Figure 0.5). The process starts with extracting, recovering, and supplying raw materials and energy. Then it includes production, distribution, use (including maintenance and reuse), and final treatment at the end of life through recovery, recycling or disposal.

Each phase contributes to specific environmental and social impacts that must be addressed holistically. Environmental aspects include consuming natural resources (water, energy, materials), waste generation, greenhouse gas emissions, pollutants, noise, vibration and radiation. Societal aspects include working conditions, exposure to dangerous substances, fairness in supply chains, respect for human rights, impact on local communities and end-users' safety.

Although the extraction and production stages are often under the most extraordinary scrutiny, numerous studies show that the distribution, utilisation and final disposal stages often have a larger environmental footprint. Therefore, a design approach for sustainability requires that all impacts be taken into account throughout the life cycle of a product – and not just in production.

Impact assessment using the LCA method

The basic tool for comprehensive assessment of the environmental impact of a product is the Life Cycle Assessment (LCA) method. It is a standardised methodology defined by the international standards ISO 14040 and ISO 14044 (ISO, 2020a).

LCA includes:

- Collection of data on inflows (e.g. energy, raw materials) and effluents (emissions, waste);
- Evaluation of environmental impacts (e.g. global warming, eutrophication, environmental acidity);
- and the analysis of environmental interventions through all phases of the life cycle.

LCA is valid for:

- identifying opportunities for improvement in production and design,
- identifying the 'critical points' with the most significant impacts in the value chain;
- support for decision-making in companies and institutions (e.g. strategic planning, sustainable purchasing policies);
- the development of environmental indicators, including tools for environmental reporting and ESG disclosures;
- marketing, e.g., developing environmentally declared products (EPDs), eco-labels, or communicating with investors.

Link to social and economic aspects

Although LCA is primarily focused on environmental impacts, in modern practices it is complemented by:

- Social Life Cycle Analysis (S-LCA), which assesses impacts on workers, communities and end users (Crul & Diehl, 2009);
- Life Cycle Cost Analysis (LCC) monitors economic impacts throughout the life cycle of a product.

Social influences emerge at an early stage of the life cycle, such as issues around child labour, unfair wages or a lack of equal opportunities. However, in the application phase, safety, health, and accessibility for users become key. Such issues are increasingly important in the context of ESG (Environmental – Social – Governance) disclosures required by modern legislation (e.g. CSRD).

The added value of a product can vary significantly through individual phases – it is often low in the raw material extraction phase, and higher in the service phases or phases with a higher degree of customisation to users. This difference opens up new possibilities for circular business models, where the emphasis is on reuse, servitization and optimisation of resources.

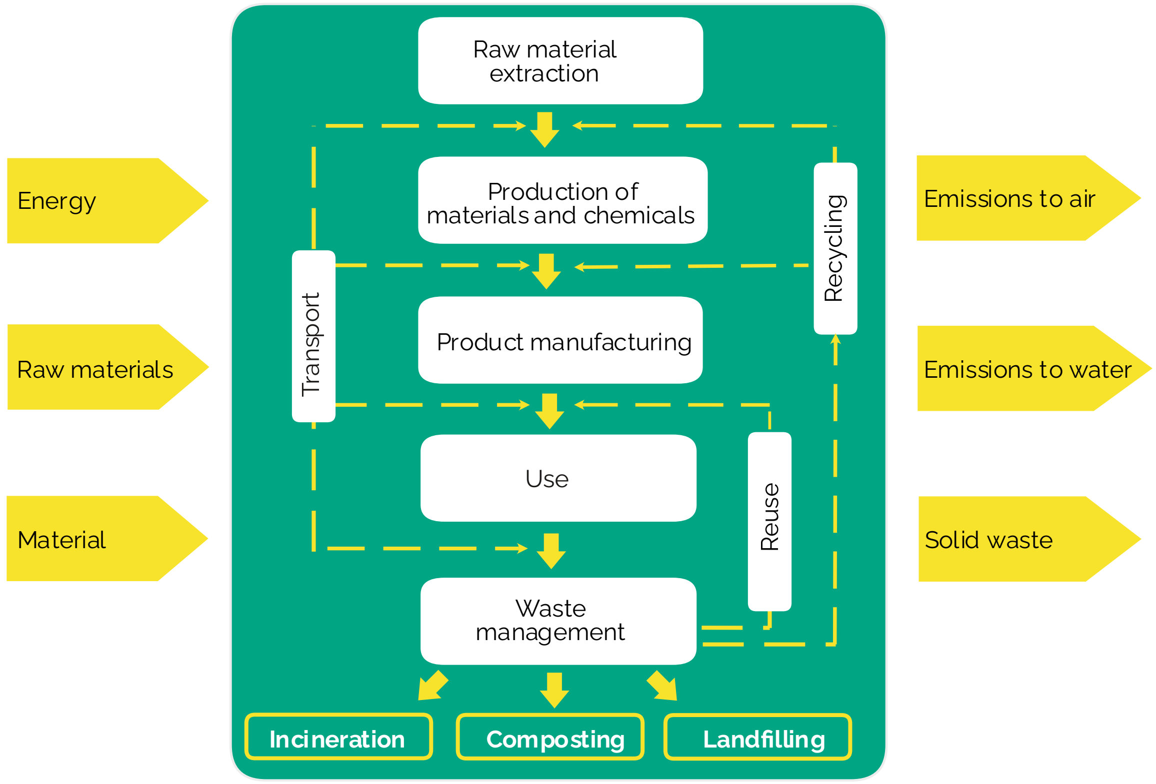


Figure 0.5: Product Life Cycle – Key Stages and Associated Impacts (IHOBE, 2001).

Example: The life cycle of a shirt

To better understand the lifecycle approach, let's look at an example of a standard everyday product – a shirt. The product incorporates various environmental and social impacts across global supply chains.

Shirts are usually made from a mixture of natural and synthetic fibres. The production of natural fibres, such as cotton, requires intensive use of water, fertilisers, pesticides and energy, and often occurs in regions where water is already a finite resource. On the other hand, producing synthetic fibres involves using fossil raw materials, chemicals, and high-energy inputs. These fibres are then transformed into fabric, which includes weaving, bleaching, dyeing and finishing processes – all of which require water, energy and chemical additives, often with a high environmental impact.

After the fabric is made, the stages of tailoring, sewing, ironing and packaging follow, usually in factories where the workforce is often not adequately protected. The shirts are then distributed worldwide – often travelling thousands of kilometres from textile production (e.g. Asia), through ready-to-wear production (e.g. North Africa), to shops in Europe. Each of these phases contributes to greenhouse gas emissions, fuel consumption, and social risks such as long working hours, low wages, or human rights violations.

At the stage of use, the average shirt will be worn and washed about 100 times. Each wash involves water, detergents and electricity, producing microfibre emissions that often end up in aquatic ecosystems. If the shirt is also dried in the dryer or ironed, the energy consumption increases even more. Research shows that use often accounts for the largest share of the environmental impact of textiles (Roos et al., 2015).

When a shirt is no longer usable – due to wear and tear, damage or fashion trends – most consumers throw it away. Due to the mixed materials (e.g. cotton + polyester), the shirt is difficult to recycle, unsuitable for composting, and often ends up in a landfill or incineration. The initial stages did not consider the circular design, so the waste management challenges were also predetermined.

It is also necessary to take into account the social impacts of the entire supply chain: working conditions on cotton plantations, safety in dyeing and sewing factories, and the political and economic situation in the countries of production. Such an example may be a factory that employs children or workers without adequate protection, which implies apparent deviations from the principles of social responsibility and ESG criteria.

This example illustrates the importance of considering the entire life cycle – not only cost and quality, but also the environmental footprint, health impacts, circularity of materials and social conditions at all stages of the value chain. This confirms the fundamental principle of design for sustainability: responsibility is not only in what we make, but also how, with whom, and with what consequences for people and the planet.

0.5 Sustainability Planning Benefits for Businesses

In addition to the environmental benefits, planning for sustainability brings several other benefits that can be very attractive to businesses.

Studies show that an integrated sustainability approach contributes significantly to the resilience of companies, innovation and long-term value for stakeholders (Taghizadeh et al., 2024).

Below, we present the key benefits a company can achieve by incorporating sustainability principles into developing its products and services. These benefits often coincide with motivating factors that drive companies to introduce holistic quality and accountability into their business.

0.5.1 Reducing environmental impacts

The most immediate and obvious benefit of sustainability design is the reduction of the negative environmental impacts of products. In doing so, it makes sense to analyse key environmental aspects at the local level, as well as impacts at the wider European and global level. In addition to greenhouse gases, emissions and waste, other impacts must be considered, such as biodiversity loss, erosion, risks to human health, impacts on rural and urban areas, and impacts of genetically modified organisms.

0.5.2 Cost reduction

Planning for sustainability can help to reduce costs for both manufacturers and users. Resource consumption is optimised by reducing the amount of raw materials and energy used, which reduces production costs. Also, by improving energy efficiency in the product use phase, the company can offer its customers long-term savings, strengthening competitiveness and satisfaction.

0.5.3 Fostering innovation

As sustainability planning is still a relatively new approach in many industries, it is an excellent starting point for innovation. Incorporating sustainability criteria into development can trigger fresh design and functional ideas that would not otherwise emerge in traditional processes. An example of such success is the Smart car developed by Swatch and Mercedes. Thanks to its innovative design incorporating sustainability principles, it became recognisable as a pioneering and energy-efficient city car.

0.5.4 Compliance with environmental legislation

By integrating sustainability criteria, the company ensures compliance with existing legislation and prepares for future regulations. An example of good practice is the replacement of hazardous oils in household appliances with biodegradable oils, which reduces environmental risk and meets the requirements of legislation such as the Water Act.

0.5.5 Meeting customer requirements

Planning for sustainability also helps companies meet the increasingly demanding expectations of customers and business partners. For example, a fuel-efficient car not only meets environmental criteria but is also one of the key consumer requirements – cost-effectiveness.

0.5.6 Improving product quality

Incorporating sustainability criteria into development processes can lead to improvements in design and functionality. Thus, in the design of the furniture element, the methods of fastening have been improved, which has led to greater strength, safety and, consequently, the quality of the product.

0.5.7 Strengthening the reputation of the company and its products

By planning for sustainability, companies can improve their public image and build trust in the market. A good example is a fruit bowl manufacturer that has solved fragility issues by switching to more durable and environmentally friendly materials while improving the sustainability profile of its products. In this way, it has improved functionality and its reputation as an environmentally responsible company.

1 Setting up a project team and planning a sustainability project

Chapter objectives:

- Launch of a sustainability planning project in the company,
- formation of an interdisciplinary project team,
- Effective planning of project activities.

Worksheets 1: Setting Up a Project Team and Planning a Sustainability Project

1.1 Formation of the project team

For a successful start of a sustainability planning project, it is crucial to establish a project team that will be responsible for its implementation at both organisational and technical levels. The team should include internal and, where necessary, external collaborators, who together cover all key aspects of sustainability – from product development, environmental impacts, marketing and management to stakeholder communication (ISO, 2020a).

Key characteristics of an effective project team:

- Compact and coordinated composition: The optimal number of members is up to 6. A project manager leads the team – usually a product development manager – who coordinates project phases, distributes tasks, and communicates.
- Strategic decision-making capability: The team should also include people who have the authority to make key decisions at the company level.
- Multidisciplinarity: The team should include experts from different fields – product development, purchasing, quality, environment, marketing, human resources and management. This ensures that all aspects of sustainability planning are comprehensively addressed.

Prioritise including the following sections:

Leadership Management:

It provides support, strategic direction and availability of resources. Management needs to understand the importance of incorporating sustainability planning into business processes.

Product Development Department:

Crucial for the development or refurbishment of products, the integration of sustainability criteria and the coordination of technical improvements. A development manager can also be a project team leader.

Purchase:

It provides information on existing materials, examines the possibilities for introducing greener alternatives and assesses their feasibility in practice.

Department of Quality and Environment:

Assesses compliance with legislation, internal quality standards, and company environmental objectives. Connects the project with existing quality management and environmental management systems (ISO, 2015).

Marketing:

He provides insight into clients' marketing needs and environmental preferences and participates in designing the project's communication and marketing messages.

Human Resources:

It is responsible for informing employees, motivating the integration of good practices, leading training and encouraging employee participation in sustainable initiatives.

External experts and partners:

In case of a lack of internal experience or knowledge of sustainable planning, cooperation with external partners such as institutes, faculties, consulting companies or clusters is recommended. Cooperation with academia (e.g. involvement of students and researchers) (Horizon Europe, 2021) It can bring fresh ideas, additional expertise, and support in conducting analyses and formulating concepts.

1.2 Planning a Sustainability Project

A carefully planned sustainability planning project can significantly contribute to a company's competitiveness and bring direct benefits – both in the market and within the organisation. Sustainability considerations are becoming a key part of requirements in supply chains, public procurement and consumer decisions (EC, 2023). Therefore, the Sustainability Planning Project is a strategic opportunity beyond mere environmental compliance – it opens the door to innovation, cost optimisation and new market segments.

As with all other development projects, the basic condition for success is a clear motivation of all participants. Experience shows that motivation can be established with the following approaches:

- Highlight business benefits (e.g., cost reductions, new markets, reputation).
- We present successful examples of sustainability planning practices with tangible and measurable results.
- Explain the long-term benefits of a sustainable approach, including social responsibility and resilience to legislative change.

Well-executed pilot projects can significantly contribute to the wider integration of sustainability planning into the company's organisational culture and encourage further improvements even after the completion of the initial project.

1.2.1 Adaptation to the capabilities of the company

The ability to implement sustainability planning projects varies from company to company, so SMEs-specific tools and approaches are needed to enable the modular and phased deployment of sustainability practices (Crul & Diehl, 2009; Fatimah et al., 2020).

It is essential to understand that not every organisation can address all aspects of sustainable development at the same time. Demanding a holistic approach from a company just starting out in this area would be unrealistic and even counterproductive. Therefore, it is recommended that the company:

- Review the specificities of its sector.
- Identify key areas with the most significant potential for sustainable improvement.
- Identify the most appropriate objectives for the first project.

This approach allows for focused project execution and measurable results.

1.2.2 Action plan and organisation

The first task of the project team is to prepare a clear action plan that sets out:

- The objectives of the project,
- Expected results,
- Key stages of implementation,
- The powers and responsibilities of individual members.

Before continuing the project, it is necessary to create a spreadsheet of all involved employees, their departments, and the tasks involved in the project. This review provides a clear overview of the role of each member and facilitates coordination.

1.2.3 Timeline and internal communication

For successful implementation, it is crucial that the team agrees at the outset on:

- project timeline (duration, milestones, time of meetings),
- the way of communicating within the team,
- How the rest of the company is informed.

The timing of the project can be very different, depending on the product's complexity and the company's innovation potential. In practice, a project usually lasts from three months to a year. It is recommended to be carried out intensively and without major interruptions, as this keeps the team engaged and brings tangible results faster.

🛠 **Worksheets 1:** Form a project team and plan a planning project for sustainability.

2 Motivational Planning Factors for Sustainability and Project Goal Setting

Chapter objectives:

- Conduct a SWOT analysis of the company in the context of sustainable development,
- To review the external and internal motivational factors for the integration of sustainability planning,
- Determine the project's goals based on the company's capabilities and market opportunities.

Worksheets 2: Overview of Planning, Motivations for Sustainability and Setting Project Objectives

2.1 SWOT analysis of the company

The second step of a sustainability planning project involves a comprehensive analysis of the company's competitive position, using the established SWOT (Strengths, Weaknesses, Opportunities, Threats) tool. This analysis provides a systematic overview of internal factors (strengths and weaknesses of the company) and external factors (opportunities and threats in the environment) that the company faces when implementing a sustainable approach (European Commission, 2022).

SWOT analysis reveals and enables a structured approach to the strategic positioning of companies in a sustainable context (European Commission, 2022; Mihajlović et al., 2024):

- current innovation and organisational capacity;
- environmental advantages and vulnerabilities;
- opportunities that the company can take advantage of to develop sustainable products,
- threats that could jeopardise the implementation of the project or its long-term sustainability.

Based on the analysis, the project team can then set realistic but ambitious sustainability planning project goals.

Example: Possible factors in a SWOT analysis

Table 2.1 shows factors that can be considered in preparing a SWOT analysis.

Table 2.1: Examples of possible factors from a SWOT analysis.

Internal factors

ADVANTAGES	DISADVANTAGES
+ **Innovation team**	- Competence gap
+ **Efficient development department**	– Lack of financial reserves
+ **Environmental awareness**	- Poor environmental reputation
+ **Access to sustainable resources**	– Lack of motivation of employees
+ **Established brand**	- Lack of systematic sustainability management
+ **Environmentally Conscious Suppliers**	– Limited access to high-quality natural materials
+ **Environmental management system introduced**	– Dependence on one type of customer or market

External factors

OPPORTUNITIES	THREATS
+ Increased consumer awareness of sustainability	– Rapid growth of competition
+ Trends of sustainable and circular economy	- Volatile economic conditions
+ New markets (bio, eco, local)	– Unreliability of suppliers
+ European legislation and environmental standards	– Strict regulation and excise duties
+ Technological progress (e.g. digitalisation)	– Short product life cycles
+ Options for environmental certifications (e.g. Ecolabel)	– Seasonal fluctuations and weather influences
+ Recessions that weaken competition	– Departures of key personnel to the competition

🛠 Worksheets 2: SWOT analysis of the company

2.2 Research on the Motivational Factors of Planning for Sustainability

The sustainability challenges of our time – from climate change to social inequality – demand proactive responses from companies. Businesses of all sizes, from global corporations to small and medium-sized enterprises (SMEs), are increasingly aware that sustainable development and social responsibility are not only ethical commitments but also key drivers of long-term success.

Integrating sustainability into product development and business planning provides companies with clear benefits: improved environmental and social performance, enhanced resilience, and a stronger competitive edge in rapidly evolving markets.

2.2.1 External and Internal Motivational Factors

The motivation to engage in sustainability planning usually arises from two interconnected groups of factors: external pressures and internal drivers. Both play an important role in shaping a company's approach to sustainable development.

External motivational factors

These factors originate outside the company and are largely beyond its direct control. They act as requirements, expectations, or pressures that encourage the adoption of sustainable practices. Key external factors include:

- Environmental legislation (e.g. bans on hazardous substances, packaging regulations);
- Supply chain requirements (e.g. sustainability or social responsibility standards demanded by large customers);
- Consumer demand for sustainable and ethically produced products;
- Market trends and social pressures that reward transparency and responsible business conduct;
- Standards and certifications (e.g. EU Ecolabel, ISO 14001) that establish measurable benchmarks.

By responding to these pressures, companies not only ensure compliance but also gain the opportunity to strengthen their market position. For example, when customers request environmental performance data, integrating sustainability early in product development can lead to better design choices, improved environmental outcomes, and a stronger competitive advantage.

Eco-labelling is particularly influential. Labels provide independent confirmation that products have been designed according to defined environmental criteria. Companies that incorporate sustainability into their planning process are better positioned to achieve such certifications, which in turn enhances customer trust, brand reputation, and market recognition.

Internal motivational factors

Internal factors are rooted within the company itself and reflect its values, vision, and organisational culture. They often serve as proactive drivers of change, ensuring that sustainability becomes an integral part of business strategy rather than merely a response to external pressures. Common internal factors include:

- Leadership commitment – the personal values and strategic vision of managers and owners who champion sustainability;
- Corporate culture – organisational values that promote responsibility, innovation, and continuous improvement;
- Employee engagement – motivated employees who support sustainability through creativity, knowledge, and operational practices;
- Innovation opportunities – the pursuit of efficiency, new product design, and business models that align with sustainable principles;
- Reputation and brand identity – a desire to be recognised as a forward-looking, responsible, and trustworthy company.

When companies internalise sustainability as part of their culture, they build long-term resilience. Employees become more engaged, innovation is encouraged, and the company can anticipate market shifts rather than simply reacting to them. Such intrinsic motivation often leads to more ambitious sustainability initiatives and a stronger, more authentic commitment to change.

Key eco-labelling programmes

The following table presents selected national and international eco-labelling schemes that provide valuable benchmarks and guidance for companies seeking to design sustainable products.

products.

Table 2.2: Selected eco-labelling schemes.

Program Name	State	Year of foundation	Link
EU Ecolabel (environmental daisy)	European Union	1992	ec.europa.eu/ecolabel
Blue Angel (Blauer Engel)	Germany	1978	blauer-engel.de
Austrian Ecolabel	Austria	1990	umweltzeichen.at
Environmental Choice / EcoLogo	Canada	1988	ecologo.org
The White Swan (Nordic Swan)	The Scandinavian Countries	1989	svanen.un
Green Seal	United States	1989	greenseal.org
Milieukeur	Netherlands	1992	milieukeur.nl
NF-Environment	France	1991	afnor.org
SCS Forest Conservation Program	United States	1993	scsglobalservices.com

🛠 Worksheets 2: Explore the Motivational Factors of Eco-Design

2.3 Defining the Objectives of a Design for Sustainability Project

The sustainability planning process follows the same basic steps as classic product development, but with the addition of incorporating sustainability criteria as a key part of the development process. This approach is therefore naturally intertwined with the company's existing development practices and business activities.

For the successful implementation of the project, it is crucial to define goals and expectations from the beginning clearly. The project must align with the company's strategy and business plans and focus on sustainable development. A strong link must be established between sustainability goals and the company's innovation potential – primarily based on experience in product development and employee competencies.

2.3.1 From analysis to targeted action

After conducting a SWOT analysis and determining the relevant internal and external motivational factors, the project team has a clear picture of the company's competitive position. This allows her to set thoughtful and realistic goals.

The key questions that the team needs to answer when formulating goals are:

- What does the company need to do? (e.g. due to environmental legislation, labour law or customer requirements)
- What does the company want to achieve? (e.g. cost reduction, improved market position, strengthening of social responsibility)
- What can a company do? (based on available resources, timeframes, capacities and innovation readiness)

2.3.2 Examples of possible objectives of a sustainability planning project

The objectives can range from technical improvements to broader market or societal ambitions. Some possible goals include:

- proven improvements in the sustainability characteristics of the product (e.g. lower carbon footprint, reduced consumption of raw materials);
- improving the sustainable aspects of the production process (e.g. more efficient use of energy);
- gain insight into the environmental and social impacts throughout the product life cycle,
- strengthening communication on the sustainability of the product on the market (e.g. through certificates or eco-labels);
- demonstrating the economic benefits of the planning approach for sustainability (e.g. reducing the cost of materials, energy or waste);
- readiness for new legislative requirements (e.g. in the field of circular economy or ESG reporting),
- better addressing the demands of stakeholders and civil society;
- entering sustainably oriented market niches with innovative products,
- Cost optimisation at the end-of-life phase of the product (e.g. easier disassembly, recycling).

2.3.3 Start with small but achievable goals.

Experience shows that for the first sustainability planning project, it is wise to choose objectives that can be achieved in a shorter period. Such an approach builds trust, consolidates internal support and serves as a springboard for more ambitious projects in the future.

🛠 Worksheets 2: Determine the Goal of Demonstration Design for Sustainability

3 Product selection

Chapter objectives:

- establish criteria for product selection;
- select the target product for the sustainability planning project,
- prepare a product dossier;
- Describe the context of the product's use.

Worksheets 3: Product Selection

Often, a company has a "target product" in mind from the outset, especially if market information indicates that its environmental and/or social characteristics are critical to market success. Pressure from the market, legislation, or stakeholders can encourage a company to choose a particular product as a case study, which is the first step in implementing sustainability planning.

Since a company can offer several product versions in different markets, it is essential to precisely define **the specific product** that will be analysed and optimised. The choice of the first "test" product must be thoughtful. If a company makes a choice based solely on intuition, there is a risk that it will choose a less suitable product, which can reduce the effects of the entire project.

Therefore, the criteria for the product selection should be directly related to motivational factors and objectives and include a systemic view of the product's impacts at all stages of the life cycle (Moreno et al., 2016; UNEP, 2020). Key recommendations include:

- **Adaptability of the product:** The product must have sufficient degrees of freedom for modifications (e.g., a PE bag is less suitable due to the limited possibility of changing the material and shape).
- **Impact on sustainability aspects:** A product with a high impact on sustainability factors (e.g. regulatory compliance, competitive advantage, communication with the market) is more appropriate.
- **Relevance for the first project:** If it is an initial sustainability planning project, we recommend choosing a simpler product or component for faster results and greater motivation.

After selecting a product, the project team must verify **that the product supports the company's sustainability goals**. Sometimes motivational factors can be necessary for the entire portfolio, but not necessarily for a specific product. Therefore, the team must re-evaluate the compliance of the selected product with internal and external factors and the company's goals.

⚒ **Worksheets 3:** Evaluation questionnaire for product selection

3.1 Preparation of the product dossier

To effectively plan for sustainability, we need to gather more information about the product than the company typically tracks. Therefore, at this stage, it is advisable to establish **a product dossier**, which is gradually updated with new data and insights from team members.

Areas of the dossier include:

A) Product and its use:

- product development history, initial concept, marketing data,
- sales channel, geographic markets, distribution and transport,
- lifetime, methods of use and quantities of resources consumed,
- End-of-life product handling (recycling, disposal).

B) Design and Production:

- structure of components and materials,
- supply chains, production process diagram,
- Inlets/outlets by phase (energy, materials, emissions, waste).

C) Competing products:

- alternative products and market segments,
- environmental attributes of comparable products,
- comparative performance data (journals, online databases).

D) Market analysis:

- market size and growth, market trends,
- cost structure and potential profitability.

Table 3.1: Areas of environmental impact.

Sphere of influence	Typical impacts	Related resources
Air pollution	Greenhouse gases, smog, acid rain, ozone depletion	Fossil fuels, refrigerants, foaming agents
Water pollution	Eutrophication, toxins	Phosphates, heavy metals, pesticides
Soil contamination	Solid waste, heavy metals	Waste materials, municipal waste
Use of resources	Scarcity of raw materials, rare metals, and water	Non-renewable materials, drinking water
Other influences	Noise, visual influences	Production process

Table 3.2: Areas of social influence.

Sphere of influence	Aspect	Related resources
Human rights	Freedom, legal protection, and access to education	Suppliers, production processes
Working conditions	Child labour, health, safety	Materials, production sites
Governance and ethics	Transparency, corruption	Business Models, Distribution

3.2 Description of the context of use of the product

A clear understanding **of the context of use** is essential for successfully planning sustainable improvements. It serves as a starting point for developing alternative solutions, while ensuring that any new solutions will still meet users' needs.

To describe the context, we use the following questions:

- **What is the product used for?**
  → Description of the basic function (e.g. storage, protection, lighting)
- **What function does it perform?**
  → Technical principle and expected functionalities
- **Who uses it?**
  → Primary user or user group
- **How long and how often?**
  → Time dimension of use (duration, cycles of use)

- **Where in the world?**
  → Geographical areas of use and disposal

The answers to these questions lead to **a documented description of the product's** value to the user. This description needs to be validated by the project team, as it serves as a benchmark for comparing alternative solutions later in the project.

🛠 **Worksheets 3**: Prepare a checklist of areas to include in the product dossier

4 Determination of the environmental aspects of the product

The objectives of this chapter are:

- Selection of tools for the analysis of environmental aspects,
- Defining the purpose and scope of the analysis,
- Determination of the life cycle scheme,
- Inventory of material inflows and effluents for individual processes in the life cycle,
- Impact assessment and interpretation of results.

Worksheets 4: Determining the environmental aspects of the product.

The Sustainability Planning Project is based on understanding the General Aspects of the product, which in their lifetime cause the most significant environmental impacts. The analysis should be based on the most recent life-cycle assessment methods proposed by EF 3.1 (European Commission. Joint Research Centre., 2019).

This will allow us to identify priorities for making improvements. In order to gain a general insight into the environmental aspects of a product, it is necessary to review the system of the product as a whole and not just the physical product.

In the introduction to this manual, we have already presented the main environmental impacts (Table 0.1), which give us an idea of the importance of preserving the quality of the environment. Now, in focusing on the implementation of planning for the sustainability of a specific product, we will be particularly interested in identifying all the specific environmental aspects of the product to optimise them.

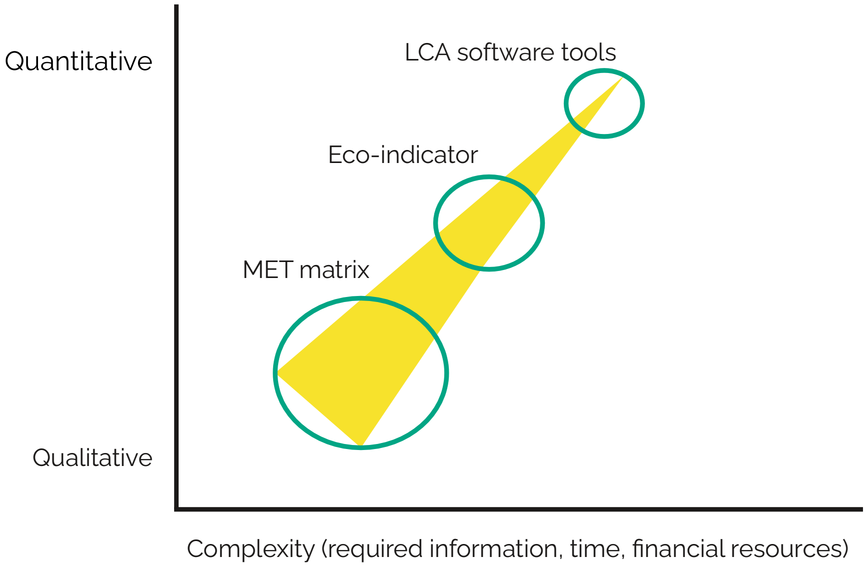
Various qualitative and quantitative methods exist for analysing a product's environmental aspects and setting environmental priorities. Most methods are based on life cycle analysis, which means that these methods analyse all stages of the product's life cycle and consider environmental aspects at each stage. These methods aim to understand a product's main environmental aspects throughout its life cycle and identify environmental priorities that will be addressed in the sustainability planning process.

The methodological framework of all LCA techniques is based on ISO 14040-43 standards. It consists of four interrelated phases: (1) defining the purpose and scope of the analysis, (2) inventory, (3) environmental impact assessment with four sub-phases (classification, characterisation, normalisation and weighting) and (4) interpretation of the results. The LCA methodology is increasingly evolving towards the integration of dynamic aspects and integration with digital decision-making tools (Kara et al., 2023). By these standards, it is recommended that, regardless of the method chosen, we carry out an assessment of environmental aspects in the following steps, which we will learn in more detail later in the manual:

- Choosing a tool for analysing environmental aspects;
- defining the purpose and scope of the analysis,
- determination of the life cycle (process scheme, process tree),
- inventory (inventory of material inflows and outflows of individual processes in the life cycle),
- impact assessment;
- interpretation of the results.

4.1 Choosing an Environmental Impact Analysis Tool

In order to properly assess the environmental impacts of a product or process, it is crucial to select an appropriate analytical tool that corresponds to the objectives, available data and the project's development stage. The main tools and methods for environmental impact analysis are presented below and classified according to complexity, usefulness, and compliance with current guidelines.



4.1.1 MECO Matrix

The MECO matrix is helpful for the initial analysis – it allows a qualitative assessment of the impacts of materials (M), energy consumption (E), pollution (C) and human health (O), however, the use of modern LCA tools and databases, such as Ecoinvent or Environmental Footprint (EF) 3.1, is recommended for more detailed quantitative assessments (IHOBE, 2001; Wernet et al., 2016).

The MECO matrix is a method that provides complete insight into the inlets and outlets at each stage of the product life cycle. The MECO matrix is a qualitative or partial qualitative tool, because despite concrete quantities on inlets and outlets, the prioritisation of environmental aspects is qualitative. The relatively simple matrix structure allows the sustainability planning team to analyse all phases of the product life cycle and the different environmental impacts of each phase.

The matrix assesses several environmental impacts and is grouped into four categories: materials. ***Materials***, ***Energy***, ***Chemicals*** and ***Other***. These aspects are included in the MECO matrix in a simplified way and are organised according to the stages in the product life cycle. The matrix columns correspond to the different stages of the product life cycle, while the matrix rows focus on the relevant design criteria for sustainability.

The rows of the matrix include environmental criteria such as:

- **Materials**: This aspect includes resource and disposal aspects for each stage of the lifetime, i.e. whether the material is derived from a scarce resource, whether it can be easily recycled, whether it needs to be disposed of, etc. We can also consider using excipients, especially in the use phase, such as paper filters for the coffee machine.
- **Energy**: This includes the energy sources and energy aspects of each stage of the life cycle. There can be significant differences in energy consumption, depending on whether we use a new or recycled raw material. Let's also consider component suppliers. This category also includes the energy required for transport and use.
- **Chemicals**: This includes using chemicals and related emissions at each stage of their life cycle, such as toxic chemicals used in production or materials. This applies in particular to excipients used in the manufacture of the product, as well as to excipients used for maintenance during the use phase, etc. This includes special chemical substances that are released into the environment.
- **Other**: This category includes all other aspects we have selected for consideration. For example, health and safety in one's own (or supplier's) production facilities, aspects related to social responsibility or general economic issues. Social criteria may also be included, such as social

responsibility, local or regional economic development, and human resource management. We can include other aspects by adding rows to the array. Examples include specific local problems or sustainability issues such as water use, biodiversity, CO_2 emissions, cultural heritage, etc. In addition, rows related to the motivational design factors for sustainability referred to in Chapter 2 may be added.

The columns of the matrix may include different stages of the life cycle depending on the process scheme of the product life cycle. Table 4.1 shows an example with 6 phases of the life cycle. Depending on the situation, the team may add or omit certain life cycle phases. For example, if the seller of our product is interested in the impact of the products, the team may choose to insert a "seller" column between the distribution and use phases. In this way, the seller's contribution to environmental impacts (e.g. refrigeration of products in supermarkets) can be assessed more clearly. When adding columns, we must be careful to maintain the clarity and transparency of the matrix and not to add more columns and rows than is necessary.

Table 4.1: Life cycle stages that can be considered in the MECO matrix.

Aspect	Raw materials	Suppliers	Production	Distribution	Use	End of life
Materials						
Energy consumption						
Solid waste						
Toxic emissions						
Social responsibility						
Human Resource Management						
Water						
CO_2						
Costs						
...						

4.1.2 Eco-indicators: a transitional tool for quantitative assessment of environmental impacts

Eco-indicators represent an early attempt to quantify the environmental impacts of products and processes within the life cycle. They have been developed to make it easier for planners to choose more environmentally friendly alternatives already at the design stage of the product. A key advantage of methods such as Eco-indicator 99 was their ability to aggregate impacts into a single numerical value, which greatly simplified decision-making.

The eco-indicator was first introduced by Goedkoop and colleagues in 1995 as an eco-indicator 95 (Goedkoop, 1995). In 1999, a more complex version of the eco-indicator 99 was released, which is adapted to European conditions. Eco-indicator 99 is a simple quantitative tool for product planners that is more accurate than the MECO matrix in prioritising the main environmental aspects of a product throughout its life cycle. We define it as a quantitative tool because prioritisation is based on numerical calculations.

When using eco-indicators for product design, forms are filled out. As a result of Eco-indicator 99, we obtain a table of numerical values that represent the environmental impact of the quantity or volume of each material or process. These values are expressed in their units, which are called milli-points (mPt) and are not comparable to any other traditional unit of measurement. This makes it possible to calculate a single result for the overall environmental impact based on the calculated effects. This result is called the Eco-indicator. An eco-indicator of a material or process is therefore a number that indicates the environmental impact of a material or process based on data from a life cycle assessment. The higher the indicator's value, the greater the environmental impact.

In fact, the absolute value of these points is not as significant as the comparison of the relative differences between products or components. The scale is chosen in such a way that a value of 1 Pt represents one thousandth of the annual environmental burden of one average European resident. This value is calculated by dividing the total environmental burden in Europe by the number of inhabitants and multiplying by 1000 (scale factor).

Standard Eco-indicators are calculated using a rather complex methodology, which is summarised popularly in the material "Eco-indicator 99 – A Handbook for Planners". In general, the methodology for calculating eco-indicators includes three steps:

1. Inventory (inventory) of all significant emissions, exploitation of natural resources and land use in all processes that make up the life cycle of a product. This standard life cycle assessment procedure is described in more detail in subsection 4.5.

2. Calculate the damage caused by these flows to human health, ecosystem quality and resource exploitation. To be able to use weights for the three claim categories, it was necessary to develop a set of complex damage models. In the Eco-indicator 99 methodology, they limited themselves to three damage categories:

- Harm to human health is expressed as the number of years lost and years of life disabled. This was combined into the *Disability Adjusted Life Years (DALY)* index, which the World Bank and the World Health Organisation also use.
- Damage to the quality of ecosystems is expressed as the loss of species in a particular area over time.
- Damage to resources is expressed as additional energy needed for future extraction of minerals and fossil fuels.

3. Weighing the impact of these three categories of damage: weighing the impact is the most critical and controversial step in the methodology. In the methodology, damage to human health and ecosystem quality were estimated to be approximately equally significant, while damage to resources was assessed as half as significant.

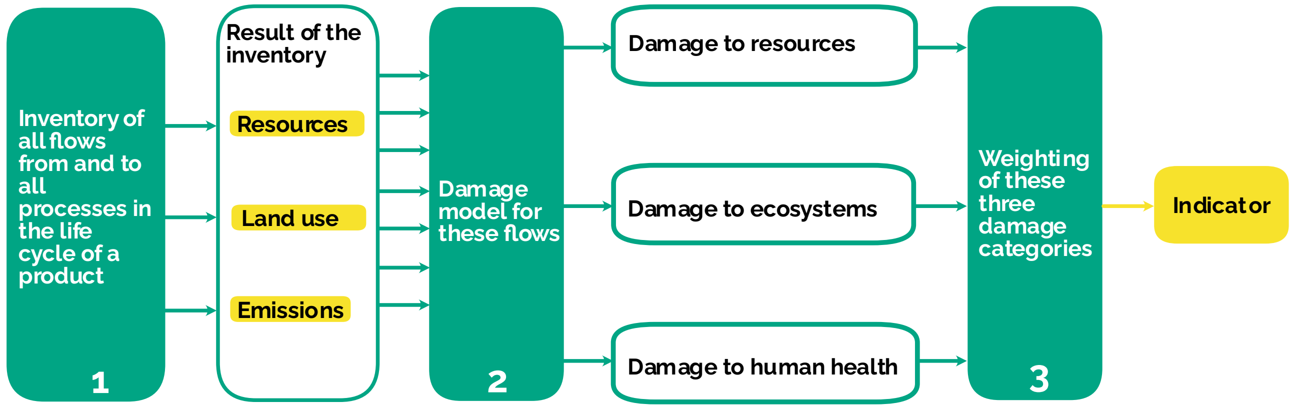


Figure 4.1: Eco-indicator concept (Goedkoop, 1995).

Standard eco-indicators

The Standard Eco-Values of Indicators have been developed as a tool for planners to find environmentally friendly alternative planning options and are intended for internal use. Eco-indicator standard values are not intended to be used in environmental marketing, eco-labelling, or to demonstrate to the public that product A is better than product B. Eco-indicator standard values are also not intended as a government instrument for setting standards or developing guidelines. The use of eco-indicators has only one purpose: to make products more environmentally friendly. Eco-indicators are, therefore, tools that can be used in companies or sectors.

Currently, there is an updated list of eco-indicators, so it may happen that the necessary indicator has not yet been determined. For example, some company did not find a suitable indicator for NiCd batteries (until then they were used in their products and are highly toxic because they contain heavy metals). Therefore, the improvement based on the replacement of these batteries with others with less impact (e.g. NiMH) is not reflected in the overall calculation of eco-indicators. Thus, this is the case when the availability of the most important eco-indicators for the product does not allow taking into account the environmental improvements obtained. In these cases, the use of eco-indicators is not recommended. A complete list of 99 available eco-indicators, together with additional information in connection with their use, is available on the website.

Although the use of these standard values is basically very simple, it is very important to understand some of the basics and learn about the advantages and limitations of using eco-indicators. Standard eco-indicators are numerical values that express the total environmental load of a product or process. With standard eco-indicators, any planner or product manager can analyze the environmental burden of a product throughout its entire life cycle. At the same time, different design alternatives can also be compared. This manual describes the use of standard indicators along with their limitations.

Description of standard Eco-indicators

The standard values of Eco-indicator 99 are available for:

- Production of raw materials and materials:

All processes are involved, from the extraction of raw materials to the final stage of production. This also includes transport processes up to the final process in the production chain. Indicators for production processes are expressed per 1 kilogram of material.

- Production processes:

Eco-indicators for treatment processes refer to emissions from the process itself and emissions from the necessary energy production processes. Fixed assets such as machinery and models are not included.

- Transport processes:

Transport processes include road, rail and air modes of transport. A standard unit is the transport of one tonne of goods over a distance of one kilometre (1 t × km), but a different unit (e.g. m3 × km). The calculations assume loading efficiency for average European conditions. Any empty returns of means of transport are also taken into account.

- Energy production:

Energy indicators relate to the production and consumption of fuels, as well as energy conversion and electricity generation. Data on the average efficiency of energy conversion are used here. To calculate the result for electricity, the different fuels used in Europe to generate electricity were taken into account. The eco-indicator has been set for high-voltage electricity for industrial processes as well as for low-voltage electricity for households and small industrial consumers. In addition to the European averages, specific indicators for a number of countries are also given.

- Waste recovery and recycling

The indicators included in the list refer to different types of waste or waste recovery methods: household and municipal waste, incineration, landfill disposal and recycling. Data for waste management were determined for the most important plastic, metal and packaging materials.

Upgrade: ReCiPe 2016 method

The modern method of ReCiPe 2016 is a direct successor to Eco-indicator 99 and significantly improves its structure. It allows the user to choose between two levels of evaluation:

- Midpoint indicators: impact assessment, e.g. greenhouse gas emissions, acidification, eutrophication.
- Endpoint indicators: impact assessment, e.g. impact on human health, ecosystems, resources.

ReCiPe also includes several philosophical perspectives (individualistic, egalitarian, hierarchical), which gives the user flexibility according to the context of use and the goals of the study.

Limitations and cautions in the use of standard eco-indicators

Standard eco-indicators (e.g. those for 1 kg of aluminium, 1 tkm of transport, 1 MJ of electricity) have been designed as a convenient tool for internal use in industrial design. Their simplicity allowed for a quick impact assessment without the need for an in-depth LCA, but today they are considered primarily as an introductory tool.

It is important to understand that:

- they are not suitable for external communication (e.g. marketing claims, labelling);
- they do not replace a comprehensive LCA analysis,
- do not always include all influencing factors (e.g. NiCd batteries were not adequately captured).

Due to these limitations, their use is recommended today mainly for:

- early stages of variant design and assessment;
- rapid internal assessment of the environmental burden;
- introductory workshops or training on sustainability planning.

Although Eco-indicator 99 is a historically important method, for modern practice we recommend switching to methods such as ReCiPe 2016 or EF 3.1. All recent studies and digital tools (EPD generators, Digital Product Passport) are based on these methodologies. The use of standard eco-indicators should be limited to information purposes, prototype calculations and internal comparison of alternatives at an early stage of design.

4.1.3 Environmental impact assessment using the Life Cycle Analysis (LCA) software tool

Although the previously mentioned tools, such as the MECO matrix and Eco-indicator 99, allow for an initial assessment of environmental impacts, today modern approaches are based on computer-aided methods of life cycle analysis (LCA). There are several software tools available, which differ in complexity, cost, usability and support for databases. The most commonly used and professionally recognized tools are presented below.

OpenLCA

OpenLCA is an open source software for LCA that enables professional modelling of the environmental impacts of products, processes and services. It supports a wide range of databases (e.g. Ecoinvent, EF 3.1, Agribalyse, Gabi databases) and a wide range of methods (ReCiPe, ILCD, EF, IPCC, etc.). It is suitable for both research and commercial use, including the preparation of EPDs, carbon calculations and sustainability analyses.

More information: https://www.openlca.org/

SimaPro

SimaPro is the leading LCA software solution developed for industrial use and research. It enables modelling of products and systems, connection to databases (such as Ecoinvent), implementation of scenarios, sensitivity analyses and reporting. It is widely used for carbon footprint calculations, the production of environmental declarations and sustainable reporting.

More information: https://simapro.com/

Sickening

GaBi is a commercial software designed for professional use in companies and research institutes. It enables fast modelling, includes extensive databases, and provides an interface for easy preparation of reports and scenarios. It is also suitable for the preparation of EPDs and ensuring compliance with regulations.

More information: https://gabi.sphera.com/

Umberto

Umberto is a software solution that enables visual modelling of material and energy flows, as well as support for LCA, MFA (Material Flow Analysis) and carbon calculations. It is popular in the manufacturing sector, as it allows you to optimize processes and monitor performance indicators.

More information: https://www.ifu.com/umberto/

Ecochain Mobius

Ecochain Mobius is a web-based application for quickly implementing LCA and calculating carbon footprint in the early stages of product design. It offers an intuitive interface, good visualisations and is especially suitable for small and medium-sized enterprises.

More information: https://mobius.ecochain.com/

One Click LCA

One Click LCA is a specialised tool for the construction industry that provides a quick assessment of the environmental impacts of buildings, construction components and infrastructure. It is widely used in architectural and engineering firms and allows for the automatic generation of EPDs.

More information: https://www.oneclicklca.com/

4.1.4 Which tool should you choose for environmental impact analysis?

Choosing the right tool to assess the environmental impacts of a product or process is crucial for a quality and reliable Life Cycle Analysis (LCA). There is no one-size-fits-all solution – the choice depends on many factors, such as the purpose and level of analysis, the availability of data, the resources available, the scope of the projects and the available knowledge of the users.

In the early stages of product development or in the first planning approaches for sustainability, simple, user-friendly tools such as Ecochain Mobius, One Click LCA (especially for construction) or OpenLCA using simplified models are often sufficient. These tools provide a quick insight into the environmental profile of a product and support decision-making as early as the concept phase.

For a more in-depth, standardised and verified LCA analysis – for example, in the preparation of environmental product declarations (EPDs) or the calculation of the carbon footprint – more advanced programs such as SimaPro, GaBi, OpenLCA with upgrades or Umberto are more suitable. These allow for a high degree of customisation, accuracy and the use of diverse databases.

In a research environment or in the need to automate analyses, Brightway2 is widely used, an open-source tool that requires advanced knowledge of Python programming.

The accessibility and diversity of databases (e.g. Ecoinvent, EF 3.1, Agri-footprint, GaBi databases) is another important factor. OpenLCA and SimaPro support a wide range of suites, allowing data to be combined and better adapted to analysis.

Cost-effectiveness is also an important aspect. OpenLCA is free and open source (basic version), so it is especially suitable for NGOs, research institutions, students and small and medium-sized enterprises. On the other hand, SimaPro and GaBi have more functionality, but also higher licensing costs, making them more suitable for professional users and larger organisations.

The user interface can be crucial for beginners. Tools such as Ecochain Mobius and One Click LCA offer an intuitive user interface and are tailored for non-professionals. OpenLCA, SimaPro and GaBi offer extensive support in the form of documentation, training and online communities, but they require some prior knowledge.

In the internal optimisation of processes, the Umberto tool is particularly useful as it visually displays material and energy flows. However, simplified methods may be more suitable for everyday use in companies where resources are limited.

Selection recommendations:

- For beginner approaches, we recommend OpenLCA because of its accessibility, flexibility, and cost-effectiveness.
- SimaPro, GaBi, or the upgraded OpenLCA are suitable for professional preparation of LCA analyses and EPD documentation.
- In the construction industry, One Click LCA is optimised for rapid assessments with appropriate regulatory support.
- When it comes to internal process improvement and flow visualisation, Umberto is a good choice.

🛠 **Worksheets 4.1:** Choose an Environmental Impact Analysis Tool Based on the Recommendations Above

4.2 Definition of the purpose and scope of the environmental impact analysis

Environmental impact analysis includes defining the purpose and intended use of the analysis, the system and its limits, assessing the quality of the data, and determining assumptions and limitations of the analysis. In this chapter, we will clearly state the intended use and the reasons for carrying out an environmental impact analysis. We have to ask ourselves why and how we are going to carry out the analysis, and who will be the user of the results. For example, the purpose of a study may be to identify critical points in the production process and use the results obtained within the company in order to reduce environmental impacts. The purpose of the analysis may also be to compare the product with other comparable products. A company may also want to use the results externally by communicating the results of the analysis to its stakeholders.

In our case of planning for the sustainability of the selected product, the most likely purpose of the analysis will be to investigate and obtain a general impression of the main, environmentally harmful processes of product production. Therefore, it will not be unusual to define the purpose of the analysis at the outset as merely "assessing the environmental impacts of a product" or "determining the environmental advantages and disadvantages of a product." On that basis, we then translate such a general purpose into a more specific one. The purpose of the analysis can be posed as a question about the environmental impact analysis. Examples of such issues are:

- What is the potential for improvements in the product lifecycle?
- What are the activities in the product life cycle that contribute most to environmental impacts?
- What would be the environmental consequences of changes to certain processes in the life cycle of a product?
- What would be the environmental consequences of using secondary recycled materials instead of the current use of primary raw materials?

The decision on the purpose of the analysis largely influences the selection of systemic boundaries. In this chapter, we need to determine the scope of the analysis by defining which stages of the product life cycle will be included in the analysis. In full LCA analyses, the system boundary is defined to cover all stages in the life cycle – from the extraction of raw materials to the final disposal of the product. Sometimes, however, the purpose of a study requires a different approach that does not include all stages of the life cycle. This is often the case with products with many different uses, where it is completely impossible to monitor the life cycle after the production phase has been completed. The scope of such analyses is known as "cradle-to-grave", as it follows the product from the extraction of raw materials to the "exit door" of the factory

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🛠 **Worksheets 4.2:** Define the purpose and scope of the environmental impact analysis.

4.3 Determination of the purpose and scope of the environmental impact analysis

A successful environmental impact analysis starts with a clear definition of the purpose and intended use of the results. At the initial stage, we need to think carefully about why we are conducting the analysis, how it will be carried out, and who its users will be. These answers have a significant impact on methodological decisions, including the choice of system boundaries and the required data accuracy.

The purpose of the analysis can be purely internal – for example, to identify environmentally critical points in the product life cycle in order to optimise them. However, it can also have an external function, such as preparing an environmental product declaration (EPD), reporting to stakeholders or benchmarking several product alternatives.

In the context of sustainability planning, the most common goal is to gain a comprehensive insight into the environmental burden of individual phases of the production process. We often start with a more general definition, such as "assessing the environmental impacts of a product" or "determining its environmental strengths and weaknesses." This general purpose is then concretised through the targeted questions that guide the analysis.

Examples of targeted questions:

- Where do the greatest environmental pressures occur in the product life cycle?
- Which materials or processes are most environmentally problematic?
- What impact would replacing materials with secondary or recycled raw materials have?
- What are the environmental consequences of changes in the production process?
- How does our product compare to alternatives in terms of carbon footprint or other environmental indicators?

Once the purpose of the analysis has been determined, the scope of the study can be defined accordingly. This involves precisely defining the system boundaries, i.e. which phases of the product life cycle will be taken into account. A complete LCA analysis includes all phases – from raw material extraction and processing, through production, use, to finishing and disposal (the so-called "cradle to grave").

In practice, however, we also often use simplistic approaches where integrity is not strictly necessary or feasible. For example, for products with unpredictable or varied uses, we can limit the scope to phases that can be reliably analysed. Most often, in such cases, the "cradle-to-door" approach is used. Cradle-to-gate), which includes the stages from the extraction of raw materials to the exit of the product from production, without including the use phase and the end of life.

Scope flexibility:

- Cradle-to-grave: the entire life cycle, including use and disposal.
- Cradle-to-gate: to the factory exit.
- Gate-to-gate: a single production stage.
- Cradle-to-cradle: A circular design that involves recycling or reuse.

Taking into account the real possibilities of the company (e.g. availability of data, time constraints, complexity of the product) helps us to select the appropriate scope that allows us to perform the analysis with sufficient accuracy and appropriate use value.

Table 4.3 provides some examples of the definition of the functional unit of certain products. They were randomly selected and can serve as inspiration for other areas.

Table 4.2: Examples of defining functional units.

Telugu / Function	Quantity	Period	Key features / required performance
Cleaning agent	Cleaning 1000 m^2 linoleum floor	1 year	Purity level 4–5, gloss 5, stability 6–7 (on the EN scale of standards)
Textile paint	Dyeing 100 kg of yarn	–	Appropriate quality and shade in accordance with DIN standard
Seat foam	Use of a single seat in the workplace	10 years	Hardness and tear resistance, compliance with fire test BS 5852, Part 2
Water heater	Heating 110 litres of water to 55 °C per day	15 years	Conforms to NP-197-N standard, adjustable thermostat, spill protection, aesthetic appearance
One-lever faucet	Water mixing and flow control (210,000 cycles)	–	One-handed implementation, compliance with the requirements of EN 817

🛠 **Worksheets 4.3:** Define a Functional Unit.

4.4 Life cycle definition

In the following, we will prepare a schematic overview of the life cycle of a product, paying equal attention to all phases of the life cycle. Drawing up a life cycle scheme is important because it documents all the stages of the product that need to be considered. This will identify stages of the life cycle that would otherwise be overlooked. Based on this, the team will be able to identify those stages of the life cycle that can be prioritized to increase the effectiveness of the sustainability planning project. The priority list of the main phases to be analysed will depend on a number of factors, such as the company's impact on changes in this phase and the availability of information.

The process diagram (flow diagram) needs to be visually presented, which can be achieved by using software for the preparation of diagrams, but the diagram can also be drawn manually. It is recommended that the physical location of each stage of the life cycle be indicated on the diagram (Figure 4.2).

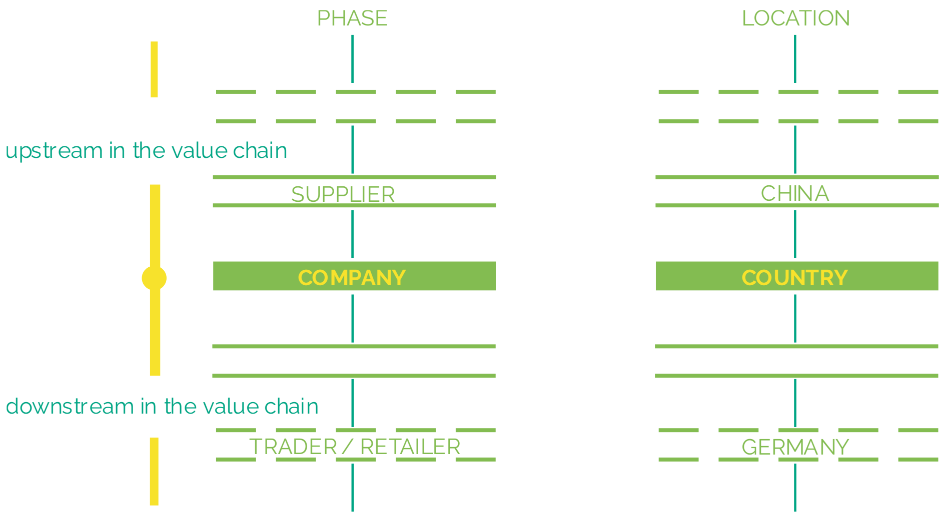


Figure 4.2: Example of a process scheme part (Crul & Diehl, 2009).

First, we start with a rough sketch of the life cycle of the product, and then add details. We prepare a basic process diagram that roughly illustrates the life cycle of a product, which usually consists of five main stages:

- *Raw materials* include the extraction and production of materials (e.g. plastic granulates from crude oil) and intermediate products (e.g. aluminium profiles).
- *Production* includes the purchase of components and the production and installation of processes at the suppliers' premises.
- *Transport* covers the entire logistics chain from suppliers to end users, including distribution by ships, trains, planes, trucks, vans and cars.
- *The use* includes the actual use and the excipients necessary for the product to perform its function. The level of use also includes installation and possible maintenance activities.
- *Disposal* includes reuse/recycling, incineration and disposal. The actual distribution of disposal options depends on several factors, including the requirements laid down, where the product is disposed of, who is disposing of the product (individual or company), etc.

Then, for each phase in the process diagram, we enter the inlets and outlets. Inlets are, for example, raw materials, materials and chemicals, energy and water consumption, etc. Discharges represent, for example, emissions to air, discharges to water, quantities of waste, etc. In addition, the process diagram should draw attention to possible health effects, such as chemical influences, noise, dust, etc. Let's also not forget to study the materials and substances used for the operation and maintenance of the product at the application stage. For the disposal phase, it is important to consider and take into account whether the entire product is removed in one way or if some parts are removed in another way. For example, we can consider that large metal parts of a product are separated and recycled, while the rest of the product goes to incineration.

🛠 **Worksheets 4.4:** Define the Life Cycle. Describe the stages in the lifecycle process diagram and indicate the physical location.

4.5 Inventory (inventory of material flows of individual processes in the life cycle)

The purpose of the inventory is to identify and determine the environmental pressures during the life cycle of the product under study. In this phase, all data on material and energy consumption in the system, air emissions, liquid discharges, solid waste released into the environment, etc., are processed. In most cases, it is advisable to start with a simple and "rough" calculation first. At a later stage, you can add details and change or supplement the data. By doing so, you don't spend too much time on details. In general, it is better to make several estimates first and look for more accurate data later, if it turns out necessary.

The inventory includes:

- precise definition of the investigated system,
- data collection and validation,
- the determination of environmental pressures in multifunctional systems, and
- quantification of environmental pressures.

4.5.1 Precise definition of the system under study

A precise definition of the studied system includes the division of the system into interconnected subsystems, which have already been defined in the process of defining the life cycle by preparing flow diagrams. Depending on the available data, subsystems may represent operating units or a group of units. The boundaries are then evaluated for each subsystem separately.

A process unit is the smallest part of a product system for which data is collected (individual production processes, production lines, cradle-to-door systems for components, transport, etc.). A product system is a collection of basic process units that are connected to lathes. The product system can perform one or more functions.

4.5.2 Data collection

Data collection is usually the most time-consuming part of an environmental impact analysis, ensuring the quality of the results and the reusability of the data collected. At this stage, we will try to obtain as much numerical data as possible, as well as descriptive, qualitative data on the entire life cycle of the product. It is recommended that data be collected in spreadsheets to make them more easily accessible to others. This will also help us illustrate what data is included in our environmental impact assessment.

The quantity and quality of the data depend on the method we have chosen to assess the environmental impacts. The least demanding in terms of data is the use of the MECO matrix, where qualitative estimates can also be used. More data-intensive are the eco-indicator method and the complete LCA analysis. Regardless of the method chosen, we will first start by collecting known information or information that we can quickly obtain.

Not all the details of the product life cycle are generally known, so certain approximation estimates are also needed, which can lead to two measures. The first measure is to abandon part of the process or the whole process, which is acceptable only when the contribution of the omitted work is smaller compared to other processes. The second measure is for the user to estimate the quantities themselves.

When collecting data, we constantly validate it to determine whether the collected data are representative and valid for the described production system. The data can be validated by comparing it with other data sources or by using mass and energy balances. We need to always check whether the data used is suitable for the intended use (e.g. whether the data represents the right type of technology, whether it represents the right production plant, whether the data is up-to-date, etc.).

4.5.3 Data on raw materials and production

Information about raw materials and production will often be available from the company's production department. Many companies have a so-called list of raw materials and processes, which includes all the necessary data. An important source of data can be product specifications, the supplier's material safety data sheets and technical specifications. When collecting raw material data, we may contact suppliers and request environmental data on the raw materials purchased. Rarely will suppliers have data for the entire cradle-to-door lifecycle. However, they will most likely have data on their processes, and we will need to supplement the data for individual stages of the life cycle with data from raw material manufacturers or other sources.

4.5.4 Product information

It is usually difficult to obtain accurate information about the chemical substances in each product. The most relevant information can be obtained from the supplier. The REACH Regulation (short for Registration, Evaluation and Authorisation of Chemicals) prescribes that manufacturers and importers of any chemical (pure substance or substances in a preparation or article) manufactured or imported in the European Union must take responsibility for the safe handling of chemicals and submit data on the substance to the European Chemicals Agency (ECHA).

4.5.5 Information on the use of the product

Information on the sale of a product is often available in the sales and marketing department, while data on actual use can be collected from sales and product development staff, etc. It is sometimes difficult to collect adequate data for the application phase, as consumer behaviour varies considerably and is not always predictable. Some products' average lifespan also changes. For some products, statistical studies of consumer behaviour and product performance are available. To represent the application phase, the results of the product's performance tests can be used as an approximate replacement. The source of data can also be environmental permits, inspection reports, and the like.

4.5.6 Energy consumption data

The company or suppliers often do not know the energy costs (energy content of substances per kilogram) to produce materials and substances. If we cannot get the necessary information, we may find it in manuals or databases. If we have access to databases that are integrated into LCA software tools, we can find a huge amount of useful information about individual processes there.

4.5.7 Transport data

When collecting transport data, we will usually collect data on distances and routes. We will later join this data with data on energy consumption and emissions from different modes of transport. It will often be necessary to obtain information on the disposal of the product from other sources, such as the local recycling warehouse, dealers (who sometimes receive old products when new ones are sold) or knowledge institutions.

4.5.8 Distribution of environmental impacts in multifunctional systems

When collecting data, we may encounter an example where the data covers the production of several products (for example, if we produce several different products and record only the total consumption of electricity and heat, or if we have calculated the total consumption of cooling water for two production lines for the production of different items). In such cases, we need to use the allocation process. *Allocation*), which divides the multi-production system into only those environmental burdens that each product generates. With allocation, we therefore define what part of the total emissions and consumption of materials can be attributed to a particular product.

As an example, where we encounter the problem of allocation, we could cite the production of gasoline as an example of a process where, in addition to gasoline, kerosene, diesel fuel, fuel oil, etc., are produced by fractionated distillation of petroleum. The question is how to allocate total emissions and resource consumption to gasoline itself. Another example could be a polymeric material that is assumed to be heat-treated (burned) at the end of its life cycle. There are many other waste products that are incinerated at once: to what extent is our product responsible for the emissions from the incinerator?

For the process of distribution (allocation), several recommendations have been developed:

- **Avoid allocation**: The first recommendation is to try to avoid allocation as much as possible. This can be done by extending the boundaries of the system, e.g. by incorporating the processes necessary for the production of a by-product.
- **Allocation according to natural causality**: In this method of allocation, we simply use common sense. For example, in the combined incineration of waste of different products, SOX emissions can be distributed based on the sulphur content of individual products, i.e. the more sulphur a given product contains, the more it is responsible for sulphur oxide emissions. If part of the waste does not contain sulphur, the product's responsibility for sulphur oxide emissions can be neglected. Unfortunately, there are many examples of allocations that are unsolvable with this approach.
- **Allocation based on physical parameters**: This allocation is based on physical parameters such as mass, energy, etc. In this case, we divide the total environmental impact (e.g. CO2 emissions) in proportion to the mass outflows of the products.
- **Allocation based on economic values (prices):** This allocation is based on economic values (prices) and is similar to the previous approach, except that here the basis is the economic value of products or by-products. For the most part, the main product has the highest value and is therefore the main culprit of the total environmental load. With this method, we must bear in mind that prices usually change over time, so economic conditions can affect allocation.
- **Arbitrary allocation**: Arbitrary allocation is the least desirable approach in which the environmental burdens of each (by-product) are distributed arbitrarily, e.g. an equal share for each product, a 100 % share of emissions per product, or any other distribution.

Editing data for further environmental impact assessment

Once we have collected all the data, we need to edit it for further environmental impact assessment. Rarely are the data collected immediately suitable for further analysis. Often, this phase also includes the conversion of units of measurement, which we have to be very careful about, as this is where major errors can occur. The data must relate to the reference flow, which represents the functional unit. Many times the data obtained are valid for the entire annual production, so we have to recalculate them (e.g. to apply to 1 kg or 1 t of product). This is done by determining the connections between inlets and outlets (mass balances) for individual process units and calculating the resulting system of equations. One of the equations will determine the reference flow. We must also be careful of the currents that cross the boundaries of the system so that we can convert them to the reference current. Data on the inflows and outflows of the processing units or the product system can then be collected into several categories to facilitate the management of the collected data (e.g. sources, products, energy, raw materials, emissions, waste, etc.).

🛠 Worksheets 4.5:

Inventory (inventory of material flows of individual processes in the life cycle).

4.6 Environmental impact assessment

Right at the beginning of the process of assessing the environmental aspects of the selected product, in Chapter 4.1, we selected the environmental impact analysis tool that best suited our needs. Depending on the chosen method, we have adapted the inventory process and collected data that are sufficient for the selected method. In this chapter, we will now focus on the chosen method and use it to assess the environmental impacts of the product.

4.6.1 Assessment of environmental impacts by classifying the identified environmental impacts in the MECO matrix

If we have chosen to use the MECO matrix to assess environmental impacts, we will now classify the identified environmental impacts into one of four categories in the matrix: materials, energy, chemicals, and more. When filling out the matrix, the existing knowledge within the team is most often sufficient. The basic idea of the approach is to bring together a sustainability planning team and discuss environmental and other aspects of the different stages of the life cycle. In some cases, it may be useful to invite an external expert in a specific field (e.g. we can invite an environmental or energy expert to discuss environmental aspects, etc.).

There are different ways to fill the matrix. The team can give both qualitative estimates and quantitative estimates (actual quantitative values of flows in the life cycle). When filling in the MECO matrix, it is recommended to use as much measured data as possible and avoid vague statements. Of course, the purpose of filling in the matrix is not to quantify all materials and processes, but only the most important ones.

To help you understand the use of the MECO matrix, here are some suggestions for the type of data collected in each category:

Material line: This row is dedicated to information on environmental problems concerning material inflows and material outflows. This row must contain information and data on the use of materials and components that are non-renewable, close to depletion, generate emissions in production (e.g. copper, lead, zinc), incompatible and/or inefficiently used at all stages of the life cycle of the product. Important questions for the team include:

- What type is used, and how much material is used?
- What method and amount of surface treatment is used?
- Is the material renewable or non-renewable?
- Are the materials incompatible (for recycling)?
- Second?

Power consumption bar: This bar indicates the energy consumption at all stages of the life cycle. This could include the use of energy for the production of the product itself, transport, operation and use, maintenance and refurbishment, etc. Material inputs with a high energy content are listed in the first cells of this row. Exhaust gases produced as a result of energy use are also included in this line. Some important questions for the team are as follows:

- How much energy is used in production?
- What raw material is used (coal, gas, oil, renewables, etc.)?
- How is the product transported, and by what distance and by what mode of transport?
- Are energy-intensive materials used, such as primary aluminium?
- Second?

Chemicals row: For each stage of the life cycle, this row indicates the consumption of chemicals and related emissions (e.g. toxic chemicals used in production or materials). Some important questions for the team include:

- How many chemicals are used in production?
- What chemicals are used?
- What is the toxicity of the chemicals used?
- Second?

Line after "other": In this line, we can highlight some of the more important environmental aspects, such as water consumption or greenhouse gas emissions, for example. We can also include an estimate of the more visible costs that belong to each stage of the life cycle. This line may also include the human resource management aspect and list the activities that are necessary for this type of improvement in the company. Some important things include:

- How safe and clean is the working environment?
- Is health care provided for employees and their families?
- Are the company's business rules anti-discrimination?
- Are there training and development opportunities in place for employees?
- Second?

🛠 **4.6 Worksheets**: Environmental impact assessment by the classification of identified environmental impacts in the MECO matrix. Determine the Environmental criteria of eco-design of products (lines) and the life cycle phase (columns) that you'll include. Fill in the first row and the first column of the influence matrix. Identify those cells or activities in the impact matrix that have a major impact on the sustainable development of the company. Table 4.3: Example of a completed MECO matrix with data for inlets and outlets.

After completing the data entry into the matrix, we examine all the cells of the matrix and highlight those with a greater impact on the sustainability of the product. In order to prioritise the main environmental aspects using the MECO matrix, it is appropriate to follow the Golden Rules, which provide guidance on the main sources of environmental impacts:

- For plug-in products, energy consumption is an interesting aspect to consider.
- pay attention to materials with high energy requirements for their extraction (e.g. Al) and heavy metals (Cd, Zn, Pb, Cu, Cr, etc.),
- pay attention to the consumption of auxiliary materials at the stage of using the product,
- To define priorities, we can seek the help of an environmental consultant (eco-design expert).

The next step is to prioritise the impacts that will become the centre of developing opportunities for improvement. In the development of the matrix, some possibilities for improvement will also become apparent. Therefore, we collect obvious opportunities for improvement, which we will be able to use at a later stage of idea generation.

Table 4.3: Example of a completed MECO matrix with data for inlets and outlets.

	Preparation of raw materials	Production	Use	Disposal	Transport
Use of materials	Aluminium: 0.2 kg Chromium: 0.3 kg Iron: 1.4 kg Copper: 0.3 kg Nickel: 0.1 kg			Aluminium: 0.04 kg Chromium: 0.06 kg Iron: 0.3 kg Copper: 0.1 kg Nickel: 0 kg	
	Waste: 6 kg	Waste: 1.5 kg	Waste: 250 kg	Waste: 6 kg Hazardous waste: 0.5 kg	
Energy consumption	550 MJ	380 MJ	22,200 MJ	20 MJ	35 MJ
Chemicals	PAH Little data	Refrigerant Lubricant Xylene		No data available	
Another		Noise Dust	Noise	Dust	

4.6.2 Environmental impact assessment using the Full Life Cycle Analysis (LCA) software tool

If we have decided to carry out an environmental impact assessment with a selected computer software tool, the preliminary implementation of the environmental impact assessment using the MECO matrix can be a good basis for further computer modelling. With it, we have already identified some areas of environmental impact of the product.

LCA analysis software, as a rule, consists of a database and a modelling module. Modelling is carried out by connecting sequential processes with material flows. This builds a process chain where each process represents a production stage that is determined by its inlets and outlets. The outflow from the previous stage represents the inflow of the next process. Most LCA software tools include (or can be integrated with) databases that are separate from the modelling module. This database includes processes and process flows and even modelled process chains that can be used to model our scenarios.

The software provides various methods of calculating environmental impacts and often includes uncertainty and sensitivity analyses. By using LCA software, we can convert the environmental burdens determined in the inventory into the corresponding environmental impacts. This is done by **classification**, which involves grouping environmental pressures into a smaller number of categories of environmental impacts, such as climate change, ozone depletion, acidification, eutrophication, human poisoning, etc. With the **characterisation** process, the software will convert and combine the results of the inventory analysis into indicators of environmental impacts using the included characterisation factors. Most LCA software tools also allow (albeit optional) **normalisation of environmental impacts** against a reference value, such as the total emissions in a given area over a given period of time (e.g. country, Europe, world). This makes it possible to estimate the extent to which an activity affects regional or global environmental impacts. In the final assessment or evaluation, many software offers (optional) weighing of individual environmental impacts with the possibility of assigning weights that indicate their importance.

4.7 Interpretation of the results of the environmental impact assessment

In order to properly interpret the results of the environmental impact assessment, it is first necessary to thoroughly analyse all the results obtained through the previous methodological steps. First, we can draw up interim conclusions based on the results of the environmental impact assessment. When analysing the results, we will certainly face uncertainty, so we must take this factor into account when interpreting them. Once we have checked for uncertainties in relation to the results, we may need to change the conclusions of our analysis. Finally, we need to check whether the purpose of the impact assessment has been fulfilled. We need to answer the questions that were asked at the stage of defining the purpose and scope of the analysis. Possible ways to reduce the environmental burden of the product should be proposed and evaluated. At this stage, we will prepare a detailed report and present the results in the most informative way.

4.7.1 Uncertainty in the results of the EIA

When interpreting the results, we are faced with uncertainty. Regardless of which tool we use to evaluate, we will encounter quite a few weak points. The quality of the results is most dependent on the quality of the data, which is often difficult to obtain. These factors must be taken into account when interpreting the results, and the conditions for the acceptability of the results must be described unambiguously.

There are usually two main sources of uncertainty. The first is the quality of the data, which is often obtained from various sources, estimates, assumptions, theoretical calculations, etc. Data uncertainties relate to difficulties in measuring and predicting impacts. This type of uncertainty is relatively easy to manage and can be expressed as a range or standard deviation. Another source of uncertainty is the inclusion of subjective decisions that cannot be avoided and are part of the model (e.g. system boundaries, allocation approach, characterisation models, etc.).

Data uncertainties

When dealing with uncertainty, it is important to distinguish between absolute and relative uncertainty. By the latter, we mean uncertainties in the differences between indicators. This relative uncertainty is most important for practical use by a user who wants to compare materials or design options. Relative uncertainty can be much less than absolute uncertainty because relative uncertainties are related and tend to compensate for each other.

Example:

1. Suppose that the reference product A is made of 5 kg of polyethene and the comparable product B of 6 kg of the same material (polyethene). In this case, it can be reasonably assumed that product B will, in any case, have a higher environmental burden regardless of the magnitude of the uncertainty of the indicators, since any error in methodology would be compensated.

2. Now suppose that product B is made of polypropylene and not of polyethene. In this case, uncertainties will play a limited role, as production processes and the most important emissions and feedstocks are not very different. For example, if there is a major error in the oil production data in a commodity damage model, that error will have the same impact in both cases. Similarly, the error in the CO_2 damage model would be almost exactly the same. We can conclude that in the case of comparing similar processes, the uncertainties of the results are small.

3. Now suppose that product B is made of wood. At present, uncertainties can be significant, as the processes, the most important emissions and the raw material sources are almost completely different. An error in the damage model for oil production cannot be compensated for by a similar error in the timber production process, as relatively little oil is used to harvest and transport the timber. Similarly, an error in the land-use model (logging in the forest) cannot be compensated for by a model error for refineries, where the size of the land used per kg of oil is low. This means that larger errors can be expected when the values of environmental indicators are used to compare two completely different materials or processes.

From the above example, we can see that it is very difficult to generalise the uncertainties of the indicator, since much depends on the way in which the shortcomings of the model compensate for each other. As a very provisional and general measure, we recommend the following guidelines when comparing different life cycles:

- determine the most important processes (processes with the highest contributions),
- find out whether these processes have similar or different raw materials, principles of operation and emissions,
- If we find that these dominant processes are quite similar, the difference between the results of the environmental assessment should be 10 to 50 % in order to be able to conclude on the best option.
- If we find that these dominant processes are not similar or that they are completely different, the difference between the results of the environmental assessment (we are talking mainly about eco-indicator points) should be more than 100% in order to be able to draw a conclusion about the best option.

When we need to make important strategic decisions based on analysis, we recommend using the Eco-Indicator methodology within a fully transparent LCA software, as this will allow for a much better understanding of uncertainties.

Uncertainties about the correctness of the model

In discussions about the significance of environmental impacts, opinions tend to be very diverse. This may have to do with differences in the level of knowledge, as well as fundamental differences in perception and views. Some people will argue that long-term effects are more important than short-term ones, while others will believe that environmental problems could be solved in the long term through technological development and appropriate measures. Another difference would be that some people would only be concerned about an issue if there is enough scientific evidence for it, while others would argue that any possible effect should be taken seriously.

It is impossible to reconcile these completely different views, and it is impossible to determine whether a point of view is right or wrong. The developers of the Eco-indicator 99 methodology were often faced with model choices that depend on these different angles. Since it was not possible to develop a specific version for each individual aspect, three "archetypes" of aspects were used. A very simplified definition, according to only three criteria of these variants, is as follows:

Table 4.3: Definition according to three criteria.

	Time aspect	Management	Required level of proof
H (hierarchist) [1]	Balance between the short and long term.	The right policy can prevent many problems.	Inclusion is based on consensus.
I (individualist) [2]	Short-term.	Technology can prevent many problems.	Only proven effects.
E (egalitarian) [3]	Very long-term.	Problems can lead to disaster.	Any potential effects.

[1] The hierarchical lifestyle is formal, embedded in strict traditions and established institutions. Those who have chosen the mentioned style maintain a strictly defined network of family and old friends.
[2] An individualistic lifestyle is a choice for a competitive, wide-open network, for enjoying high-tech devices, for sports, art, risky styles of entertainment, and for freely changing allegiances.
[3] An egalitarian lifestyle is against formality, pomp and artificiality, rejects authoritative institutions and values simplicity, frankness, genuine friendship and spiritual values.

4.7.2 Interpretation of results

In this chapter, we will analyse which processes and stages in the product life cycle are the most important, or which alternative has the lowest score (when comparing the selected product with another). When the materials, processes, transport, etc., used are evaluated by numerical values (e.g. eco-points), we can see which aspects have the highest numerical result. This allows us to further assess at what stage the main environmental impacts (e.g. production, use, waste, etc.) occur. This can help the company to identify and prioritise measures to improve the product.

When interpreting the results, let's consider the following: What surprised us? What environmental burdens are not acceptable? What aspects illustrate the clear problems that we need to solve? In many cases, the environmental profile of a product includes only a small proportion of all processes from the life cycle. In other words, usually only a few processes play a decisive role in the environmental profile, while other impacts are almost negligible and do not have a major impact on the results. On the other hand, some environmental aspects can be more or less evenly distributed across all stages of the lifespan. Perhaps a certain part of the product (e.g. a battery) appears more than once, and therefore it is worth focusing on this aspect as well.

By analysing processes in terms of their contribution to the environmental profile of a product, we identify the most important ones and focus on them. A sensitivity analysis can be performed to determine the impact of input data and methodological approaches on the results of the analysis to check the stability of the results. What happens to the result if we change the flat-rate estimated parameters slightly? Does the main finding then remain unchanged, or do the priorities or preferences of the product then change? If the results turn out to be very sensitive to all phases of the analysis, it will be necessary to evaluate the assumptions more accurately and find additional information. The results of the sensitivity analysis shall indicate whether the overall findings of the analysis are stable and reproducible. For products with a long lifespan, technological foresight also needs to be included (e.g. a completely different technology may be used for their disposal in a few decades).

When interpreting, it is important to take into account the differences between the inventory data and the impacts of the estimation method. In the classification and characterisation, a number of aspects may have been neglected due to the lack of sufficient data. Some types of emissions do not have an equivalent factor, as their impact on the environment is not yet known. It is likely that such aspects have been neglected in the inventory, which must be taken into account when interpreting the results.

5 Product Life Cycle Cost Analysis

Chapter objectives:

understanding the importance of life-cycle cost analysis,

Identifying the most financially sensitive and promising phases of the product life cycle

Worksheets 5: Product Cost Analysis

When selecting the most appropriate planning strategies for sustainability, both environmental and financial benefits and impacts on users must be considered. The goal of sustainable planning is to develop a product with minimal environmental impact and the lowest possible cost throughout its life cycle. A key step in this is to carry out an economic assessment of planning concepts, as the economic treatment of the life cycle is an integral part of sustainability planning.

This economic estimate is called life cycle cost analysis (LCC). It is a complement to the Life Cycle Analysis (LCA), where we also define the purpose and scope (system boundaries, functional unit, allocation, impact assessment, etc.) and ensure the consistency of the methodology with the LCA analysis.

In recent years, several approaches to LCC have been developed, such as classical analysis, Environmental Life Cycle Costing (eLCC) and Social LCC (sLCC), which are used according to the purpose of the analysis and the target audience (see Figure 5.1).

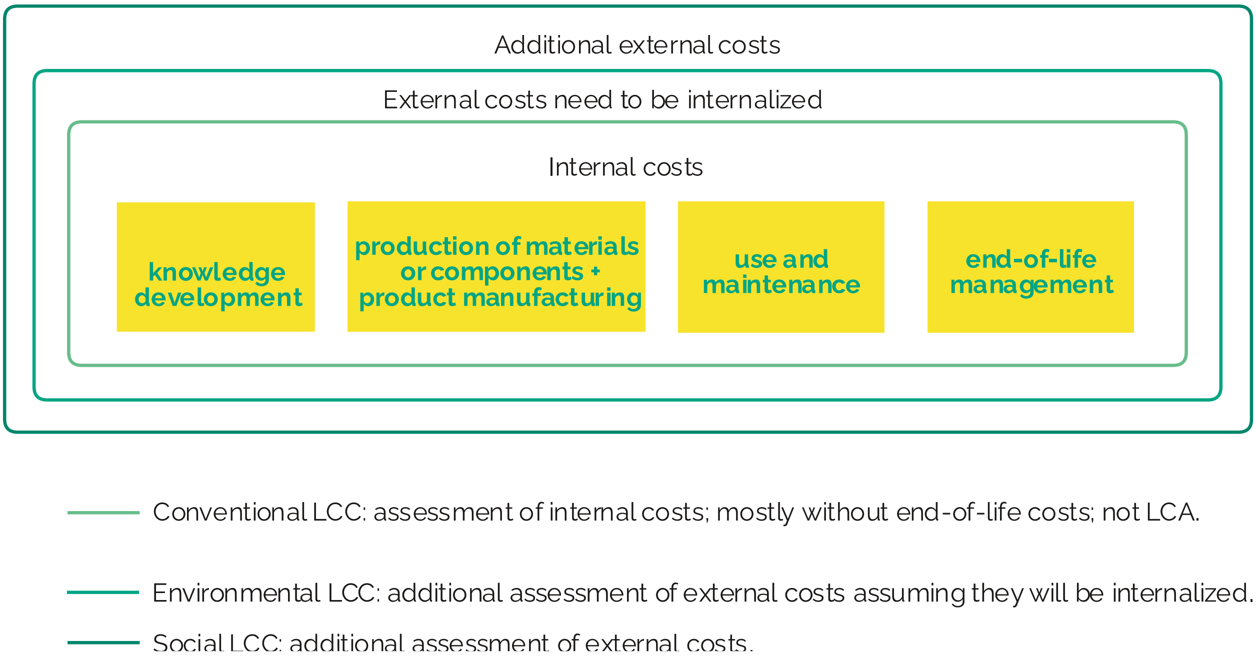


Figure 5.1: Three main forms of life-cycle cost analysis (UNEP, 2020).

5.1 Typical Life Cycle Cost Analysis (LCC)

Conventional LCC is an established practice in companies and public institutions. It focuses on direct costs such as investments, operating costs, maintenance and disposal costs at the end of the product's life. It often does not include the use phase or the end of the life cycle if the costs of these phases are borne by someone else. It is typically used from the perspective of a single market player and does not include the results of the LCA analysis (ISO 15686-5:2017).

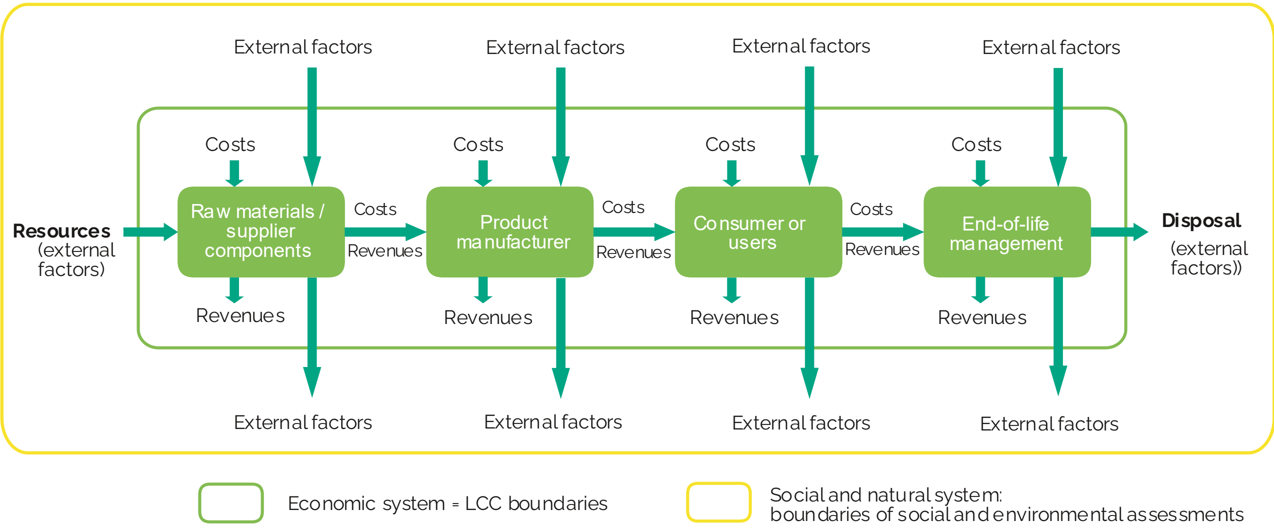
5.2 Environmental Life Cycle Costing Analysis (eLCC)

An environmental LCC expands on the usual LCC by incorporating external environmental costs. It is usually carried out in conjunction with the LCA, sharing the system boundaries and the functional unit. Data for the assessment of externalities are derived from LCA results (e.g. global warming, eutrophication, acidification). The ISO 14008:2019 standard defines ways to monetarily evaluate environmental impacts.

Environmental LCC includes:

- internal costs (e.g. materials, energy, labour);
- external costs (e.g. greenhouse gas emissions, land use), which are expressed in monetary units and are likely to be internalised.

Due to its integrity, the eLCC is useful for both internal decision-making and reporting, labelling, and supporting marketing strategies (UNEP, 2023).



Picture 5.2: Conceptual Framework for Environmental LCC (adapted from Horizon Europe – (CircHive, 2023) (Rebitzer & Hunkeler, 2003).

5.3 Social Life Cycle Cost Analysis (sLCC)

A social LCC incorporates all components of an environmental LCC and further assesses the long-term externalities for society as a whole, at a national or global level. It includes methods such as willingness to pay and eliminates double-counting by adapting to transfers between social actors.

sLCC enables the monetisation of social impacts and thus the link between LCA, corporate social responsibility and policy-making (e.g. Horizon Europe, CircHive 2023).

Table 5.1: Comparison of three types of life-cycle cost analysis.

Aspect	Conventional LCC	Environmental LCC	Social LCC
Added value	-	Link to LCA and environmental efficiency	Considers social externalities
System boundaries	Internal costs	Internal + external environmental costs	Internal + all external costs
Reference unit	Product	Functional unit	System
Model	Quasi-dynamic	Steady-state	Quasi-dynamic
Application	Internal decision-making	Internal and external decision-making	Public policies, social responsibility

🛠 **Worksheets 5**: Cost analysis of the product life cycle.

6 Developing a strategy and preparing a sustainability planning brief

The objectives of this chapter are:

- Identifying the most important sustainability planning strategies to improve the product,

- Preparation of a brief overview (draft or brief) of planning for sustainability.

Worksheets 6: Developing a Sustainability Planning Strategy and Preparing a Sustainability Planning Brief

While conducting a life cycle analysis with any of the tools described above, we learned what the main environmental aspects of the product are. Therefore, some ideas for improving the environment will be created quite spontaneously. Of course, they will not be the only possible ones, so when generating ideas, we will not only focus on the main environmental aspects, but we will also take into account all stages of the life cycle of a product, which will give us more freedom of choice.

The lessons learned from the previous chapters are the starting point for the approach to this chapter. Knowledge of the main environmental aspects and the motivational factors of an eco-design company will help us evaluate and prioritise the ideas created and their introduction into a new product.

There are various strategies in which most ideas about improving the environmental aspect of a product can be placed. We can consider seven strategies (see Figure 6.1) that cover a wide range of possible improvements:

0) A new product concept by optimising its function.
1) Choice of materials with a lower environmental impact.
2) Reduction of material flows.
3) Optimisation of production techniques.
4) Optimisation of the distribution system.
5) Reduction of environmental impacts during use.
6) Planning for longevity.
7) End-of-life planning.

In addition to the seven strategies listed above, which address different stages of the product lifecycle, the strategy wheel also includes the "0" strategy, which addresses a completely new concept of a product or service by optimising its function. This is an important innovation strategy of "radical change", where the development of a product and/or service defines consumer needs to be met in the most sustainable way possible. We examine the product "from a bird's eye view" in terms of the different needs it needs to meet and consider other ways to meet those needs.

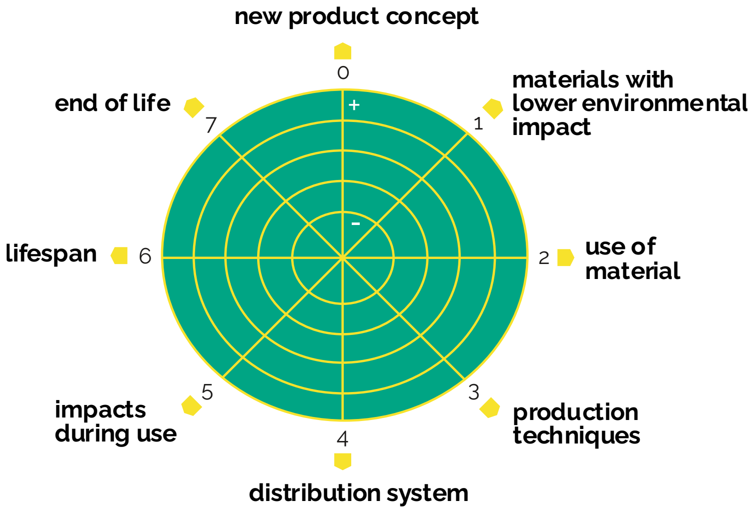


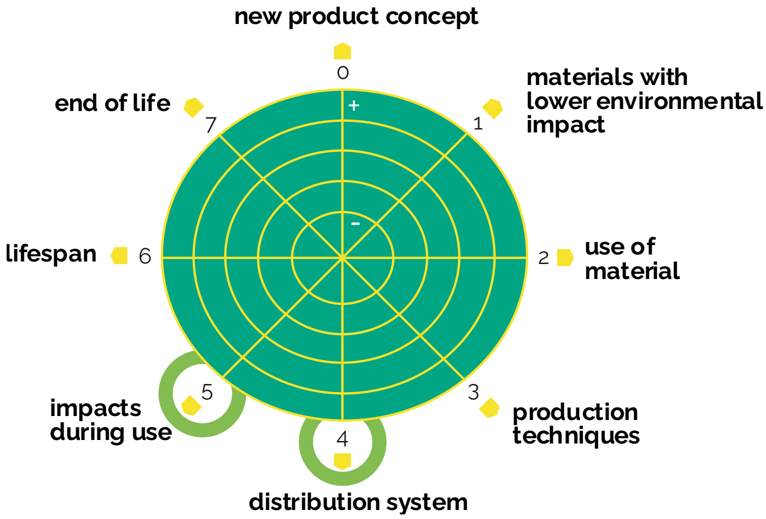
Figure 6.1: Sustainability Planning Strategies Wheel (Brezet, 1997).

Throughout the process of defining a planning strategy for sustainability, we must keep in mind the motivational factors analysed in the second chapter of this guide (customer requirements, legal requirements, etc.) as they will help guide our work.

The strategy wheel (Figure 6.1) can be used to identify the planning strategies that are most appropriate for the selected product. The results of the EIA (Chapter 4) are linked to a possible improvement of the sustainability planning strategy. However, the SWOT analysis results and the identification of the priority motivational factors of planning for sustainability (Chapter 2) can lead to a completely different direction of product improvement.

For example, in the case of an electronic product developed by a company, the results of the environmental impact assessment in Chapter 4 could highlight energy use and distribution as the aspects with the most significant environmental impact. As a result, the team would focus on planning strategies for sustainability related to "reducing impacts during use" (strategy 5) and "optimising the distribution system" (strategy 4). On the other hand, the outcome of the assessment of the motivational factors of planning for sustainability could show that environmental legislation on the take-back of waste apparatus and the use of hazardous substances is essential. These findings could lead to the decision to focus on "low-impact material selection" (Strategy 1) and "end-of-life planning" (Strategy 7), as shown in Figure 6.2.

This can lead to an assessment of the trade-offs between the results of different assessments. To facilitate the decision-making process, the team can choose two strategies for possible improvements, based on the impact assessment of sustainability planning, and two strategies based on the motivational factors of sustainability planning.



Picture 6.2: Example of choosing sustainability planning strategies based on (1) priorities of the Sustainability Planning Impact Assessment (above) and (2) priorities based on the motivational drivers of sustainability planning (below) (Crul & Diehl, 2009).

After defining the project goals and selecting the four priority planning strategies for sustainability, the team has a foundation for the next steps of planning for sustainability, where they will generate ideas and develop concepts.

🛠 **Worksheets 6.1:** Develop eco-design strategies (determine which eco-design strategies the company and the project team will focus on when generating ideas and developing the product concept).

Brief overview (draft, briefing) of planning for sustainability

Once the leading sustainability planning strategies have been selected, the team also produces a well-defined draft (often referred to as a brief) of sustainability planning with clear goals and important information that covers the company's strategic vision and specific objectives for the product. It is recommended that the draft be defined by top management in collaboration with the Sustainability Planning Project Team. The draft sustainability planning has the following meaning:

- It is a project planning instrument.
- It is a written document consisting of a set of ideas that enable the team to understand and implement the objectives of the project.
- includes a brief description of the project, typical users and their requirements or needs,
- it may include requirements and constraints at technical, financial and legislative levels, provided that they are known from the outset;
- It is an open document that can change during the planning process.

A clear and well-prepared draft contributes to the success of the project by reducing the possibility of a mismatch between the final results and the objectives and business needs. The draft sustainability planning should include at least:

- the reason(s) for choosing the product,
- an indication of social (people), environmental (planet) and financial (profit) goals,
- selected planning strategies for sustainability,
- the way the project is managed,
- the final composition of the project team;
- the project plan and timeline, and
- project budget and activity overview.

🛠 Worksheets 6.2: Prepare a brief overview (draft/brief) of ecodesign.

6.1 Strategy 0: A new product concept by optimising its function

Strategy 0 encourages reflection on a completely new concept of a product or service that provides the user with the same or better functionality with significantly less environmental and social impact. It is a so-called systemic consideration, in which we recognise the basic need that the product satisfies and try to address it with alternative solutions that are more sustainable.

Analysing the needs of the user is key to the successful implementation of this strategy. It often leads us to service models, dematerialisation, or sharing instead of individual property.

6.1.1 Dematerialization

Dematerialisation refers to the replacement of physical products with digital or intangible solutions, thereby reducing the need for materials, energy, transport and storage. Examples of this type of practice are e-mail (instead of paper correspondence), streaming video services (instead of DVDs), virtual offices, and digital receipts.

Modern trends, such as digitalisation, automation and ICT development, allow dematerialisation to be widely implemented, which directly supports the SDGs (Goedkoop, 1995).

6.1.2 Shared use of products

Product sharing (e.g. shared laundries, tool rentals, coworking spaces, shared mobility) allows for greater product utilisation and reduces the need for individual ownership. Such models benefit both users and service providers: they reduce costs and simplify maintenance for users, and allow providers to develop new business models and sustainably oriented services.

Successful examples include car-sharing schemes (e.g. car-sharing, car-pooling), public cycling systems and cooperative communities with shared equipment.

6.1.3 Service instead of product

The Product-Service System (PSS) model replaces ownership of a product with a service that provides the same benefit to the user. The company thus remains the owner of the product, takes care of its maintenance, updating and proper disposal, and the user pays for the function (e.g. cleaning service, mobility, cooling).

Example: Instead of selling air conditioners, a company offers cooling as a service. Thus, it is interested in providing an energy-efficient and reliable solution, thereby reducing overall environmental impacts. This approach is often combined with a circular economy model.

Tips for implementing strategy 0

By its very nature, Strategy 0 is geared more towards strategic reflection than immediate operational action. It is intended to transform the company in the long term towards sustainable business models. Therefore, decisions on its implementation are often the responsibility of the company's management, while the development team can prepare analyses, proposals and scenarios.

It is particularly suitable when:

- There is a need for radical innovation,
- detects a transformation of the market or consumer habits;

- The company wants to develop new sustainable business models (e.g. subscription systems, PSS, digital services).

6.2 Strategy 1: Choosing a material with a lower environmental impact

The first step in the cycle of planning strategies for sustainability focuses on the impact of the materials used. It is divided according to the different properties of the materials, with it being advisable to choose non-toxic and renewable materials, low-energy materials, recycled materials (from recycling), and recyclable materials (suitable for recycling).

Some materials and additives are best avoided because they are toxic or cause toxic emissions during their production, use, incineration or disposal. These materials are often not the main material of the product (with the exception of some, e.g. batteries, lead), but are additives in the form of dyes, heat or UV stabilisers, fire retardants, emollients, fillers, expanders, antioxidants, etc. Some dyes and flame retardants are especially dangerous. In many countries, the use of highly toxic substances is prohibited by law.

In the process of product design, it is important to choose the least toxic materials. When designing a product, special attention should be paid to heavy metals, mercury and lead among the most dangerous. Mercury is slowly becoming banned in several countries. Cadmium, the content of which is increasing in the environment, is also a cause for concern. In some countries, it is banned in products, such as dyes.

It is necessary to avoid materials from resources that do not regenerate themselves or are time-consuming, thus indicating the depletion of that resource. Examples include fossil fuels, tropical deciduous trees, and metals such as copper, tin, zinc, and platinum.

Some scientists believe that resource depletion is a minor environmental problem, as these are materials that will become very expensive over time due to their increasingly difficult availability. As a result, such materials will increasingly be recycled or replaced by alternative materials. However, as a rule, the dispersal of material from a site to which it is never returned leads to the accumulation of material in the environment, which thus becomes harmful even before the resource is depleted.

Non-renewable materials are used non-sustainably. Petroleum is the basic raw material used in petrochemical processes, and it is prevalent in the chemical industry. The replacement of petroleum-based chemistry is slowly being implemented under the name "green chemistry". The basic chemicals in this case are produced on the basis of biomass and can be further processed into plastics and other materials. In some processes, vegetable oils (e.g. rapeseed) are used. Most petroleum products are burned for thermal recovery, so the replacement of fossil fuels in industry is a necessity.

The use of non-ferrous metals is also extensive, although they are not a renewable material. The production of primary metals has a significant impact on the environment compared to secondary materials that are reused or replaced. For example, the replacement of copper with optical fibres in communication systems has a positive effect on the environment, although copper is not close to depletion and is non-toxic. The use of recyclable metals also has a positive impact on the environment. Recycling metals is an environmentally important act, especially when it comes to toxic metals such as lead. Recycling can be very efficient with carefully designed systems, up to 99% for lead, for example.

Some materials have a higher energy content than others due to the high energy intensity of extraction and production. The use of such materials is justified only if it leads to other positive environmental advantages in practical use. Aluminium, for example, has a high energy content, as it consumes a huge amount of electricity. However, despite this, its use is justified for a product that is frequently transported and for which there is a recycling system. The reason lies in the lightness of aluminium and its suitability for recycling.

Recycled materials are materials that have already been used in a product. If appropriate, it is necessary to use such material as often as possible so that the materials and the energy invested in their manufacture are not lost. Such an example is copper: recycled copper is several times less material-intensive than primary copper. The ecological burden of primary copper is several times greater than that of recycled copper. Recycled iron and recycled aluminium also use fewer resources than the primary metal. The use of recycled materials corresponds to "closing material streams".

Strategy Tips 1: Choose a Low-Impact Material

Cleaner materials

- Do not use materials or additives that are prohibited due to their toxicity. These include, but are not limited to, PCBs (polychlorinated biphenyls), PCTs (polychlorinated terphenyls), lead (in PVC, electronics, dyes, batteries), cadmium (in dyes and batteries) and mercury (in thermometers, switches, fluorescent tubes).
- Avoid materials and additives that deplete the ozone layer, such as chlorine, fluorine, bromine, methyl bromide, halons, aerosols, foams, refrigerants and solvents that contain CFCs (chlorofluorocarbons).
- Avoid using hydrocarbons that cause summer smog.
- Look for alternatives to surface treatment techniques such as hot electroplating, electrolytic zinc electroplating, and electrolytic chrome plating.
- Look for alternatives to non-ferrous metals such as copper, zinc, brass, chromium and nickel, as harmful emissions are produced during their production.

Renewable materials

- Find alternatives to exhaustible, non-renewable materials.

Materials with low energy content

- Avoid energy-intensive materials such as aluminium in products with a short lifespan.
- Avoid raw materials produced in intensive agriculture.

Recycled materials

- Use recycled materials whenever possible to increase the market demand for recycled materials.
- Use secondary metals such as secondary aluminium and copper instead of their virgin (primary) equivalents.
- Use recycled plastics for the internal parts of products that have only a supportive function and do not require high mechanical, hygienic or tolerant quality.
- When hygiene is important (as in coffee cups and other packaging), you can use a laminate with a core made of recycled plastic and with an outer layer of virgin plastic.
- Take advantage of the unique characteristics of recycled materials in the design process (e.g. variations in colour and texture).

Recyclable materials

- Choose only one type of material for the product as a whole and for individual assemblies.
- If this is not possible, choose mutually compatible materials.
- Avoid using materials that are difficult to separate, such as composite materials, laminates, fillers, flame retardants, and fibreglass reinforcements.
- If possible, use recycled materials that are already on the market.
- The use of materials that pollute the environment, such as labels that impede recycling, should be avoided.

Materials with a positive social impact (generating local revenues)

- Take advantage of materials produced by local producers.
- Encourage local businesses to implement material recycling measures that can (partially) replace the company's raw materials.

6.3 Strategy 2: Reducing the use of materials

The reduction in the weight and size of the product is reflected in the reduced amount of material used and energy consumption. Reducing the use of materials means using the smallest possible amount of material for the production of reliable and strong products. This also includes planning for the minimum volume of the product so that the product occupies the smallest possible volume during transport and storage.

Products are often deliberately designed to be heavier or larger to make them look better quality. This idea of the product can also be achieved through different design techniques. It is clear that products should not be so light as to affect their technical lifespan, but in many cases, reducing the weight or volume of the product is feasible.

Using fewer raw materials to produce a product has a direct impact on reducing its environmental impact. Fewer materials mean the use of fewer raw materials, less waste, and less environmental impact on transport. As an example, we can cite computers that are now based on miniature electronic components, which is why their size has decreased significantly compared to those of 20 years ago.

Dematerialisation is very important when it comes to transporting raw materials from suppliers to manufacturers, as well as the final product to dealers and consumers. By reducing the size and volume of the product, the requirement for transport and storage facilities and the energy required for transport are reduced. This can significantly improve the economy of production.

Tips for Strategy 2: Reduce the use of materials

Weight reduction

- Ensure the strength of the product through design techniques such as reinforcing the ribs instead of oversizing the product.
- Express the quality of the product by good design and not by oversizing the product.
- Consider the multifunctional use of the product (for example, a solar collector on the roof can also act as a roof).

Reduction of (transport) volume

- Reduce the volume required to transport and store a product by reducing its size and weight.
- Design a product that will be foldable or be part of a set of products that go into each other (nesting).
- Consider transporting the product in a non-assembled form, where the assembly is left to a third party or even the end user.

6.4 Strategy 3: Optimisation of production techniques

Product planning involves careful consideration of the production stage. Production techniques are expected to have a low environmental impact with reduced use of auxiliary (especially hazardous) materials and energy, leading to limited losses of raw materials and minimal waste generation.

Such a strategy is known as the cleaner manufacturing approach, which the industry is becoming increasingly familiar with. Environmental improvements to the production process are one of the components of the environmental management system used in industry today and can be certified through the EMAS scheme (EU Environmental Management System for Organisations) or the ISO 14001 standard. Environmental improvement of the production process is one of the components of the environmental management system. However, the cleaner production approach goes beyond the boundaries of the production plant and also applies to suppliers, who must also strive for a more efficient use of materials in production, e.g. through good management, a closed production system and internal recycling. Nowadays, many companies require their suppliers to have a certified environmental management system.

The sustainability planning team will not always have the opportunity to consult on alternative manufacturing techniques. In this case, it is recommended that manufacturing techniques that reduce environmental impact be chosen. In the production process, it is recommended to use the minimum possible number of manufacturing techniques.

The extraction of raw materials and the production of the product require energy. In both processes, significant environmental benefits can be achieved by minimising energy consumption and using the appropriate type of energy. Some extraction processes are energy-intensive, such as the production of primary aluminium. Reducing energy consumption brings significant financial benefits, as reduced taxation of energy products reduces costs. Energy dependency is also reduced, making production less vulnerable to energy supply problems, e.g. during cold winter days.

The existing production process needs to be optimised for the most efficient material metabolism in order to minimise waste flows and emissions. The goal of environmental planning should also include reducing the consumption of consumables or propellants and preventing the use of hazardous substances. In order to detect these possibilities, it is recommended to review (audit) production in terms of the amount of materials used, the consumption of hazardous substances and the amount of waste.

Strategy Tips 3: Optimising Production Techniques

Cleaner production techniques

- If possible, choose a cleaner production technique that requires fewer harmful excipients or additives. For example, CFCs and other chlorinated bleaching agents can be replaced in the degreasing process.
- Choose manufacturing techniques that generate fewer emissions, such as bending instead of welding and connecting instead of soldering.
- Choose processes that allow the most efficient use of the material, such as powder coating instead of paint spraying.

Production with fewer steps

- Use the minimum number of steps of manufacturing techniques.
- Combine component functions into a single component so that fewer manufacturing processes are required.
- Use materials that do not require additional surface treatment.

Lower/cleaner energy consumption

- Reduce energy consumption in existing production processes.
- Motivate the production department and suppliers to produce more energy efficiently.
- Promote the use of renewable energy sources such as biomass, wind, hydro, solar energy, natural gas, and low-sulfur coal.

Reduced waste production

- Plan the product to reduce material waste, especially in processes such as sawing, turning, milling, pressing and cutting.
- Reduce the amount of waste and the percentage of ejection during production.
- Recycle production residues within a process or company.

Less/cleaner consumption of consumables

- Reduce the consumption of consumables during production, e.g. by designing the product so that waste is limited to a specific area during cutting, which reduces cleaning costs.
- Consult with the company's production department and suppliers about the possibilities for more efficient use of materials in production, e.g. through good management, a closed production system and internal recycling.

Safety and cleanliness in the workplace

- Choose manufacturing technologies that require fewer harmful substances and generate fewer toxic emissions.
- Use production techniques that generate less waste and organise an efficient reuse and recycling system for the remaining waste within the company.
- Implement an integrated business performance assessment system that includes ensuring the health and safety of the company, such as the Social Responsibility Standard – SA 8000.

6.5 Strategy 4: Optimisation of the distribution system

The strategy of an efficient distribution system ensures that the product is transported as efficiently as possible from the factory to the retailer and the user. This applies to the product itself, packaging, mode of transport and logistics. If the project also includes a detailed analysis of the packaging, it is necessary to consider the packaging as a product in itself, with its own lifespan.

The most obvious way to reduce transport is to work with local suppliers, as this can avoid long-distance transport. With the principle of smaller/cleaner/reusable packaging, we can prevent waste and emissions. The less packaging is needed, the greater the savings in materials used and transport energy. The optimisation of the distribution system is also influenced by the choice of transport mode (e.g. sea transport is more environmentally friendly than air transport). Efficient loading in the chosen mode of transport and efficient distribution logistics can also reduce environmental impacts.

Strategy Tips 4: Optimising the Distribution System

Smaller/cleaner/reusable packaging

- If all or part of the packaging serves to make the product attractive, use an attractive but slim design to achieve the same effect.
- For shipping and open packaging, consider reusing the packaging in combination with a cash deposit or return system.
- Use appropriate materials for the type of packaging – e.g. avoid PVC and aluminium in non-returnable packaging.
- Use the minimum volume and weight of the package.
- Make sure the packaging is suitable for reducing the volume, folding, and nesting of the product.

An energy-efficient mode of transport

- Motivate the sales department to avoid environmentally harmful modes of transport.
- Transport by ship or train is preferable to transport by truck.
- Air transport should be avoided if possible.

Energy-efficient logistics

- Motivate sales to work with local suppliers to avoid long transport distances.
- Motivate the sales department to implement effective forms of distribution – for example, the simultaneous distribution of large quantities of different goods.
- Use standardised transport and bulk packaging (e.g. Euro pallets and packaging modules of standard dimensions).

Involvement of local suppliers

- Explore options for contracting transport/distribution locally.
- Form a logistics consortium with community partners for joint and more efficient distribution and transportation, and by involving local distributors.

6.6 Strategy 5: Reducing environmental impacts during use

Most often, in order to meet the user's needs with a product, consumables (such as water, detergents, food, energy) and additional products (batteries, charging cartridges, filters, etc.) are needed. This also applies to aggregation and repair. This strategy is aimed at designing the product in such a way that the likelihood of spillage or unnecessary waste materials will be minimised, and therefore, they will not look for a more environmentally efficient alternative.

The objective of reducing energy consumption is to choose more energy-efficient components or omit certain components, which also reduces emissions of greenhouse gases and gases that cause acidification (SO_x and NO_x). Environmental analyses have shown that the use phase of energy-using products has the greatest environmental impact. The use of clean energy sources can significantly reduce environmentally harmful emissions, especially for energy-intensive products. The goal of the strategy to reduce the consumption of consumables is to design a product for the operation of which a minimum amount of auxiliary materials is required. If an ancillary product or consumable is also to be improved in a project, it must be considered as a stand-alone product with its own life cycle. The product can also be designed to encourage the consumer to use the product more efficiently and thus reduce waste.

Tips for Strategy 5: Reducing environmental impacts during use

Low power consumption

- Use the lowest power consumption components on the market.
- Use the default shutdown mode.
- Make sure that the user can turn off watches, stand-by features, and similar devices.
- If energy is used to move the product, the product should be as light as possible.
- If energy is used to heat the substance, the relevant components should be adequately insulated.

Clean energy source

- Choose the least harmful energy source.
- Don't encourage the use of non-rechargeable batteries – for example, A portable radio may be equipped with a charger that encourages the use of rechargeable batteries.
- Promote the use of clean energy, such as low-sulphur energy sources (natural gas and low-sulphur coal), biofuels, wind, hydro and solar energy.

Fewer consumables needed

- Plan your product to reduce the use of auxiliary materials – for example, use a permanent filter in a coffee machine instead of paper filters, and plan the correct filter shape to ensure optimal use of coffee.
- Study the feasibility of reusing consumables (e.g. reusing water in the dishwasher).

Cleaner consumables

- Design your product to use the cleanest consumables available.
- Make sure that the use of the product does not lead to hidden and harmful waste (e.g. by installing appropriate filters).

Reduction of energy and consumables losses

- Prevent misuse of the product by drawing up clear instructions and appropriate formatting.
- Design the product in such a way that the user does not waste auxiliary materials unnecessarily (e.g. the filling inlet must be large enough to prevent spillage).
- Use calibration marks on the product so that the user knows exactly how much auxiliary material (e.g. washing powder) needs to be used.
- Make sure that the default state of the product is most desirable from an environmental point of view (e.g. "no caps on the beverage cups from the vending machine" or "double-sided copy", etc.).

Health support, social added value

- Check the effects of the product on the user's health and avoid the use of toxic substances, radiation, etc.
- Design the product according to the socio-economic needs and capabilities of user groups.
- Evaluate product planning options for low-income social groups.

6.7 Strategy 6: Optimising the lifetime of the product

The goal of a product lifetime optimisation strategy is to extend the technical lifespan (the period of time during which the product works properly) and the aesthetic lifespan (the period of time during which the product is found attractive to the user) so that it can be used for as long as possible. All the principles that follow describe this goal, because the longer the product meets the requirements of the user, the lower their needs for the purchase of a new product.

Sometimes, however, it is better not to extend the life of the product; If the technical life is longer than the aesthetic lifespan, it is necessary to find a new ratio. It is necessary to shorten the technical service life or, if possible, extend the aesthetic one. A shorter lifespan is acceptable if new, less energy-intensive alternatives emerge. Increasing product reliability and durability is a familiar task for product planners. Easy maintenance or repairs are important assurances that the product will be cleaned, maintained and repaired in a timely manner. Choosing a modular structure or a flexible product makes it possible to "revive" a product that is no longer optimal from a technical or aesthetic point of view. In this way, the product still meets the (changed) needs of the user. One of the goals of sustainability planning is also to avoid trendy design that can cause the user to replace the product as soon as it becomes unfashionable. Most products require some maintenance and repairs to keep them attractive and functional. The user will be willing to spend time on these activities if he is caring for the product. Therefore, when designing a product, it is necessary to build a strong attachment of the user to the product.

Tips for Strategy 6: Optimising Product Lifetime

Reliability and durability

- Set a well-thought-out product design and prevent its weak points. For this purpose, special methods are available, such as the analysis of possible errors and their consequences (Analysis of Possible Errors and Their Consequences). FMEA – Failure Mode and Effects Analysis.

Easier maintenance and repair

- Design the product in such a way that it is easy to maintain.
- Indicate how the product opens in case of cleaning or repair, e.g., where the screwdriver lever is used when opening parts of the product.
- Indicate which parts of the product need to be cleaned or maintained in a special way, e.g., by colour-coded lubrication points.
- Indicate which parts of the product need to be inspected more often (rapid wear).
- Make the location of wear detectable so that the replacement or repair is done in a timely manner.
- Place parts that wear out relatively quickly, close together, and within easy reach to make them easy to replace or repair.

Modular product structure

- Design the product in modules so that the product can be upgraded at a later time by adding new modules or features (e.g., plugging in a larger memory capacity in your computer).
- Design the product in modules in such a way that technically or aesthetically obsolete modules can be refurbished (e.g. furniture with replaceable caps that can be removed, cleaned and possibly refurbished).

Classic design

- Plan the appearance of the product so that it does not quickly become uninteresting. This ensures that the aesthetic life of the product is not less than its technical life.

Strong connection between product and user

- Design the product in such a way that it meets the (perhaps hidden) requirements of the user for a long time.
- Make maintenance and repair of the product a pleasure and not just a duty.
- Add value to the product in terms of design and functionality in such a way that the user will not want to confuse it.

Integration of local maintenance systems and services

- Plan your product with local service and maintenance companies in mind.
- Jointly develop new innovative services and reuse centres in the region, which can be involved in servicing both new and existing products.

6.8 Strategy 7: End-of-life planning for a product

The end-of-life system refers to the management of a product at the end of its life. The aim of this strategy is to reuse the valuable ingredients of the product and ensure proper waste management. The reuse of a product, its components or materials can reduce environmental impacts by reusing virgin materials and energy and avoiding the generation of additional hazardous emissions. If it is not possible to close the material and energy loops, safe incineration or disposal of waste must be ensured.

The most appropriate solution is to recycle the entire product for the same or a new use. The more a product retains its original shape, the lower the environmental impacts, taking into account the simultaneous development of return and recycling of the product. A product can be reused by replacing parts of it or by using it elsewhere. When designing a product, it is necessary to consider the possibility of reusing parts or the entire product. Recycling, as a reuse of a material in a product, is a frequently used strategy, as it requires little time and little investment: it is necessary to design a product that is easy to disassemble and use suitable materials for it. Another reason for the popularity of recycling is the financial benefit it brings. It's also easy to communicate about the importance of recycling both inside and outside the company.

Recycling requires a system for collecting materials, transporting the material to the appropriate companies and possibly a return system. It is wrong to emphasise the recyclability of a product if no return and recycling system is in place. When we prioritise recycling over other strategies with higher environmental benefits, it is advisable to consider this decision carefully. There are several levels of recycling, which together form a "cascade of recycling": primary recycling (intended for original use); secondary recycling (intended for lower quality use); and tertiary recycling (breaking down the material into basic raw materials). Only when all possibilities for reuse or recycling have been exhausted does the possibility of thermal treatment of waste in modern waste incineration plants come into consideration.

Tips for Strategy 7: Planning for the End of Life of a Product

Reuse of the product

- Give the product a classic design to make it aesthetically pleasing and attractive to the secondary user.
- Consider how the user might use the product after fulfilling its original function.
- Make sure the design of the product is suitable so as not to become obsolete in technical terms too quickly.

Processing and refurbishment of the product

- Design the product for disposal (from the product to the assembled parts) to ensure that the product is available for inspection, cleaning, repair, and replacement of vulnerable or innovation-sensitive parts of the product.
- The product should have a hierarchical and modular structure; Each module can be removed and reworked in the most convenient way.
- Use detachable joints such as snaps, bolts, or daggers instead of welded joints and glued or soldered ties.
- Use standardised joints to disassemble the product with a few universal tools, e.g. using one type and size of screws.
- Position the joints in such a way that the person in charge of dismantling does not have to turn or move the product.
- Indicate on the product how to open it correctly (e.g. indicate where and how to open the contact with a screwdriver.
- If it is not possible to carry out non-destructive separation, it is necessary to provide different materials that are easy to separate into groups consisting of mutually compatible materials.

Recycling of materials

- Prioritise primary recycling over secondary and tertiary.
- Design the product for disassembly (from subassemblies to components).
- Use recycled materials available on the market.
- When the use of toxic materials in a product is unavoidable, focus them on adjacent areas so that they can be easily separated.
- Choose one or as few different materials as possible for the whole product.
- Avoid using elements that interfere with the recycling process, such as labels.
- Label all parts made of synthetic materials with a standardised material code.

Safer incineration

- The more toxic the substances in the product are, the more the responsible party has to pay for their incineration. Toxic elements must therefore be concentrated and easily extracted so that they can be removed and treated as a separate fraction of waste.

Consideration of local (informal) collection systems and recycling

- Assess the possibilities of incorporating existing formal or informal recycling activities within the community into the acceptance and recycling of end-of-life products.
- Jointly develop or support new and efficient collection and recycling systems in the region.

7 Product Improvement Ideas

The objectives of this chapter are:

- organising a creativity session,

- create new ideas and solutions to improve the product,

- categorising and evaluating the ideas generated.

Worksheets 7: Product Improvement Ideas.

In Chapter 4, we learned about the main environmental aspects of our product, and in Chapter 6, we selected planning strategies for sustainability. In this chapter, we will deal with generating ideas for improving the sustainable aspects of the product. While conducting a life-cycle analysis with any of the proposed tools in Chapter 4, we learned what the main environmental aspects of the product are. Therefore, some ideas for improving the environment will be created quite spontaneously. Of course, they will not be the only possible ones, so when generating ideas, we will not focus on the main environmental aspects, but will again take into account all stages of the product life cycle. This will give us more freedom and a variety of options.

Through the process of creativity, a variety of ideas for improvement will emerge. Once we have all of them collected, we will proceed with their selection, analysis and priority evaluation, as our goal is to focus on improving the main environmental aspects or meeting the company's motivational factors for implementing sustainability planning.

In order to generate ideas for improving the environmental or sustainable aspects of the product, we will use as a basis in Chapter 6, a brief overview (draft) of planning for sustainability and selected planning strategies for sustainability. A strategy scoreboard can serve as a good starting point, guide and inspire us. Idea generation is a creative process that involves various techniques, which we will describe below.

7.1 Creativity techniques

Creativity is an inseparable part of the product development process, and various creativity techniques can help us with this. Creativity can be defined as "all ways of thinking that lead to something new and useful to the thinker". The technique of creativity is supposed to help us generate new ideas. Creativity tools can help us:

- To come up with new ideas,
- Go beyond existing ways of thinking.
- to think "outside the box", i.e. to think outside the current solutions,
- build ideas by taking into account each other's ideas, and
- develop new, inspiring and surprising ideas.

Creativity can be used at the conceptual level of product development, as well as to solve technical problems. In order to understand how creativity techniques work and how they can contribute to the product development process, it is necessary to put them into practice. The challenges they face in the product development process require different approaches to creativity – there is no single best technique. In this chapter, we will introduce some techniques that cover different situations. It is advisable not to stick to just one technique, but to learn to use different techniques and thus develop our own experience.

In general, the flurry of ideas in a group generates more ideas, but sometimes the culture of the group can hinder revolutionary ideas. Group techniques use the ideas of others for inspiration. Team members can use each other's data for additional stimulation.

A person's whirlwind of ideas can lead to original ideas, but there is a danger that the results will be predetermined or limited by the mindset of the brainchild. In the whirlwind of an individual's ideas, free association can initially lead to seemingly irrational results, which can later be refined into more recognisable concepts. Given the advantages and limitations of these two approaches, it is advisable to use individual and group brainstorming in the same project.

7.2 Step-by-step creativity session

Similar to the process of product development, each process of creativity has several stages:

- organisation of creativity sessions,
- appointment of a moderator,
- definition of the problem,
- divergent (different-directional) phase,
- grappling/categorisation,
- convergent (aggregating) phase.

A creativity session begins with organising it and appointing a facilitator, and continues with the definition of the problem. The next divergent phase involves "creating" or "expanding" the field of possibilities and involves collecting and obtaining facts, stating problems and ideas without any criticism. The resulting solutions are then clustered and categorised, followed by a convergent (aggregation) phase, in which the choice is narrowed down based on criteria of usefulness and relevance (Figure 7.1):

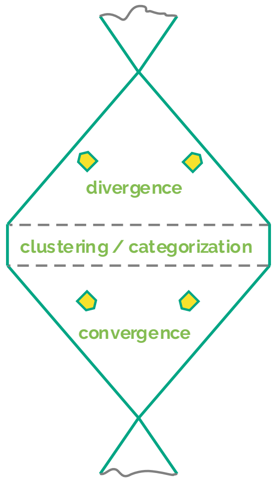


Figure 7.1: Stages of the Creativity Session (Crul & Diehl, 2009).

7.2.1 Organisation of the Creativity Session

For a successful creativity session, the participation of different departments in the company is important, as it offers diversity in interactions and allows you to create unusual associations. Each participant may have a different opinion, which leads to a richer process and encourages consideration of all important matters. For the same reason, the presence of management is also very important, as it will be easier to understand the conclusions and also to approve them more easily. The free flow of ideas can be encouraged by involving team members from different disciplines who are not afraid to ask "stupid" questions. For example, a group may include a range of different people, from experts to creative people who are not experts in the field themselves.

When using creativity techniques, participants should be as open-minded as possible and should try to avoid criticism of emerging ideas, as this could interrupt the generation of potentially useful ideas. A positive attitude is a strong foundation for a successful creativity session. There are basic rules for the implementation of creativity techniques, which must be explained to all participants at the beginning of the session. The following rules can facilitate creative processes:

- Give all ideas,
- Criticism is not allowed.
- Say the first thought that comes to your mind,
- "lying" is allowed,
- What matters is the quantity and not the quality of ideas (quality will be taken into account when evaluating ideas),
- Combine these ideas with other ideas because the idea is a matter of the group, not the individual.

7.2.2 Appointing a moderator

It is necessary to determine the person who conducts the creativity session. This person, preferably from the technical or product development department, will act as a facilitator of the entire creativity process. The moderator must strive to remain neutral and not direct participants in the direction of their opinions. At the same time, it must keep up with the time available and allow everyone to express their opinion. It is very welcome that the moderator has a good general knowledge of the matter at hand. The tasks of the facilitator in the session of implementation of the technique of creativity will be as follows:

- Convene all participants.
- Explain the objectives of the session.
- Explain the rules for the implementation of the creativity technique.
- To present eight planning strategies for sustainability that can serve as inspiration for participants (the order of the strategies is not specified).
- To make the meeting dynamic, which means that everyone is active and that there is no moment of silence. To prevent this from happening, it is recommended that the moderator give some new ideas to ensure the dynamics of the meeting. If it is obvious that the creativity of the participants is exhausted, it is better to conclude the meeting and proceed to the selection of the best ideas for further consideration.
- Encourage a selection of ideas.

7.2.3 Definition of the problem

Formulating a problem definition has a huge impact on the results of a creativity session. If the problem is not precisely defined, the results generated may be irrelevant to the project. Guidelines for identifying the problem include:

- Let's formulate the goal of a creativity session in one sentence.

The problem needs to be formulated from the project's point of view in a concise and clear way. This forces the team to solve the core of the problem. Often, the problem consists of several sub-problems. In this case, it is advisable to approach the solution of the sub-problems first, and then combine these partial solutions together.

- Let's keep a realistic and tangible goal.

If the definition of the problem is too abstract, the results will be too general and will lead to suboptimal solutions.

- Let's start with the question "how".

The pronouns "who, what, where, when, why" provoke data collection. To encourage the creation of solutions, it is best to start with the question "how". This question focuses on how to solve the problem.

🛠 **Worksheets 7:** Identify a Problem to Conduct a Creativity Session.

7.2.4 Creating as many new ideas and solutions as possible

At this stage, we identify as many alternatives as possible because the most important rule here is "quality is quantity", with the aim of generating as many new ideas and solutions as possible. Free associations play an important role at this stage. In addition, it is essential at this stage that the condemnation of ideas is strictly prohibited. When participants are confronted with new ideas and concepts, it is important that they adopt a constructive attitude.

To encourage the generation of new ideas, we can use the Sustainability Planning Strategy Wheel as an incentive. We examine the product "from a bird's eye view" in terms of the different needs it needs to meet and consider other ways of satisfying those needs. Throughout this process, we must also keep in mind the motivational factors analysed in the second chapter of this guide (customer requirements, legal requirements, etc.), as they will help guide our work.

🛠 Worksheets 7: Suggest as many improvements as possible using selected eco-design strategies as a model for idea generation.

7.2.5 Clustering/categorising of ideas phase

With the correct implementation of the previous phase, we will create and collect a lot of ideas and solutions. With so many new options, it will be difficult to choose the best one. For this purpose, before moving on to the evaluation and selection of the idea, it is useful to "refine" and create an overview of the ideas generated (over 200 ideas are not unusual!). Therefore, at this stage, it is advisable to cluster the ideas generated on the basis of their common characteristics. Most of the ideas generated can be sorted according to the seven planning strategies for sustainability presented in Chapter 6. In the task, the participant can choose those ideas that he thinks are the best, and based on the joint scores, we can determine the 10-15 most promising ideas.

7.2.6 Evaluation of ideas

In this phase, we will quantitatively assess the value of ideas, even though their value is often not obvious at first glance. Knowledge of the company's motivational factors for eco-design (step 2) and the main environmental and economic aspects (chapters 4 and 5) will help us evaluate and prioritise the ideas generated. The most represented ideas will be evaluated in more detail and prioritised. For prioritisation, it is advisable to consider the following criteria, among others:

- ***Technical feasibility***. This refers to the possibility of using the proposed idea with the company's available technical means.
- ***Financial viability.*** It assesses the economic viability of improvements. Does the proposed idea justify the necessary costs? To this end, it will be necessary to study the costs involved in the introduction of the idea both in preliminary studies and in practical deployment in the production chain.
- ***Expected environmental benefits.*** It assesses the significance of the chosen idea in terms of environmental impacts.
- ***Positive response to the main motivating factors.*** An idea has more value if it has a positive impact on the motivational factors for the implementation of sustainability planning in the company.

Each of these criteria can be assessed on the basis of the following assessments as set out in the table below.

Table 7.1: Proposal of grades for each criterion taken into account

++	2	Very positive review/very feasible
+	1	Positive assessment/feasible
0	0	Neutral result
–	−1	Negative result/almost unfeasible
– –	−2	Very negative result/completely unfeasible

In addition to the criteria proposed above, each company can define new criteria according to its characteristics and needs (e.g. quality, etc.) or give more weight to some criteria than others. To evaluate ideas, it is necessary to involve other departments that may not have been involved in the process before, such as the finance department in the company.

🛠 Worksheets 7: Determine what criteria to **use** when prioritizing possible improvements.

For each idea, we also define whether it is actually interesting and useful in the short (K), medium term (S) and long term (D). This will be displayed in the priority column "priority".

🛠 Worksheets 7: Rank the ideas options according to their assessment of time feasibility – short-term (K), **medium-term (**S), **and long-term (**D).

Once all the selected ideas for improvement have been evaluated, we proceed to prioritise them. Ideas are ranked according to the overall score achieved. The final selection of ideas is usually possible only after the ideas have been developed in more detail. This process is known as the development of the "product concept", which we will learn about in the next (eighth) chapter of this manual.

7.3 Examples of creative idea generation techniques

There are dozens of creativity techniques that we won't go into detail about in this guide. This is what manuals and books devoted exclusively to creative thinking techniques are for. Therefore, below, we present only some of the techniques that are relatively simple and useful in the sustainability planning process. It is definitely not necessary for you to master all the techniques of creativity. It is important that you master the technique that suits your needs and use it appropriately.

7.3.1 Brainstorming the Wheel of Sustainability Planning Strategies

The brainstorming technique is used in many companies due to its simplicity, and makes it possible to achieve one of the most important planning requirements for sustainability: *the collaboration and integration of different departments in the company*. The term brainstorming is derived from the English language. *Brainstorming* is a general term for creative thinking. The basic rules of brainstorming are:

- The moderator writes down all the ideas on a large sheet of paper or cardboard,
- Participants invoke their spontaneous ideas in response to identified problems,
- Participants relate to the ideas of others,
- Participants do not express their criticism of the ideas of others, and
- Participants try to act quickly.

7.3.2 Brainwriting

Writing down ideas, *Brainwriting* is a brainstorming-like technique that has evolved due to the time lag of verbal transmission of ideas in the brainstorming method. There are several variations of this technique, but its basis is that the individual writes down all their ideas. He then passes the recorded ideas to a neighbouring person, who uses them as a reason for his ideas. The technique of writing down ideas ensures anonymity for team members, so they can express their ideas more easily and without shame.

One way to write down ideas is for each person to write down ideas on post-it cards and place them in the middle of the table. Everyone is free to choose one or more of these ideas for inspiration. Team members can generate new ideas or change existing ideas.

7.3.3 The 6-3-5 Method

The 6-3-5 method is one form of writing down ideas. Its name comes from its system, in which a group of 6 participants each lists 3 ideas in 5 minutes. Each participant is given a blank 6-3-5 worksheet (Figure 7.2).

Each participant writes a problem at the top of their worksheet (from the common problem definition). Next, members write 3 ideas in the top row of the worksheet with whole and concise sentences (6-10 words). After five minutes, they pass the worksheet on to the next person, and they receive a worksheet from the neighbour on the opposite side with another problem. On each ticket received, participants add three ideas. Thus, in just thirty minutes, they can collect one hundred and eight ideas.

Problem formulation: How...			
	Idea 1	Idea 2	Idea 3
1			
2			
3			
4			
5			
6			

Figure 7.2: Example of a spreadsheet for writing down ideas.

7.3.4 Thought patterns

Thought patterns represent ideas, notes, information, etc., using tree diagrams. Drawing a thought pattern is carried out according to the following steps:

- In the middle of a large sheet of paper, write the title of the topic.
- For important subtopics, we draw lines from the centre on all sides and write keywords on them (more important thoughts lie closer to the centre, and less important ones on the periphery).
- We can put colours into thought patterns.
- To connect and combine different areas of the pattern, arrows, broken lines or lines of a special colour are used.
- Groups of words that mean areas can also be surrounded or other characters (asterisks, question marks, etc.) can be used. Geometric figures are especially useful, as words with special meanings can be denoted.

7.3.5 The Five Ws and H Technique

This technique gets its name from the initials of the English words Who? (*Who*), Why? (*Why*), What? (*What*), Where? (*Where*), when? (*When*) And how? (*How*). With this divergent technique of creativity, we try to answer these 6 universal questions and create a checklist. The technique is particularly useful in the early stages to gather information and to identify the main (sub)problems more precisely. A checklist can be useful either as an informal or systematic way to create a list of questions that you would like to find answers to.

7.3.6 The SCAMPER technique

The SCAMPER technique is a checklist that helps us think about possible changes to an existing or new product. These changes can be used as direct proposals for amendment or as starting points for lateral thinking. The term "SCAMPER" is derived from seven types of potential product modifications :

- S – replace (*Substitute*) components, materials, people.
- C – Combine – mix, combine with other sets or services, combine.
- A – *Adapt* – modify, change the function, use parts of other elements.
- M – modify – increase or decrease the scope, transform, change properties.
- P – Put to another use.
- E – *Eliminate* – remove elements, simplify, reduce to the core of functionality.
- R – turn and edit differently (*Reverse*) – turn outwards or from top to bottom.

The technique begins by isolating the product or topic on which the emphasis is. In the next chapter, we ask about the product or subject matter with seven SCAMPER questions. We continue to question each idea: "How can ...?", "What else...?", "How else ...?".

7.3.7 Analogies

Analogies are used to alienate participants from the original problem in order to come up with inspiration for new solutions and approaches. These analogies can take several forms, which are presented in Table 7.2 below.

Table 7.2: Types of analogies.

Analogy	Description
It's a direct analogy.	We start with a problem and think about a comparable or analogous situation.
Personal analogy	What if we were the subject of the problem?
Natural analogy	What situations in nature does this remind me of?
It's a fantastic analogy.	Can you place the problem in a fairy tale or other mystical situation and develop a solution from it?
It's a paradoxical analogy.	Define the matter in two words that contradict each other.

8 Development and evaluation of product concepts

The objectives of this chapter are:

- preparation of draft product specifications,

- creation of concepts for new products.

Worksheets 8: Product Concept Development and Evaluation

In the previous chapter of the sustainability planning process, ideas for product improvement were generated and their applicability in the short, medium and long term was determined. In this chapter, we will develop selected product ideas into comprehensive concepts and develop the most suitable ones in more detail in the next chapter. In a way, the ideas for improving environmental aspects from the previous chapter define new requirements for product design (e.g. design the product for minimal energy consumption). These environmental requirements must be included in the specifications that will be developed in this chapter and will be translated into product concepts. The selected concept will be further developed in the next chapter.

The objective of this chapter is to obtain a number of solutions for a product or parts of a product that meet the required specifications. The difference between this sustainability planning phase and conventional product development is that environmental criteria are also included in the evaluation and selection process of the best concept.

8.1 Preparation of draft specifications

At this stage, we will prepare a draft specification that will take into account all the specifications of the product, not only the environmental, but also the technical, ergonomic, economic and social specifications (Brezet, 1997). Previous phases of planning for sustainability have focused on environmental aspects, but environmental protection is only one of the requirements of the product, as we must not overlook other requirements that are as important or even more important to the company than environmental requirements: technical, economic, quality requirements, etc. (Figure 8.1).

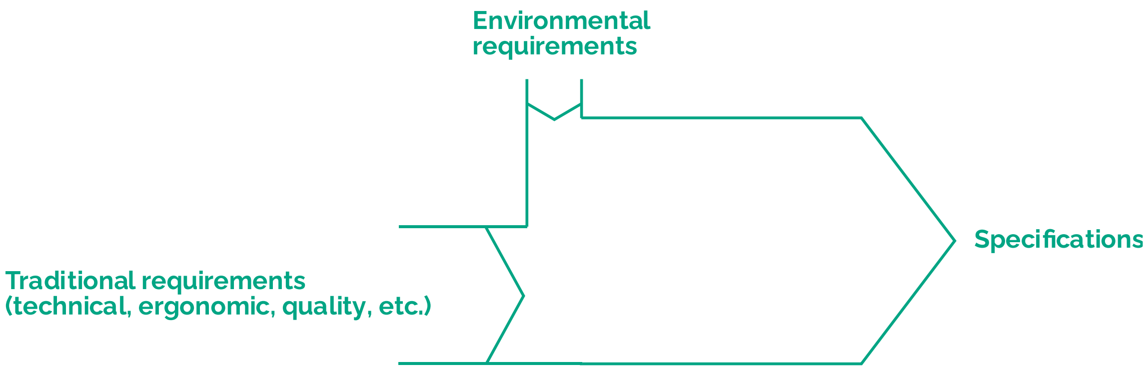


Figure 8.1: Drafting of specifications taking into account environmental protection in addition to other requirements.

Test models, prototypes and computer equipment for simulations and calculations can be used to evaluate technological feasibility. The project team will also need to pay attention to the financial feasibility of new concepts and check whether the benefits of the proposed options outweigh the costs.

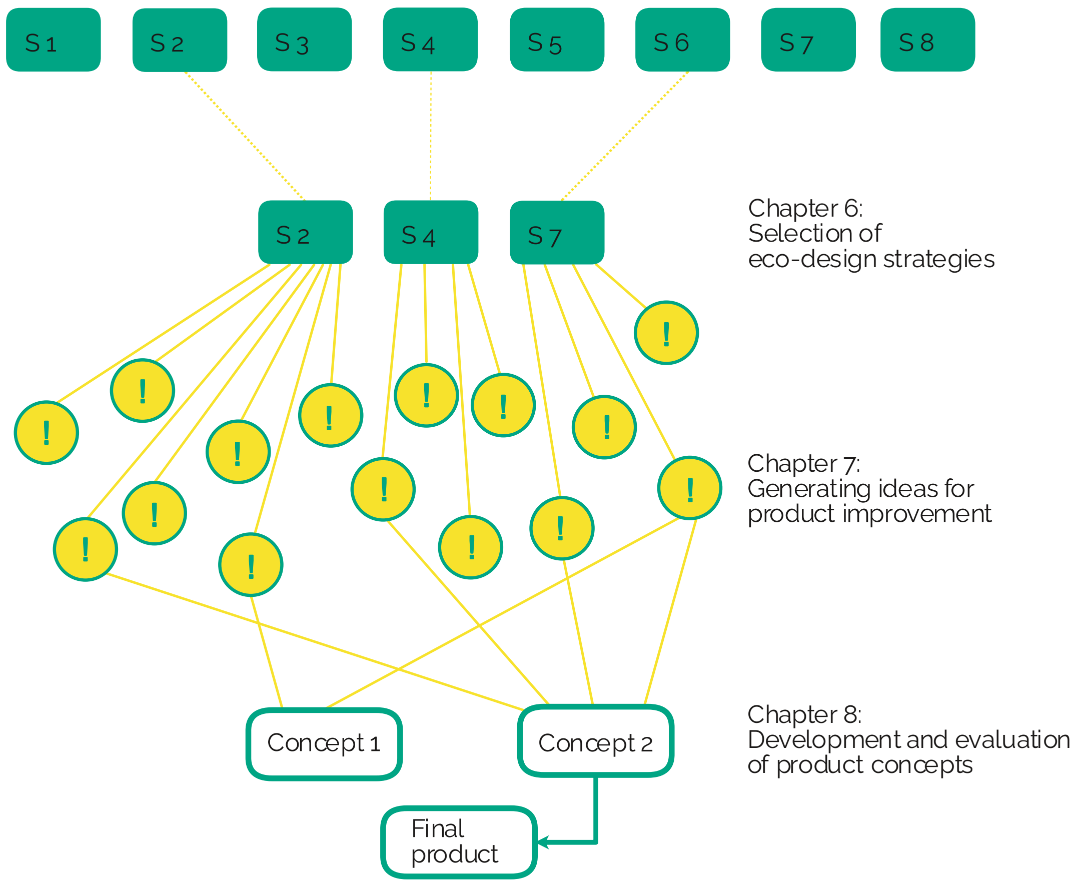
8.2 Creating concepts for new products

As mentioned earlier, the goal of this chapter is to develop product concepts. This step pursues a preliminary design where the composition, shape and material of the product are provisionally defined. To this end, all this information should be collected periodically, and the technical or product development service should be informed of the conclusions. In the event that the company cooperates with an external planner, the latter must meet with different departments in the company at the beginning of this phase in order to keep all this information in mind when planning.

In order to find the solution that best meets the required specifications, it is necessary to consider several parallel developments in conceptual solutions. There are many ways to (re)design a product, most of which start with sketching. In doing so, each planner has their own method and way of working.

When the selected design ideas for improvements from the previous chapter are uncertain and ambiguous, they may need to be studied or developed in a little more detail, as well as their implications for the product. For example, if the chosen measure is "design an appliance that consumes less energy", the use of different energy sources probably needs to be explored.

When designing a complex product with a large number of components (the detailed determination of these will be carried out at the next stage), it can be divided into various functional subsystems, all of which are interconnected and form a product. As a result, each will have different parts, but for the time being, we can only consider the product subsystems in general. The relationship between the different subsystems can also be represented by flowcharts.



Picture 8.2: Product Development Process (Crul & Diehl, 2009).

8.3 Analysis and evaluation of product concepts

An important task after creating concepts for new products is to evaluate them in comparison with the base product or with existing solutions on the market. Not all developed concepts will be equally useful, so it is necessary to evaluate them and select the most suitable ones. In doing so, the best ideas of each concept can be combined into one concept. To make the combination of multiple ideas into one concept systematic, the team can use a technique called a "morphological box"..

When implementing the morphological box approach, we first compile a list of all the attributes of the product so that they comprise a complete description of the product. We ask ourselves, can we find alternatives for different attributes of the product? If, for example, a certain part is made of aluminium, could it also be made of any other material?

Next, we prepare a spreadsheet where we use these attributes as items in a column (at least 6 attributes). Write in the lines as many variations of each attribute as possible (at least 6). The spreadsheet should show all possible variations of each attribute. Now we choose one item from each line at random or as a selection of interesting combinations. By combining elements from each line, we can even come up with an idea for a new product, a new service or a new strategy.

To evaluate all concepts, it is best to use the same tools and approaches as we used for the analysis of the baseline reference product, as they allow for a complete assessment and comparison between the basic product and the new proposed product concepts. To assess the environmental improvements of different concepts, the tools in Chapter 4 for the analysis of environmental aspects may be useful. For each concept, we re-perform an environmental impact analysis (either with a MECO matrix, eco-indicators or LCA analysis software). This will give us an accurate or at least approximate estimate of the expected environmental improvements of the selected concept compared to previous product plans (in the case of re-design) or existing products on the market. For the economic evaluation of the selected concepts, we use the tools from Chapter 5 to support the decision on the most suitable product concepts.

In order to choose between existing concepts, it is advisable to draw up an evaluation table for them. We can use different methods of assessment (descriptive with grades good, acceptable, bad or with points from 1-10, etc.). With all these values, a complete assessment of each of the developed concepts will be made. This process may be similar to that used at the stage of creation and selection of ideas (Chapter 7). Along with the development of the concept, the preparation of the production plan and marketing plan also takes place at this stage, similar to traditional product innovation projects.

Since we are still in the initial stage, the information obtained on each concept is not complete. Evaluating concepts will almost certainly be subjective in many respects as well. The experience of the technical department or product development department of the enterprise, as well as the external planner in the case of his external support, will be relevant here. In the latter case, knowledge of sustainability planning will be of great help to him. It is recommended that both parties discuss and harmonise environmental criteria with each other and make sure that the goals and requirements have been equally understood by both parties.

This step is completed by choosing one of the concepts. In the next phase, the selected concept will be developed in more detail (production and marketing plans can also begin to be prepared on the basis of this selected concept).

🛠 **Worksheet 8:** Evaluate Product Concepts.

9 Detailed product development, preparation for production and market launch

The objectives of this chapter are:

- sufficiently detailed product specifications to allow us to proceed with production, including all technical documentation, models and prototypes approved in terms of environmental, technical, economic and other requirements,

- Prototype

- Production plan.

- the final product, including information on the packaging and instructions for users,

- A plan for launching a product on the market using all marketing and communication approaches.

After the product concepts have been created in the previous chapter, we will develop the selected concept in more detail in this chapter to the final plan. At this stage, the exact dimensions, materials and manufacturing processes are determined. As in the previous phase, the process will be iterative and quite chaotic. In practice, the distinction between Chapters 7 and 8 is not as sharply defined as is presented in this manual. Since product planning is an iterative process, it is normal to go through several different phases at the same time.

We will develop the definition of the product from the rough definition level to the exact details. In this and the previous chapter, we do not pay attention exclusively to the environment as in the first chapters of the manual. However, the environment (unlike conventional product design) is an important additional aspect that must be assessed and taken into account along with economic, technical, aesthetic, ergonomic and other aspects.

9.1 Precise definition of product specifications

The result of this chapter will be a final product plan that will be almost ready for production and presentation on the market. Although the designer or the design team will elaborate on the product as a whole, sketches of its individual parts will probably also be produced. Typically, designers, engineers, production planners, service providers, and marketing staff work together to achieve design specifications. Commonly used tools at this stage include:

- software and modelling tools, such as those used to assess performance during use.
- databases of materials and technologies,
- Tools for optimising production and processes.

To define the product precisely, let's first define in more detail the properties of the concept selected in Chapter 8. At this stage of setting the product specifications, the level of detail achieved should allow for the production of the prototype(s) of the product and provide information for the introduction of the product on the market. This process includes the production of documentation describing the technical aspects of the product, the ergonomic and functional characteristics required by customers, the economic aspect of production and the overall marketing of the product. The aspects to be taken into account when defining the product specifications are as follows:

9.1.1 Technical aspects:

The technical description of the product design should specify all the components of the product and the technological processes used to manufacture the product. Such a description of the technical aspects shall include at least:

- the definition of the shape of the product and all its components,
- exact dimensions, including deviations,
- surface properties,
- selected materials with reference to the environmental criteria assessed,
- selected production techniques with an emphasis on the assessed environmental criteria,
- environmental criteria,
- product testing plans;
- a description of the production of the prototype(s),
- the process of testing and evaluating the prototype(s),
- a concise product definition and additional technical documentation.
- applicable standards.

9.1.2 Quality and safety aspects:

These aspects are essential to ensure customer advantage and market acceptance of the product. Product planners must take all appropriate measures to ensure the required quality and safety in the early stages of a sustainability design project. The definition of product quality and safety aspects usually includes:

- identifying and assessing risks in the early stages.
- determining the applicable legal requirements for product quality and safety,
- a description of the measures applied to ensure the quality of the product,
- a description of the measures taken to ensure the safety of the product,
- a declaration of product reliability,
- information about product testing,
- consumer demands.

Safety involves a formal inspection of the product's materials, components, configurations, packaging and labelling (instructions and warnings) to identify, assess and control potential hazards of the product. The hazard identification and assessment criteria must include objective assessments of the conditions under which the product is to be used. This also includes aspects such as age groups and physical limitations for users, as well as potentially fatal conditions that may arise as a result of misuse of the product.

9.1.3 Environmental aspects:

At this stage, the planner must take into account all kinds of specifications, and an important part of them will be environmental specifications. The environmental aspects of the detailed product design are assessed using the same methods and assumptions that were used to evaluate the reference product and evaluate new concepts.

In order to define the product, it is advisable to contact suppliers to identify the possibilities of using more environmentally friendly materials and components with lower costs or better functionality.

At the same time, when choosing materials and processes from an environmental point of view, it is useful to use eco-indicators or some of the software tools referred to in Chapter 4. For example, we will be able to evaluate different materials or alternative processes.

Take, for example, a product where we can choose between primary aluminium or polypropylene (PP) in terms of material. Based on the result of multiplying the quantities by the appropriate eco-indicators, the most appropriate will be the use of PP (35,1 millipoints, including material and processing), followed by the use of primary aluminium (63,9 millipoints), despite the fact that a smaller amount of material is required for the aluminium product.

Table 9-1: An example of environmental impact assessment in the selection of two materials: primary aluminium and polypropylene.

Material production (millidots/kg)				
Material	Quantity	Indicator	Together	Description
Aluminium – primary (0% recycled)	0,075	780	58,5	Ingot from primary material
Polypropylene (PP)	0,100	330	33,0	

Material processing (millidots/kg)				
Material	Quantity	Indicator	Together	Description
Aluminium – Casting	0,075	72	5,4	per kg
PP – Injection Compression	0,100	21	2,1	per kg PE, PP, PS, ABS, without material production

This is a very simple case, but in practice the choice is much more difficult due to conflicting requirements. So, for example, the use of one or another material will be associated with certain technical characteristics in such a way that the weight of the same part of the product can be different, and hence the final numerical result. It could also affect other dependent Eco-indicators, such as transport: material with a higher weight or volume will have a negative effect on the numerical result of transport in the calculation of eco-indicators. Therefore, it is necessary to study whether the change in material also affects other eco-indicators and recalculate these numerical results before choosing one or another material. Let's also consider the following example, which refers to the choice of material for a wind deflector:

The wind deflector is a useful element for reducing aerodynamic drag in trucks. However, the weight of the deflector itself contributes to increased fuel consumption. Therefore, reducing the weight of the deflector is an environmentally important requirement. A comparison was made between the applications of deflectors made of steel and deflectors made of expanded polypropylene PP. Expanded PP has a higher eco-indicator value than steel. However, taking into account the service life, the PP deflector has a lower environmental impact due to its lower weight and thus lower energy consumption in the use phase.

9.1.4 Financial aspects:

At this stage, some financial aspects must be taken into account, such as :

- an assessment of the investments needed to produce a sustainable product, including the cost of laboratory analyses;
- an assessment of the investments needed to launch a product on the market,
- Cost estimation in relation to the entire life cycle of the product (Life Cycle Costing),
- Prediction, evaluation of product sales,
- analysis of the cost and profitability of the product,
- other financial analyses.

9.1.5 Legal and other requirements:

The product specifications must comply with the legal requirements, so it is necessary to draw up a list of all relevant mandatory legal provisions regarding the technical, safety, environmental and other characteristics of the product that exist or are in the pipeline. When selecting a new raw material, the sustainability planning team often has to determine compliance with the requirements of REACH.

9.2 Selection of product concept details

In the process of detailed planning, several solutions can be born for a particular concept that need to be analysed in more detail. For each of these cases, a comparative table of different possible alternatives can be created, similar to the one used to choose from the existing concepts in the previous chapter. In this case, the aspects assessed will be more precise than in the previous chapter, but the methodology used will be quite similar.

9.3 Internal promotion of product durability

Proper communication of the results of a sustainability planning project to the company's employees is an important prerequisite for success. However, companies often underestimate this phase. Internal communication regarding the project can underpin changes in relation to the activities and routine of workers resulting from the introduction of sustainability planning.

The importance and necessity of the proposed changes must be clear and acceptable to all involved. One of the important tasks of a project manager is to ensure that the project team's decisions are not reversed at a later stage due to the ignorance of colleagues who were not directly involved in the project. By now, all those responsible for the start of production and product launch should be convinced of the benefits of the new plan, thanks to their involvement throughout the implementation of the project. This can be achieved by the following:

- make the company's environmental policy publicly recognisable,
- We present a new eco-design by the project team,
- publish information in the company's newsletter,
- We organise training courses for employees,
- Publish planning instructions for sustainability, e.g. in a manual.

9.4 Preparation for production

The road from the first design step for the sustainability of the product to the actual production stage was long and arduous. A condition of preparation for production is an approved product plan that satisfies both the initial brief overview (draft or brief) of the sustainability design set out in Chapter 6 and the list of required specifications. The technical and financial feasibility of the project must be positively assessed by the project team and the company's management.

From here on, the company follows the usual production processes. This phase includes prototype production, sample testing, tool testing, and initial batch production planning. Once a prototype of a product has been produced, it must be tested and evaluated to determine its actual compliance with the objectives defined in the Sustainability Planning Brief (Draft). At this stage, we can make all the necessary planning adjustments and changes. During prototyping and testing, the actual sustainable performance of a product can be assessed for the first time. At this stage, the environmental aspects of the final product can also be assessed, again using the methods and assumptions that we have used before.

9.5 Market launch

Market launch involves presenting and communicating the main features and benefits of a product in order to encourage consumers to purchase and use it. In this regard, the environmental profile of a sustainable product can form the basis for a marketing strategy.

A marketing test can assess consumer reactions to the sustainability qualities of a product, along with other standard criteria. With these findings, final changes can be made before a large-scale market roll-out. Key stakeholders identified in the initial phase of the project may also be taken into account. After the product goes on sale, the company can monitor its sustainable performance. Consumer feedback and data from internal product testing can be incorporated into the design process to further improve the product.

At the same time, the company needs to come up with a communication strategy. The company can decide whether to present environmental statements or not. Sustainable benefits of the product in its ads, or it will not do so. Both strategies have their advantages and disadvantages. Explicit marketing can be useful if a group of consumers is interested in sustainability issues or if marketing contributes to the reputation of a brand or company. The disadvantage, however, may be that they may require the company to substantiate its claims regarding the sustainability or environmental friendliness of the product. External environmental communication in relation to a product has two main aspects:

- communicating environmental aspects throughout the life cycle using various tools and means, such as eco-labels and environmental product declarations;
- informing the user to reduce the environmental impact of the product during its use and final disposal.

10 Assessment of the product and design project for sustainability

The objectives of this chapter are:

- project evaluation,

- Product evaluation.

Worksheets 10: Evaluating the Product and Planning Project for Sustainability

10.1 Why evaluate a sustainability planning project and for what purposes?

Evaluating a sustainability planning project will help us see the extent to which we have met or improved the motivational factors that have driven the company to implement sustainability planning and establish mechanisms to get the most out of the improvements. In addition, the results of the project evaluation can be very valuable information for training, informing and motivating staff within the company and for integrating green marketing into marketing campaigns or strategies of the company and for informing other external stakeholders (social groups, financial institutions that provide green loans, business groups, environmental organisations, etc.).

The evaluation of the results of the project and the product itself must be collected in a report prepared by the project team. In this way, the knowledge and experience gained during the implementation of the project are not forgotten or lost. The report may be circulated to all participants in the sustainability planning project, including management.

10.2 Assessment of a planning project for sustainability

This part of the assessment process is designed to analyse the performance aspects and procedures in the sustainability planning project. In doing so, the company must consider the appropriateness of the methodology used. A step-by-step sustainability planning process is a general model that many companies will modify according to their own needs. Some companies have their own internal project management system in which certain aspects of the sustainability planning project can be integrated, as described in this guide.

The company must also evaluate the project team and the support team. That assessment should focus in particular on the composition of the team, the level of participation, commitments and the human resources available. We need to weigh the pros and cons of a team-based approach to sustainability planning in order to be able to use the most effective method of work in the future. In principle, teamwork in product development is more complex, but this disadvantage is compensated for by the higher quality and speed of the product development process.

This process may reveal the need for additional knowledge and training within the project team. Eco-design is a newer approach that may indicate a lack of adequate knowledge regarding the environmental aspects of product development. Therefore, when evaluating a project, we need to ask ourselves about the lack of relevant knowledge in the company itself, among team members and other employees. In this case, specific measures are recommended to organise appropriate training or external advice.

There are many ways to assess a sustainability planning project, and every company should include such an assessment in its methodology or customary project evaluation procedures. Nevertheless, in this assessment, we must certainly analyse the impact of environmental improvements on the fulfilment of motivational factors. When improvements in environmental aspects are apparent, it is necessary to examine how these improvements affect the fulfilment of motivational factors. This means that it is necessary to analyse the extent to which we have achieved the objectives that led us to start the sustainability planning process.

For this purpose, we can use the Sustainability Planning Assessment Questionnaire, in which we can combine environmental improvements and the fulfilment of motivational factors and express this in the most understandable way for the users we want to inform (do not use the values of eco-indicators directly for marketing, as they are only an evaluation and analysis tool!).

🛠 **Worksheets 10.1:** Evaluate Your Planning Project for Sustainability.

10.3 Assessment of the final sustainable product

This part of the evaluation process focuses on the improved performance of the new product compared to the original, competitor or other reference product. In doing so, we assess the improvement of the main environmental aspects, compare the main environmental aspects of the new product with those of the base product (where possible), and verify compliance with environmental requirements. Also, at this stage, the final result of the project is compared with a brief overview (draft or brief) of the sustainability planning. If there are discrepancies, the team should ask why they occurred and learn from it.

In addition to the financial and environmental aspects of the new product, we need to look at its functionality and technical characteristics at this stage. Such information will give us a complete picture of the newly designed or refurbished product and support the marketing of the product and the internal justification or promotion of the sustainability planning project.

After the start of sales of a product, the company can monitor its sustainable operation. An important aspect is monitoring the product to ensure its function. The environmental qualities of a product are only one aspect of a modified (or completely new) product. Once the project is implemented, it will become clear whether the product better fulfils other functions. Assessing consumer perception of a redesigned product is another important aspect of product evaluation. Such an assessment will provide insight into consumers' opinions on the sustainability of the product and on the visibility of sustainability planning (e.g. on a scale from "barely noticeable" to "radical"). By "radical" we mean essential changes that make a product fulfil its function in a different, innovative way.

Consumer feedback and data from internal product testing can be incorporated into the design process for further product review in order to improve current or future products as well as the design and development process. Of course, companies need to take into account the fact that information about improvements is not available soon after the completion of the project, but it takes some time to obtain reliable and meaningful data.

🛠 **Worksheets 10.2:** Evaluate the durability of the product.

10.4 Practical Application of the Planning Project Assessment for Sustainability

The results of a sustainability planning project assessment can be used for a variety of specific purposes for each company. The results can be used to evaluate a sustainability planning project or to confirm its eligibility. Documentation with results can serve as a guide for future sustainability planning projects in the company (e.g. we can estimate the percentage of improvements that were possible with regard to a particular aspect, etc.). We would like to give two further aspects that we believe are in the common interest of most companies in terms of the use of results:

10.4.1 Motivating employees

If the company-level action plan was aimed at familiarising the sustainability planning methodology, the results of the project are crucial to motivate each department to carry out sustainability planning tasks, not as an additional obligation, but as an opportunity to improve products and the environment. It is therefore advisable to use the results as key material to disseminate the company's action plan on sustainability planning.

10.4.2 Green marketing

If consideration of environmental considerations distinguishes the company from others or improves the quality of the product, environmental improvements can be incorporated into the company's marketing campaigns and green marketing. Of course, green marketing is not as easy as it may seem at first glance. Like other marketing strategies, it requires specific techniques and must be based on a series of fundamental principles. Sustainability planning and marketing operations must be influenced by all chapters of this manual and must affect all stages of the life cycle (using the results of the motivational factor analysis). The aim of this guide is not to describe in detail the implementation of green marketing, since for this purpose, there are a number of publications that deal in depth with this extensive topic.

11 Action Plan for Follow-Up Planning for Sustainability

The objectives of this chapter are:

- Developing a medium and long-term action plan for further sustainability planning activities at both the product and company level.

Worksheets 11: Action Plan for Follow-Up Planning Activities for Sustainability.

Once the "planning for sustainability" methodology has been successfully implemented and the appropriate tools have been used, the company has a range of improvement measures at its disposal, many of which are aimed at implementation in the medium and long term. Short-term measures are usually already implemented or are in the final stages.

However, practice shows that without a structured action plan, there is a risk that some important measures will not be implemented, either due to a lack of coordination or due to a gradual return to established, traditional methods of development. Moreover, there is also a risk that the sustainability planning methodology will no longer be used in the future if it is not systemically integrated into the company's existing processes and standards (e.g. ISO 9001, ISO 14001, ESG reporting).

It is therefore essential to develop a clear, feasible action plan:

- At the product level, so that concrete actions are not lost.
- At the company level, the methodology is integrated into the company's broader strategy and becomes part of its sustainable culture.

11.1 Medium and long-term action plan

In this guide, we have outlined one of the possible design approaches for product sustainability. Implementing this approach on existing products is very practical to start introducing the concept of sustainable development in the company. Improving sustainability overall through the introduction of sustainability planning is a good start, but it is usually not sufficient to achieve a long-term level of environmental and social sustainability. This requires much more radical innovations.

Sustainable development requires taking into account the needs of future generations, which means dealing with future environmental and social problems. Global environmental pressures are directly related to the size of the population, which determines the level of consumption and the materials and energy needed to produce each "unit" of consumption. It is estimated that environmental pressures need to be reduced by about half. Taking into account the current growth rates of emerging economies, the efficiency of products and processes should be improved by a factor of 4. Future generations will live in a world with a growing population and a much higher level of consumption, which will require an improvement in material and energy efficiency by a factor of 10 to 20.

This type of "factor thinking", otherwise called "X-factor thinking", indicates the dimensions of current tasks and the urgent need to improve production processes, products and entire systems. The short-term, incremental refurbishment of existing products is also known as "inside the box" innovation. *Inside-the-box*), can usually lead to improvements by a factor of 2–4. To achieve long-term factors of 10 to 20, radical product innovations, or so-called "out-of-the-box" innovations, are necessary. *Outside-the-box*). This includes the development of completely new products and the improvement of both products and related services, as well as the development of completely new functional systems of products and services. Figure 11.1 shows the different degrees of environmental benefits and the innovation needed.

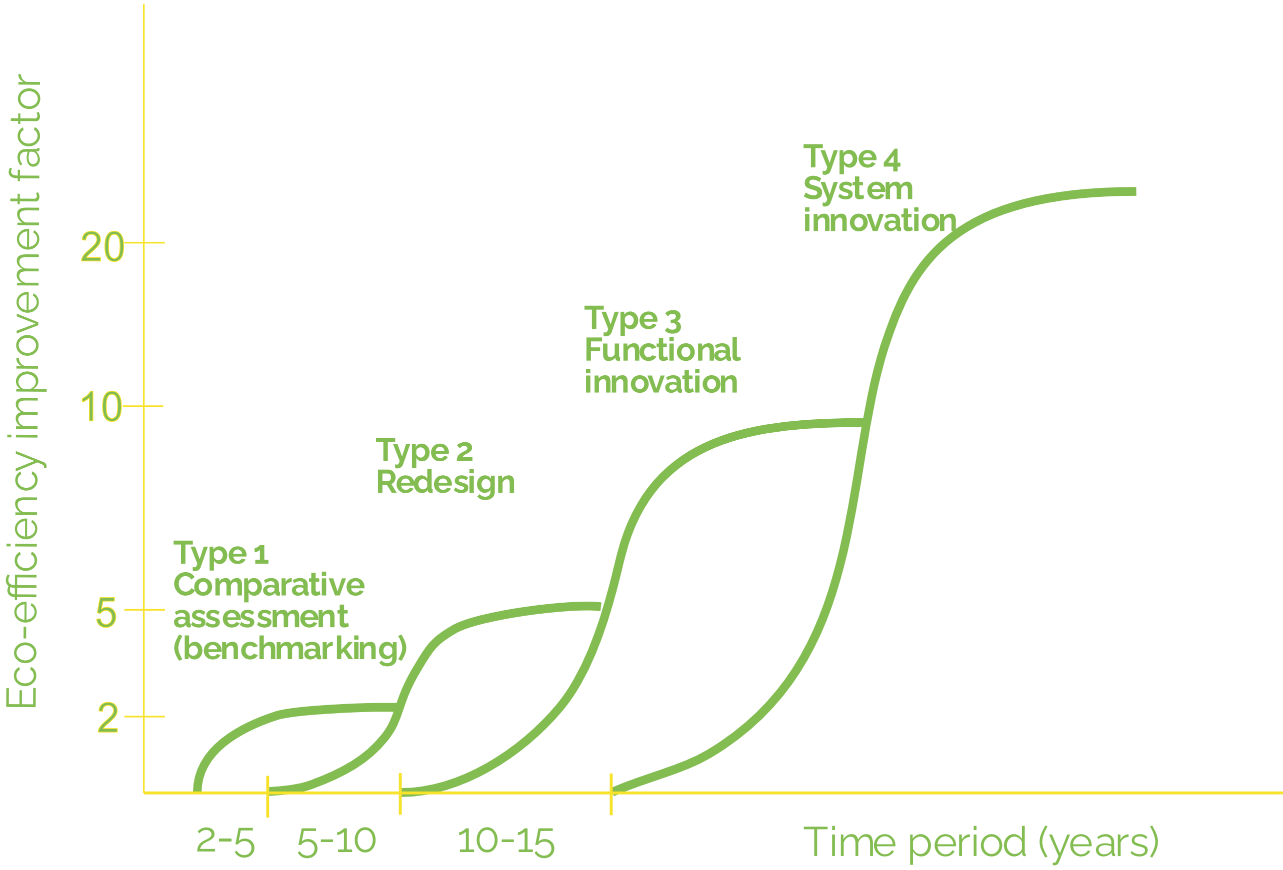


Figure 11.1: Rates Environmental Benefits and type necessary for this Innovation (Crul & Diehl, 2009).

Given the environmental improvement measures that have been created and prioritised in the previous chapters of this manual (related to the development of a new product), we now have a vision for the implementation of the various selected measures to improve the environmental situation. Most likely, the sustainability planning project focused on short-term strategies. However, long-term strategies for functional and systemic innovation will also need to be taken into account in order to achieve sustainable development. We have to ask ourselves to what extent the short-term strategy has led to concrete improvements in the product. An important question is also whether a long-term sustainability planning strategy has led to the beginning of new product development or has become part of the company's R&D programme.

Now would be the time to draw up an action plan that clearly contains all those selected non-implemented improvement measures (medium and long term), together with the deadlines for implementation, the measures needed, the persons responsible, and the persons responsible for those actions.

🛠 **Worksheets 11:** Action Plan for Follow-Up Planning Activities for Sustainability. Answer the questions: what, who, when, how and how much.

11.2 Planning an Action Plan for Sustainability at the Company Level

When the sustainability planning methodology and tools in the product development department were first used, it was possible to conclude which of these tools is of interest to the company and how to incorporate them into the process of designing new products. To find out, the following steps are proposed:

1) We hold a meeting in the product development department, where we analyse in parallel the planning methodology for sustainability and all stages of the company's product development process (along with other measures implemented by other departments: exchange of information between the marketing department and the product development department, etc.) and consider the possibilities of combining the two methodologies. We are also trying to combine all this with other business management tools (ISO 9001, ISO 14001).
2) As a result of this analysis, we prepare an action plan, this time at the company level, to incorporate the necessary changes in the product development plan, ISO 9001 or ISO 14001, the competent department, the necessary tasks and their frequency.
3) As a final step, the development or adaptation of the methodology and necessary planning tools for sustainability will be carried out.

As we can see, this stage is specific to each company. Documents and activities must be tailored to the company so that it can familiarise itself with sustainability planning and adapt it to its needs and tools. It should be emphasised that, despite the possibilities of adapting the planning methodology for sustainability to the specific needs of the company, it is not advisable to omit any stage, although some seem more important than others, since they are all interconnected and have their own purpose. As a basis, it is proposed to use the company-level Sustainability Planning Action Plan form, which is one of the tools in the Annexe to this Guide.

It is advisable to consolidate and anchor the experience and knowledge gained after the first sustainability planning project in the company. This will achieve continuous improvement of the environmental aspects of the products. The control and systematic improvement of the environmental aspects of products in an organisation is called Product-Oriented Environmental Management Systems (POEMS). A way to ensure continued attention to the environmental aspects of products is to integrate the results of a sustainability planning project (based on knowledge and experience) with an ISO 14001 environmental management system or an ISO 9001 quality system.

11.2.1 Integration with ISO 9001 (quality management)

ISO 9001:2015 promotes systematic planning and evaluation of objectives. Environmental considerations can be effectively integrated:

- in the formulation of product specifications,
- in procurement procedures and supplier valuation,
- into procedures for monitoring customer satisfaction and sustainability expectations.

11.2.2 Integration with ISO 14001 (environmental management)

ISO 14001:2015 promotes a systematic approach to controlling environmental impacts, including:

- environmental aspects of the product at all stages of the life cycle,
- environmental policies for products.
- impact reduction goals and programs.

Combined with planning for sustainability, the company is able to implement Life Cycle Thinking (LCT) and reduce its environmental footprint in the long term.

11.2.3 Link to ISO 14006:2020 and POEMS

ISO 14006:2020 is an up-to-date standard that provides companies with guidance on environmental management in the design and development phases of products. The standard is particularly useful for linking sustainability planning to an environmental management system.

POEMS (Product-Oriented Environmental Management Systems) promote systematic monitoring and improvement of the environmental performance of products throughout the life cycle.

11.2.4 Application of ISO 26000 Guidelines for Social Responsibility

ISO 26000:2020 provides a framework for integrating social responsibility and ethical practices into strategic and operational aspects of a company, including:

- Fair treatment of employees,
- Stakeholder involvement.
- responsibility towards the community and the environment.

The standard is not intended to be certified but allows for important links to ESG goals and sustainability reporting.

🛠 **Worksheets 11:** Environmental Management System and Eco-Design Checklist.

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12.1 Glossary

Acidification

The process of lowering the pH of soil or water with a low buffer capacity, often as a result of acid rain. It often affects forest floors.

Certified environmental labels (Type I)

Independently verified labels for products or services that demonstrate above-average environmental performance compared to competing alternatives. They are based on predetermined criteria.

Cleaner production

A preventive environmental approach that involves changes in materials, technologies or processes to reduce emissions, waste and resource consumption at source.

Dangerous substances

Chemicals, in solid, liquid or gaseous form, which may cause adverse effects on human, animal, plant or environmental health. The use of these substances is often subject to legislative restrictions.

Dematerialization

A strategy to reduce the use of materials by optimizing products, processes and replacing products with services. It is associated with greater material efficiency.

Design for the Environment (DfE)

Designing products or services to reduce environmental impacts throughout the entire life cycle – from material selection to end-of-life.

Eco-design (environmental planning)

Incorporating environmental considerations into the design of products or services with a view to reducing environmental impacts throughout the life cycle.

Eco-indicator

A quantitative value that represents environmental impacts based on a life cycle analysis. It is used to assess and compare the environmental performance of products.

Eco-innovation

Any innovation that leads to a significant reduction in environmental impact, whether through products, services, processes or business models.

Eco-labelling

A voluntary scheme that labels products with above-average environmental performance and allows consumers to make informed choices.

End-of-life processes

They include the collection, dismantling, reuse, recycling, composting, incineration or disposal of products at the end of their use.

End-of-life system

A set of processes that take place after the end of the use of a product. It covers the dismantling, reuse, recycling, recovery, incineration or final disposal of waste.

End-of-pipe technology

Solutions that address pollutants at the end of the production process – before they enter the environment – e.g. filters, treatment plants.

Environmental aspect

An element of an organisation's activity, product or service that may have an impact on the environment, e.g. energy consumption, emissions or waste (ISO 14001).

Environmental benchmarking

A method for systematically comparing environmental practices, indicators or results with industry best practices in order to improve efficiency.

Environmental impact

Any change in the environment – harmful or beneficial – caused by the activities of an organization. It can cover impacts on air, water, soil, ecosystems and human health.

Environmental Management System (EMS)

A structured approach of an organization to manage its environmental aspects. It includes policies, procedures, objectives, responsibilities and mechanisms for achieving compliance and improving environmental outcomes.

Environmental policy

A set of strategic directions, objectives and commitments of an organization regarding its relationship to the environment, often formalized as part of an environmental management system.

Environmental product declarations (Type III / EPD)

Standardised and independently verified information on the environmental profile of the product obtained on the basis of a life cycle analysis in accordance with the rules of the production category (PCR).

Externalities

Direct or indirect impacts of economic activities that are not included in the market price of a product or service, e.g. pollution.

Green marketing

Marketing that promotes environmentally friendly products and services and addresses environmental benefits as part of a marketing strategy. It increases the awareness and decision-making power of sustainable consumers.

Green Public Procurement

The process of integrating environmental criteria into procurement procedures – from technical specifications and selection criteria to implementation conditions – with a view to reducing the environmental impact of the products and services procured.

Hierarchist

A person who prioritizes structured decision-making and stability. In the context of sustainability, he often advocates incremental changes within existing systems.

Individualist

A person who prioritizes his own judgment, independence, and personal responsibility. In sustainable approaches, it often emphasizes innovative solutions.

Life cycle

A sequence of interrelated stages of a product or service – from the extraction of raw materials, production, distribution and use, to disposal at the end of use. It includes all environmental, social and economic impacts over time.

Life Cycle Assessment (LCA)

A systematic method for evaluating the environmental impacts associated with a product or service, covering all stages of the life cycle: from raw materials to disposal.

Life Cycle Inventory (LCI)

Collection and quantification of all material and energy inputs and emissions (e.g. emissions, waste) for individual stages of the life cycle of a product or service.

Life Cycle Thinking (LCT)

A conceptual framework that promotes consideration of impacts throughout the lifecycle of a product or service, even when a full LCA analysis is not performed.

LiDS Wheel

A tool for assessing the environmental improvements of a product compared to the previous version. It uses several criteria (e.g. materials, energy, lifetime) to determine sustainable progress.

Lower impact materials

Substances whose extraction, processing and use cause lower environmental burdens compared to conventional materials. They often include recycled, renewable, or non-toxic materials.

Market analysis

The process of collecting, analysing and interpreting information about the market, competition and customers to support decision-making in companies.

Material Input per Service Unit (MIPS)

The quantitative ratio between the total material input (MI) and the number of functional units (S). It is used as a material performance indicator and a comparative assessment tool.

MECO Matrix

A qualitative or semi-quantitative method for analysing the effects of materials (M), energy (E), chemicals (C) and other aspects (O) in the life cycle of a product. It is used to quickly identify environmental priorities.

Nutrients

Chemical elements or compounds that are essential for the growth and vital functions of organisms. A key role especially in agriculture and ecology.

Product Development

A comprehensive process of planning, designing, testing and launching a new product on the market, including possible improvements to existing solutions.

Product System

The totality of processes, flows and functions that together make up the life cycle of a product or service as modelled in LCA analysis. It includes all the input and output currents necessary to fulfill the function of the system.

Quality Management System

A set of interrelated elements in an organization that enable the planning, implementation, verification and continuous improvement of the quality of products, processes or services. It is usually based on the ISO 9001 standard.

ReCiPe method

A modern method for assessing impacts in life cycle analysis, which converts data on emissions and resource consumption into damage indicators (e.g. impact on human health, ecosystems, resources).

Recyclable materials

Materials that can be collected, processed and reused as raw material for new products after use.

Recycled material

Material that has been collected and processed after use and reintegrated into the production process – either from industrial (pre-consumer) or consumer sources.

Recycling

The process of processing waste materials into new products or raw materials with the aim of reducing the consumption of natural resources and the amount of waste.

Self-declarations of environmental products (Type II)

Statements on the environmental performance of the product by the manufacturer, importer or distributor. They are based on one or more specific claims (e.g. 'biodegradable') and are not necessarily validated by an independent institution, although verification increases their credibility.

Social responsibility

The responsibility of the organization for its impacts on society and the environment, expressed through ethical conduct, transparency and contribution to sustainable development.

Stakeholders

Persons, groups or organisations directly or indirectly affected by the decisions and activities of an undertaking or project.

Sustainable development

Development that meets the needs of the present without compromising the ability of future generations to meet their needs. It is based on a balanced consideration of environmental, social and economic factors.

SWOT analysis

A strategic tool for evaluating internal strengths and weaknesses, as well as external opportunities and dangers that affect a project or business. It is used in strategy planning and risk assessment.

The X Factor

A concept that expresses the relationship between increased added value (e.g. quality of life) and reduced environmental impact – e.g. "factor 4" means a fourfold improvement in environmental performance.

Toxicity

The ability of a substance to cause adverse effects on living organisms. In impact analysis, it includes both acute and chronic impacts on human health and ecosystems.

Triple Bottom Line approach

A sustainable framework that addresses the economic, environmental and social impacts of business equally. The goal is to create shared value for all stakeholders.

Waste management

Planning and implementing measures to prevent, reduce, collect, treat, reuse, recycle or dispose of waste in an environmentally sound manner.

Waste prevention

A measure that reduces waste at source, including reducing the use of hazardous substances and optimising processes and products.

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