Re-FREAM

Re-Thinking of Fashion in Research and Artist collaborating development for Urban Manufacturing

Working Package WP 5

Dissemination and Exploitation

Deliverable 5.1

Guideline for eco-design process for the creation of environmental friendly artworks

Grant agreement no.:	**825647**
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Lead Beneficiary for this deliverable: IZM (Max Marwede, Andre Paukstadt)

Contributions by: IED

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Dissemination Level		
PU	Public	X
CO	Confidential, only for members of the consortium (including the Commission Services)	
Type		
R	Document, report (excluding the periodic and final reports)	X
DEM	Demonstrator, pilot, prototype, plan designs	
DEC	Websites, patents filing, press & media actions, videos, etc.	

Contents

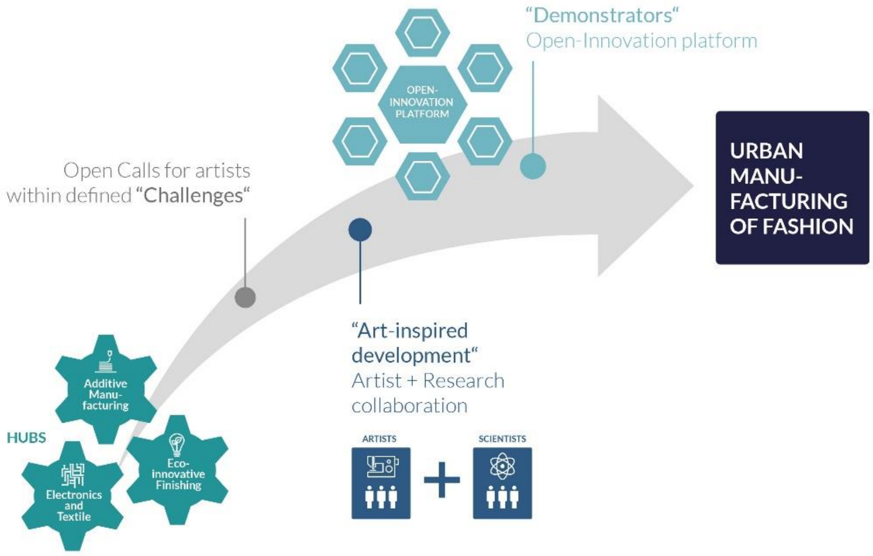
List of Figures

List of Tables

0 Context Information

0.1 The Re-FREAM Project

Re-FREAM will support **art-driven innovation** in European R&I projects by inclusion of artists in research consortia via linked third-parties. The artistic community receives a strong support from art-related partners like the Art University of Linz (UFG) and the European Institute of Design (IED), creative hubs and facilitators like Wear-IT Berlin (FashionTech), AITEX, ARCA and Creative Region combined with remarkable technology from Fraunhofer IZM (E-textiles), Stratasys, Haratech (3D-printing), EMPA (3D body simulation), Care applications (Garement nebulization) and Profactor (Additive manufacturing).



Re-FREAM boosts **art-inspired urban manufacturing**, where the city becomes a new production space. Especially for **creative fashion**, urban manufacturing offers a great opportunity to create an alternative to the much criticized production in low-wage countries.

Three technologies (additive manufacturing, electronics on textiles and eco-innovative finishing of fashion) will be explored together. **In co-creation** 20 awarded Artist/ Researcher teams, digitalized manufacturing of fashion will be developed up to TRL 5 to enable small-scale production of fashion in urban environment. An **Open-Innovation Platform** will finally link the know-how and the communities of the hubs, will offer access to relevant facilities and make the Re-FREAM art-inspired urban manufacturing working model sustainable.

0.2 Description of the Work Package concerned

Work package number	5	**Lead beneficiary**		WIB
Work package title	Hub “Electronics and Textile”			
Start month	1	**End month**	36	

Objectives

1. Development of urban fashion manufacturing framework in the field of “Electronics and Textile”
2. Provision of an individualized support package (training on collaboration and creative techniques, collaboration facilitating, design, technical, prototyping, validation/fab labs) to the awarded projects in the course of prototype development;
3. Printing strategy for hybrid integration of electronics in fashion
4. Optimizing conductive and dielectric inks for PolyJet printing

Description of work

Task 5.0: Coordination [WIB]

Hub coordination ensures that the activities in the hub does not run out of budget, co. research projects are in time and the expected results are achieved. This includes:

- Management of the actors in the hub: technology providers, artists, additive manufacturing facilities
- Contribution to preparation and updating of the project webpage
- Organising Meetings
- Grant management with awarded artists

Task 5.1: Mapping Electronics and Textile Ecosphere and Networks [WIB]

This tasks aims to build up a sustainable ecosystem of electronic and textiles technologies and networks for urban fashion manufacturing including:

- Desk top research on e-textile facilities for urban fashion manufacturing,
- Research on state of the art technologies
- Mapping of e-textile networks
- Providing a state of the art profiles on relevant technologies and network on WP7 platform

Task 5.2: Art&Tech Collaboration Support & Facilitation & Monitoring [WIB]

This tasks aims to coordinate and implement the art/tech transfer within the Urban Fashion manufacturing hub and the implementation of the 7 operational co-research projects , including:

- Implementation of 2 Art/ Tech transfer local events
- Recruiting of Collaboration facilitators
- Implementation of collaboration trainings for researcher and awarded artists
- Set up of CO.Research projects including co.research agreements
- Monitoring and evaluation of the Co.Research projects

Task 5.3: Optimization of Electronic Module Kit [IZM]

IZM will develop miniaturized electronic modules that can be integrated into textiles by means of ICA/ ACA, NCA bonding, embroidery or soldering. This so called Re-FREAM e-Textile kit will consist of functional modules, like microcontroller, wireless communication, sensors and actuators

In workshops we will discuss with artists the needed form factor in order fulfil an easy-to use system as well as required design aspects

Task 5.4: Optimization of Textile Circuit Board Technology [IZM]

IZM will adopt the Textile Circuit Board manufacturing technology that it can be applied to low-cost equipment as plotters and thermos-transfer press. The technology will be further developed into a multilayer technology. Based on open innovation approaches IZM will document and publish the production process and suitable materials in order to enable external use of the project results

Task 5.5: Conductive and dielectric ink optimization and printing strategies [PRO, STR]

PRO will do a market research on conductive (Cu and Ag) and insulating (TPU, acrylate systems) The different parameters related to formulation optimization (e.g. solvent and solvent monomer ratio, additives, etc.) will be studied as to how they influence the polymerization quality, speed, energy balance, printability, geometry and electrical properties of the printed pattern, etc. If necessary Taguchi Design-Experiment (DOE) will be implemented.PRO will deal with the further ink development and optimization. Physical properties of the ink as well as printability will be characterized. Tests of finally printed objects after curing in terms of desired material properties will be done. STR will validate the inks for their PolyJet printers and test for proper printing

Task 5.6: Development of methodology for sustainable creation of artworks (IZM)

Aim of this task is to identify easy to use eco-design tools (checklists, assessment tools, creative methods) applicable to art-works and develop a process for the co-creation of eco-designed artworks in an urban manufacturing environment.

- Identification of artists needs with respect to eco-design (qualitative interviews)
- Screening of the available eco-design processes and tools according to needs, usability, and adaptability to art
- eco-design process for the creation of environmental friendly artworks (methods and steps along the product development phases ideation, definition, and development)
- Application and test of process for challenge 6

Deliverables (brief description and month of delivery)

D 5.1: Guideline for eco-design process for the creation of environmental friendly artworks (Month 3) (IZM)
D 5.2: First version of four E-textile artworks and two eco-designed art-works (month 18) (IZM)
D.5.3. Mapping “e-Textile Ecosystem and Network” Report (month 20) (WIB)
D.5.4. Hub “e-Textile” Final Report (month 36) (WIB)
D 5.3: Final version of four E-textile artworks and two eco-designed art-works (month 36) (IZM)

0.3 Purpose and Scope of Deliverable Report D5.1

This deliverable is the results of Task 5.6 and should support the art-tech teams and the hub manager to not only solve technical issues but also improve the artefact which shall be created from an environmental perspective. It provides a description of tasks in combination with relevant tools and methods.

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1 Introduction

This eco-design process was developed for the Re-FREAM Art-Tech collaboration. Insights for art-tech collaboration were gained through two expert interviews[1] and through a close exchange with the project partner IED, which was in charge of developing the overall art-tech collaboration process.

2 The Eco-design Process

The eco-design process follows the art-tech collaboration process as described in D 2.2 “Collaboration Training Concept” as seen in Figure 1 below. The eco-design process is especially integrated into the Phase 2 of the collaboration process plus the envision phase. All other phases are not explicitly expanded, but of course the eco-design process, insights and results shall be reflected and communicated in the presentations (mid-term and prototype presentation) as well as during the communication phase.

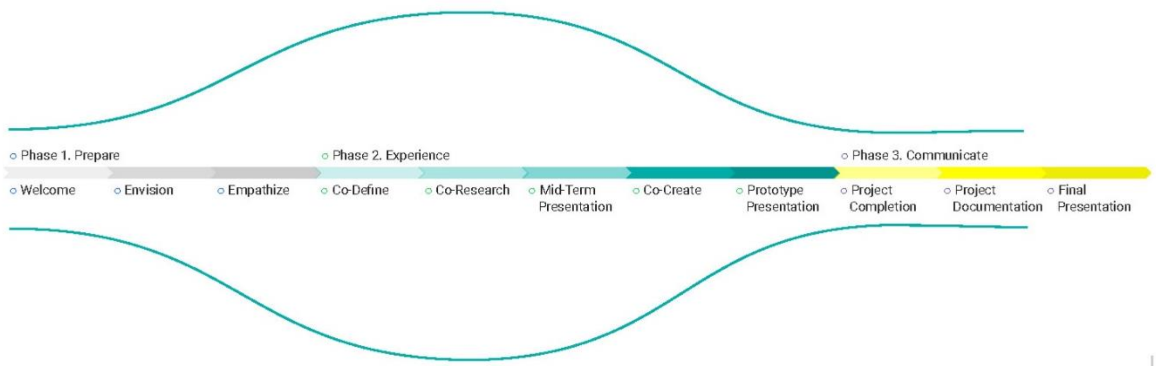


Figure 1: Art-Tech Collaboration Methodology: Phase 2 Experience (source Deliverable 2.2)

Table 1 gives an overview of specific eco-design tasks during the are-tech collaboration process. Required tools are added and the necessary steps are further detailed. In the following section we describe the required eco-design steps and tasks in each phase of the process and relevant tools to be used. An overview of all the tools is given in Table 3 in ANNEX I.

In section 2.2 we describe an elaborated eco-design process. A sustainability/eco-design expert is required for this process who is familiar with the terms and methods. In section 2.3 we describe a simplified process for which we developed an easy to use excel tool. To use this tool no special expertise is required. This tool will be provided to the hub managers and teams which have no internal expert and the use of the tools will be explained by Fraunhofer IZM.

The advantage of the elaborated process is that the environmental analysis is more specific and detailed so that it is easier to identify environmental hot-spots and eco-design measures along the life-cycle to address. However, this requires much more time and expertise.

The simplified process can just give general eco-design strategies based on design principles which are prioritized (e.g. design for easy repair and maintenance). However, within both processes it is up to the art-tech team to research, test, validate and implement technical solutions in order to reduce the environmental hot-spots identified and realize the chosen eco-design strategies. Of course it is also possible to combine both processes and use additional tools.

[1] Veronika Liebl, ars electronica, 29.1.2019; Ida Urmas, Beneficial Design Institute, 3.5.2019

Table 1: Eco-design tasks within the Art-Tech Collaboration Phases

	ENVISION	CO-DEFINE	CO-RESEARCH	CO-CREATE
General Description	HUB KICK-OFF MEETING Meetup of the entire Hub Community.	PROJECT CO-DEFINITION Space for the Art/Tech Team to review the presented Project and co-define what and how they are going to attain it.	PROJECT EXPLORATION Space for collaborative research, experimentation and conclusion of the final version of the Prototype.	MATERIALIZATION Space for the realization of the Prototype. Coordination of the Project´s specific procedures and needs.
What	General introduction to eco-design	Discussion of concept with respect to eco-design: identify expected sustainability challenges, frame common research questions.	• Analysis of environmental. requirements, aspects and impacts • Develop environmental targets • Develop a product specification addressing the environmental targets • Research, develop and test technical solutions	• Implement technical solutions • Assess whether environmental targets were achieved
Why	Get a common understanding.	Define the project and set research goals. Find a common understanding of potential sustainability issues to be solved.	Research potential solutions to reduce environmental impact	Implement and assess, whether targets were achieved
Who	Introduction to eco-design through eco-design expert to Hub Manager and Art/Tech Team	Art/Tech Team, eco-design expert if available	Art/Tech Team, eco-design expert optional	Art/Tech Team, eco-design expert if available

	ENVISION	CO-DEFINE	CO-RESEARCH	CO-CREATE
How	Presentation of basic concepts and methods.	- Life-Cycle Thinking - MECO Matrix - Re-FREAM EcoTool - Eco-design Brief: o *How does the concept transport the idea of sustainability?* o *Which environmental goals should be reached* o *What do we still need to find out?*	Environmental Assessment (Identify „hot-spots”) - MECO Matrix - EcoDesign Pilot - Circular Economy Toolkit – Assessment Tool Search for potential solutions - Circular System Design - Circular Flows/Opportunities - Eco-design Strategies & Checklist - Re-FREAM EcoTool - Biomimicry - Smart Material Choices - Open LCA Databases	Validation - Re-FREAM EcoTool (qualitative) - Simplified Life Cycle Assessment (quantitative)

2.1 Envision

In the envision phase a general introduction to eco-design shall be given. It's possible to present common sustainability trends and political agendas such as the UN Sustainable development goals (United Nations, 2019) and the European Circular Economy Strategy (Europa, 2019).

Furthermore, one should explain the benefit and purpose of eco-design (section 2.1.1 Why eco-design?), explanation of the basic principles (section 2.1.2 What is eco-design?), and the eco-design process (section 2.1.3 How to eco-design?). Best practice examples can complement the presentation.

The basic introduction can be given by a eco-design expert present in the hub or remote through an expert of Fraunhofer IZM via a web conference.

2.1.1 Why eco-design?

Important to mention here are of course climate crisis, loss of biodiversity and resource scarcity although the focus should be set on that eco-design means developing a better product. Eco-design means that you innovate something based on following social, environmental and economic sustainability goals and measures, which means you create something which is good for the people (user-centered design), good for the environment (not just reducing impact but also create environmental benefits) and economically viable (see Figure 2).

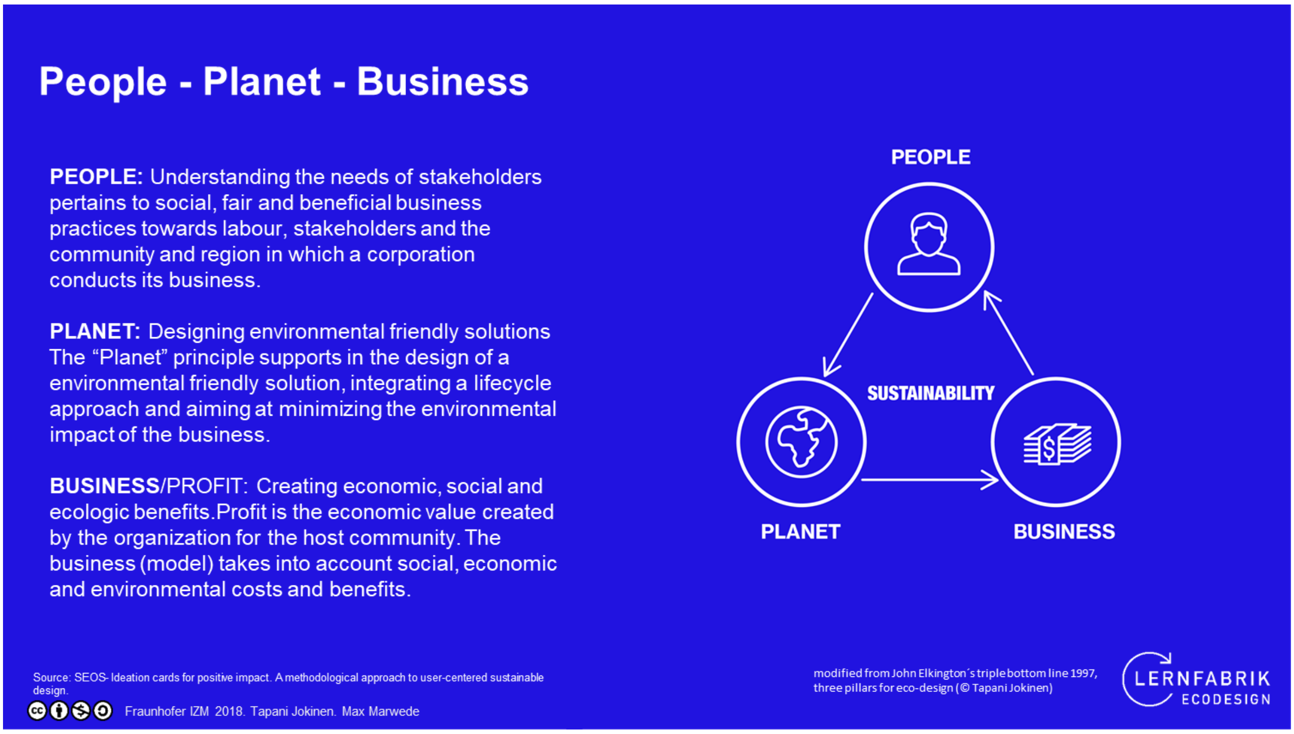


Figure 2: Three pillars of sustainability (source: Fraunhofer IZM adapted from (Elkington 1999))

2.1.2 What is eco-design?

Eco-design is a systematic approach which takes into account environmental aspects in the design and development process with the aim to reduce adverse environmental impacts (IEC 62430, 2009).

Key concept of eco-design is *life-cycle thinking*, which requires consideration during the design and development process of the significant environmental aspects of a product in all life cycle stages. The life cycle stages usually include the processing of materials, manufacturing, distribution, use, maintenance and end-of-life management (including reuse, recycling,recovery and final disposal). Figure 3 show systematically all life-cycle phases including inputs and outputs, which can lead to adverse environmental impacts. Key elements of life-cycle-thinking are:

a) Having an objective to minimize the overall detrimental environmental impacts of the product
b) Identifying, qualifying and where feasible quantifying the significant environmental aspects of the product

This shall be initiated as soon as possible in the design and development process, when when most opportunities exist to make changes and improvements to the product affecting its overall environmental performance throughout its life cycle (IEC 62430, 2009).

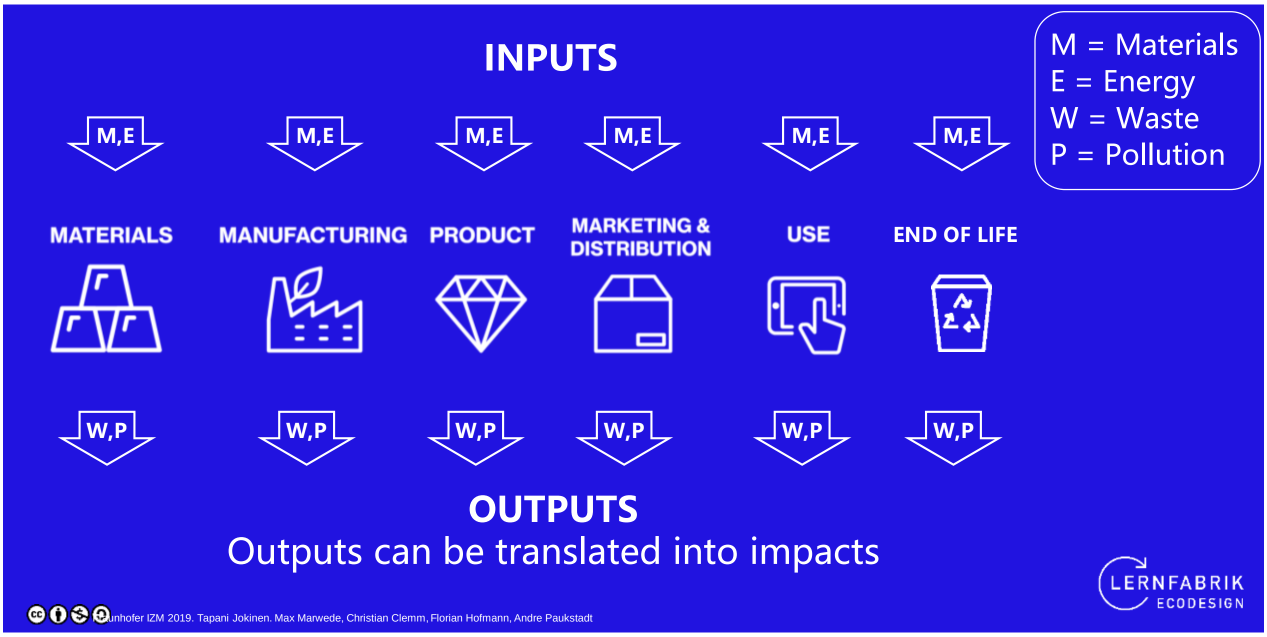


Figure 3: The Life-Cycle phases and related inputs and outputs (source: Fraunhofer IZM)

The mapping of all relevant processes, input and outputs is the so called Life Cycle Inventory. The outputs can be translated into environmental impacts, which can effect human health, the ecosystem or resource availability (see Figure 4).

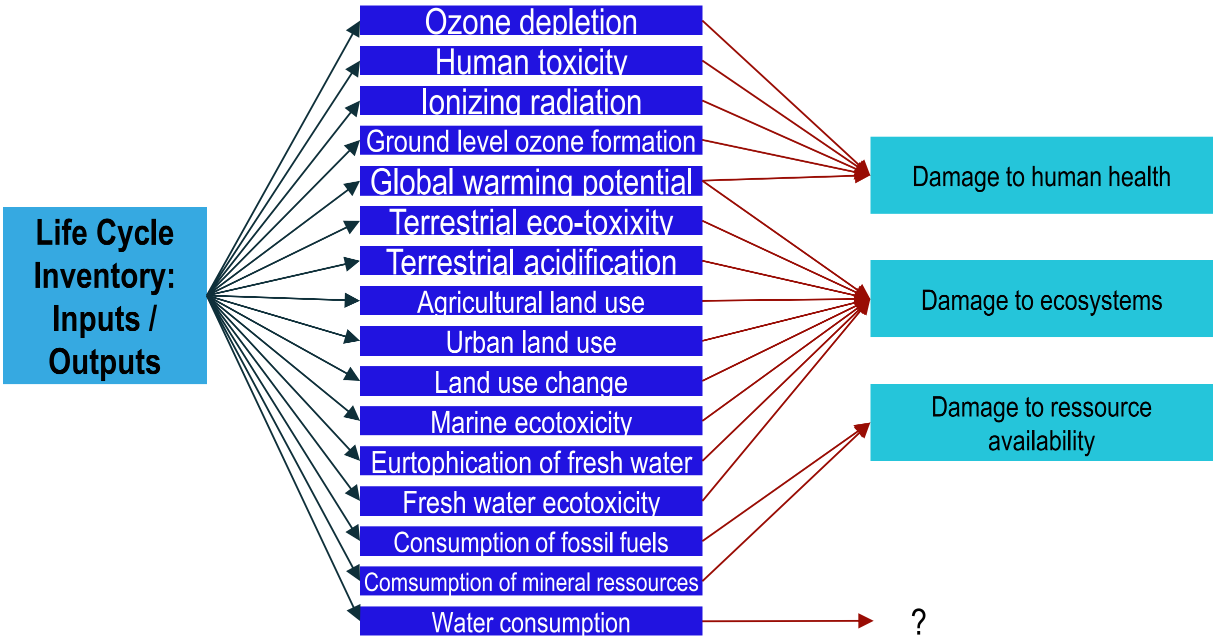


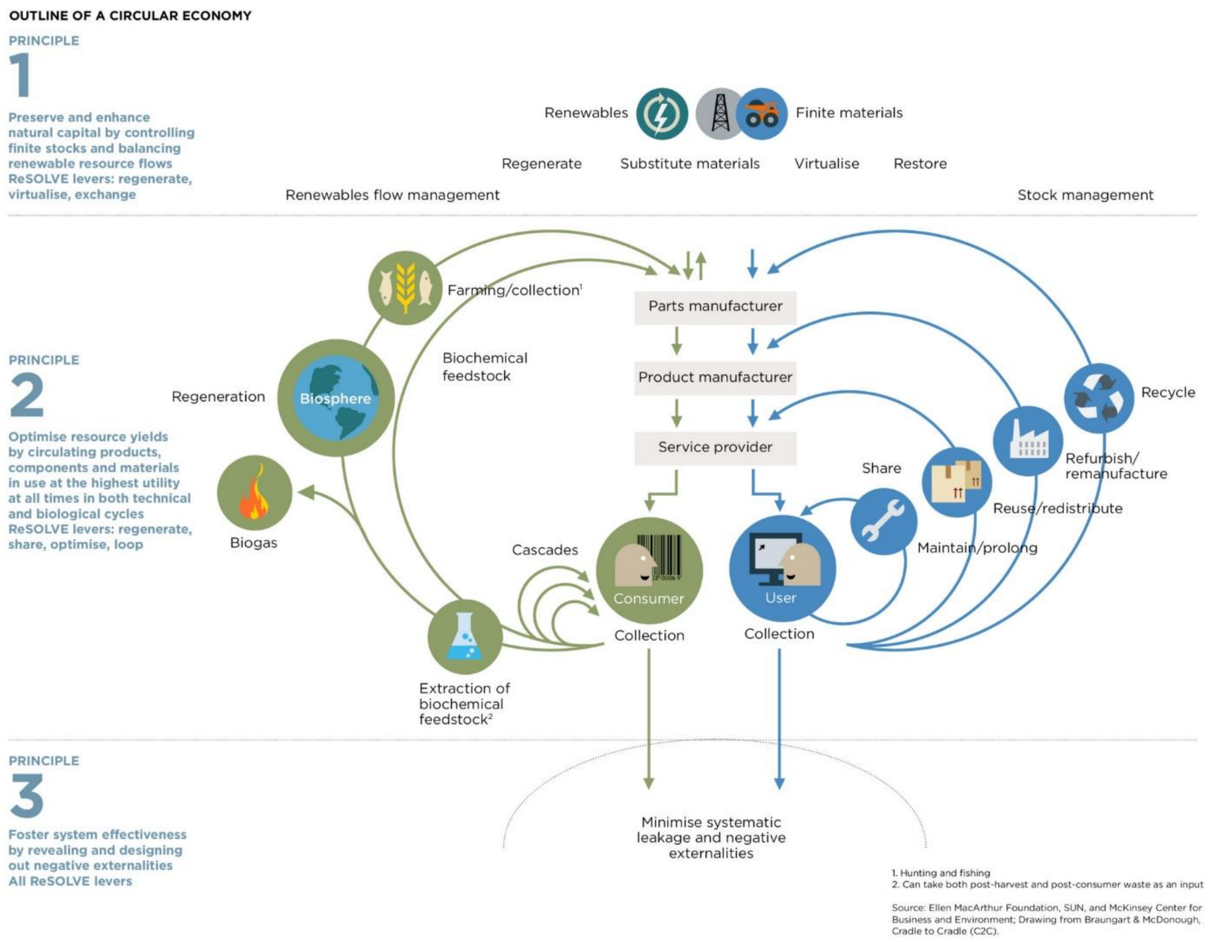
Figure 4: Life cycle impact indicators (source: Fraunhofer IZM)

Thus, it is important that you move from product design to life-cycle system design based on the principles of the Circular Economy (see Figure 5). The Circular Economy is based on the principle of closed metabolisms. It aims at keeping products, components and materials in use as long as possible and separates biological material flows from technical material flows (Ellen Macarthur foundation, 2019).

Circular economy is all about retaining product value for user, extending lifetime and treasure longterm relationship. Walter Stahel (2014) highlights characteristics of a circular economy that distinguish it from a linear economy based on extraction, production, consumption and disposal (waste):

- “The smaller the loop (activity-wise and geographically) the more profitable and resource efficient it is.” The aim is not to create one globalized circular economy, rather, the most effective strategy is to appropriately scale-link multiple circular economies at local, regional and global scales.
- “Loops have no beginning and no end”, so they require continuous collaboration along the entire value chain.
- “The speed of the circular flows is crucial: the efficiency of managing stock in the circular economy increases with a decreasing flow speed”; and therefore companies will have to rethink strategies based on ‘planned obsolescence’ and create high-quality, durable products.
- “Continued ownership is cost efficient: reuse, repair and remanufacture without change of ownership save double transaction costs.” This creates an incentive for companies to sell (lease) the use or service provided by their products, rather than the products themselves.
- “A circular economy needs functioning markets”.

Figure 5: Circular Economy system diagram



Source: Ellen McArthur Foundation

2.1.2.1 Eco-design principles

The main sustainability principles are sufficiency, efficiency and consistency as see in Figure 6.

Sufficiency

The idea behind sufficiency is to minimize the consumption of raw materials and energy to become more sustainable. To achieve that, sufficiency is linked to questions regarding self-limitation, abstinence from consumption or even asceticism, but also deceleration and the dropping of ballast. In all cases it is about changes in behaviour as a means of environmental protection.

Efficiency

Efficiency describes the ratio between a particular (economical) benefit and the (environmental) expenditure required to achieve it. In the context of sustainability, the point of interest lies in the quantity of resources (raw materials and energy) needed to manufacture a product or provide a service. Accordingly, to operate more efficiently is to improve the ratio of resources used to the results achieved with them, i.e. producing the same or more with less.

Consistency

Consistency (also eco-effectivity) strategies are about reconciling nature with technology. The idea behind this approach is that there is no waste. All energy and material can be (re)used for something. Enabling material- / product-loops to avoid the end of life.

Figure 6: Strategies towards sustainability

Source: Fraunhofer IZM

2.1.2.2 Eco-design strategies

Common eco-design strategies are seen in Table 2. More strategies can be found in ANNEX II and ANNEX III.

Table 2: Strategic eco-design approaches

Approach *Design...*	Explanation Design principles...
... for minimised production waste	...which allow for a less waste intensive production. Layout of parts makes optimal use of semi-finished products, components can be manufactured with more efficient technologies, less process steps, etc.
... for production waste recycling / downcycling	...which result in production waste, which meets the specification of downstream use on the (economically and environmentally) highest possible level.
... in low-impact materials	..., which consider the use of recycled, bio-based and other materials, which are characterized by lower environmental impacts for acquisition; including the definition of specifications for sub-assemblies, which correspond to the quality levels, which could be met by low-impact material.
...out materials and components (1)	..., which are characterized by a minimized number of components and/or material to be used.
for product attachment and trust	…, which creates a relationship between user and product. The user of this product will feel personally attached to it, encouraging him or her to be careful with it and postpone replacement of this product. In this way, the product's lifetime will be extended.

... for lifetime extension	...which thereof results in longer use of the product or individual components. This might include technical lifetime (proper functioning of the product and its parts) and fashion lifetime (appealing timelessly design).
... for reuse	..., which allow a removal of still working components / sub-assemblies in a non-destructive way to allow a reuse in other products, and which allow an efficient functional check, upgrading, and refurbishment of the product as a whole.
... for repair	..., which ease the repair of defect products by providing features for efficient failure analysis, fast access to most critical components, facilitate exchange of the failed component (and to avoid an exchange of larger sub-assemblies, if technically not needed).
...for upgradeability (1)	..., which allow a later expansion of technical capabilities to meet advancing user expectations.
...for collection	..., which allow a collection at end-of-life, which minimizes damages resulting from typical collection practice.
... for disassembly	..., which speed up the process of taking a product apart for defined purposes (material separation, cannibalization of reusable components, depollution).
...for refurbishment	..., which allow in the case of technical products an upgrade of hardware and software to meet the user requirements for an extended life span, which allow an exchange of wear affected components, which ease a cleaning, and which allow for re-establishing an appealing appearance of the product.
... for depollution	... Which allow an easy identification and separation – without releasing substances - of materials and components, which contain substances of concern for humans and the environment. This approach also covers to design out substances of concern as such. There is no defined list of substances of concern. Such a list and priority setting has to be established individually for products or industries, but there are some guidance documents available, and legal requirements and restrictions define a baseline to be considered.
... for material recycling / high recovery ratio	..., which allow an identification of materials and an efficient separation according to the needs of a high level material recycling, avoiding fractions of material combinations, which lead to losses of individual materials in the recycling route or even to an adverse impact of the recycling of other materials.

Source: (Marwede & Middendorf, 2011) (Circulardesigncases, 2019)

2.1.3 How to eco-design

As mentioned above during the course of the project the eco-design process follows the phases as seen in Table 1. In general it follows similar steps as each design process:

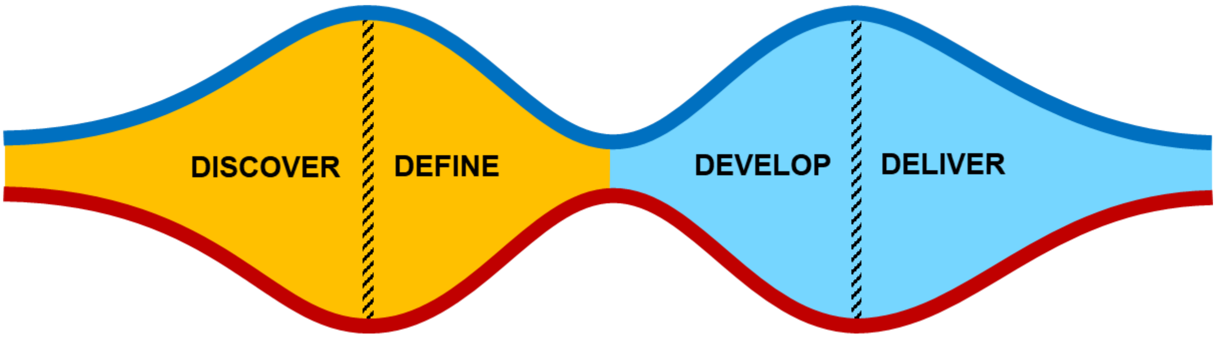


Figure 7: The Eco-design process (source: Fraunhofer IZM adapted from British Design Council's double diamond process (Design Council, 2019))

Discover/Understand

This is the research phase, where environmental challenges are identified.

Define

This is the phase where environmental goals are set and potential improvement strategies are identified

Develop

During the develop phase eco-design measures, product specifications and technical solutions are being developed.

Deliver

Here solutions are “prototyped” and validated (estimated, in which respect eco-design goals are reached).

This is of course also an iterative process

2.2 The elaborated Eco-design Process

2.2.1 Define

2.2.1.1 What and How

During the definition phase the concept should be discussed with with respect to eco-design:

- Answers should be found on “What does the “artefact” communicate, manifest, demonstrate or reflect with respect to sustainability?”
- Based on the concept one can identify expected challenges with regards to sustainability, for example mix of different materials which follow different recycling routes or energy demand in the use phase.
- Development of common research questions, important sustainability aspects and goals based on identified challenges

The concept should be adapted based on identified challenges and research questions

2.2.1.2 Tools and Methods

- Life-cycle thinking
- Eco-design strategies and checklist (see ANNEX II and ANNEX III)
- Re-FREAM EcoTool (see section 2.3)
- Brief on
    - *How does the concept transport the idea of sustainability?*
    - *Which environmental goals should be reached (e.g. reduction of hazardous substance, reduction of CO2 Emissions)?*
    - *What do we still need to find out?*

2.2.2 Co-Research

2.2.2.1 What and How

During the co-research phase, following steps should be taken according to (IEC 62430, 2009).

1. Analysis of env. requirements (related to user, regulatory requirements, stakeholders, …) and relate these to the environmental aspects to be achieved throughout the life cycle of the product
2. Identify significant environmental aspects for each life-cycle stage, i.e. identify inputs such as materials, energy and other resources as well as outputs (emissions, waste), which cause environmental impacts.

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2.1. Map out the product life cycle stages and what significant environmental aspects apply to each.

2.2. Analyse and evaluate the impacts on the environment, taking into account the foreseeable product life cycle

3. Relate environmental impact to relevant parameters of the product (parameters include the type and quantity of materials used (weight, volume), power consumption, emissions, rate of recyclability, etc.)
4. Develop environmental targets (e.g. reduction of CO2 emission) and requirements based on the improvement strategies;
5. Analysis of the product's intended functions so that these can be modified, if required, to achieve the environmental targets for the product
6. Develop a product specification addressing the environmental targets (environmental product specification);
7. Research and develop technical solutions to meet the environmental targets while taking into account other design consideration (e.g. functionality, aesthetics, reliability, costs)
8. Test technical solutions against environmental targets
9. Select technical solution taking into account other design considerations (e.g. technical feasibility)

2.2.2.2 Tools and Methods

Environmental Assessment (identify „hot-spots")

- MECO Matrix: http://orbit.dtu.dk/files/3996106/mpu-elektronisk-uk.pdf
- Re-FREAM EcoTool (see section 2.3)
- EcoDesign Pilot: http://pilot.ecodesign.at/pilot/ONLINE/ENGLISH/PDS/INDEX.HTM
- Circular Economy Toolkit - Assessment Tool: http://www.circulareconomytoolkit.org/Assessmenttool.html

Search for potential solutions:

- Eco-design strategies & checklists (ANNEX II and ANNEX III))
- Re-FREAM EcoTool (see section 2.3)
- Circular System Design: https://sustainabilityguide.eu/methods/system-design/ https://sustainabilityguide.eu/wp-content/uploads/2018/12/Learning-Factory-Ecodesign-Manual_EN_14.pdf
- Circular Flows: https://www.ellenmacarthurfoundation.org/assets/design/Circular_Flows_Final.pdf
- Circular Opportunities: https://www.ellenmacarthurfoundation.org/assets/design/Circular_Opportunities_Final.pdf
- Biomimicry:
  - https://www.circulardesignguide.com/post/biomimicry,
  - https://toolbox.biomimicry.org/methods/process/
- Smart Material Choices:
  - https://sustainabilityguide.eu/ecodesign/materials-parts/
  - https://www.circulardesignguide.com/post/materials
- Open LCA databases
  - Probas (German Environment Agency) for energy generation, materials, waste processes, agriculture processes, transport, electronics and metals: www.probas.umweltb undesamt.de/php/index.php

- PlasticsEurope Eco-profiles for polymers and semi-finished chemicals www.plasticseurope.org/en/resources/eco-profiles
- Open LCA Nexus: nexus.openlca.org

2.2.3 Co-Create and Prototype

2.2.3.1 What and How

1. Implement technical solution into prototype
2. Detail and optimize the product's design so as to satisfy environmental and performance requirements
3. Evaluate whether environmental targets were achieved

2.2.3.2 Tools and Methods

Validation

- Re-FREAM EcoTool (see section 2.3) - qualitative
- Life cycle Assessment -quantitative
    - Methodology for the Ecodesign of Energy-related Products (MEErP) – EcoReport Tool: https://ec.europa.eu/docsroom/documents/5309/attachments/1/translations/en/renditions/native
    - Ecolyzer. http://ecolizer.be/

2.3 The simplified Eco-design Process

For the artists that don't have an eco-design expert in their respective hub, a simplified eco-design process is provided via the so called „Re-FREAM EcoTool". It's a simple excel program, that will provide strategies and tips based on chosen ecodesign principles. The principles will be chosen by the artist in the beginning and are distinguished in four different categories:

- Design approach ...for easy repair and maintenance
- Design approach ...for improved material consumption
- Design approach ...for improved energy consumption
- Design approach ...for improved end of life.

It is also possible to choose more than one approach. Based on the chosen design approach, strategies and tips will be provided. They will act as a guidance for the artists during their product development process. All provided tips & strategies are linked to the six life cycle phases of a product:

1 (Product)Design
2 Material
3 Manufacturing
4 Distribution
5 Use
6 End of Life

In order to act sustainable in a holistic way, the artist should have all phases along the life cycle of a product in mind. The differentiation between these six life cycle phases will help to provide tips & strategies much more targeted.

Besides providing the eco-design strategies, the tool will be used as an assessment in the end of the project. There, the artists will assess their final product and identify eco-design strategies they couldn't fulfill. This is the time where the artists reflect on their problems and challenges they had along the creation process.

So overall, the tool can be distinguished in two parts.

1 Choice of design approach and based on that, provision of strategies and tips to fulfill the prioritized design approach (in the beginning of the project)
2 Assessment of the final product and reflection whether the prioritized design approach was achieved (at the end of the project)

Like the elaborated eco-design process (chapter 2.2, page 16), the simplified process based on the „ Re-FREAM EcoTool" can be linked to the same process steps, which are explained in the following sub chapters. Please note that the tool is still work in progress, so that the following screenshots might differ slightly from the final version.

2.3.1 Define

The tool starts with an introduction page, where the usage of the tool is explained (Figure 8). In the beginning of the project, the user only needs the first part of the tool – the strategies and tips based on their chosen design approach. To get to the list, the user has to click on the first button “1. Choose your design approach”.

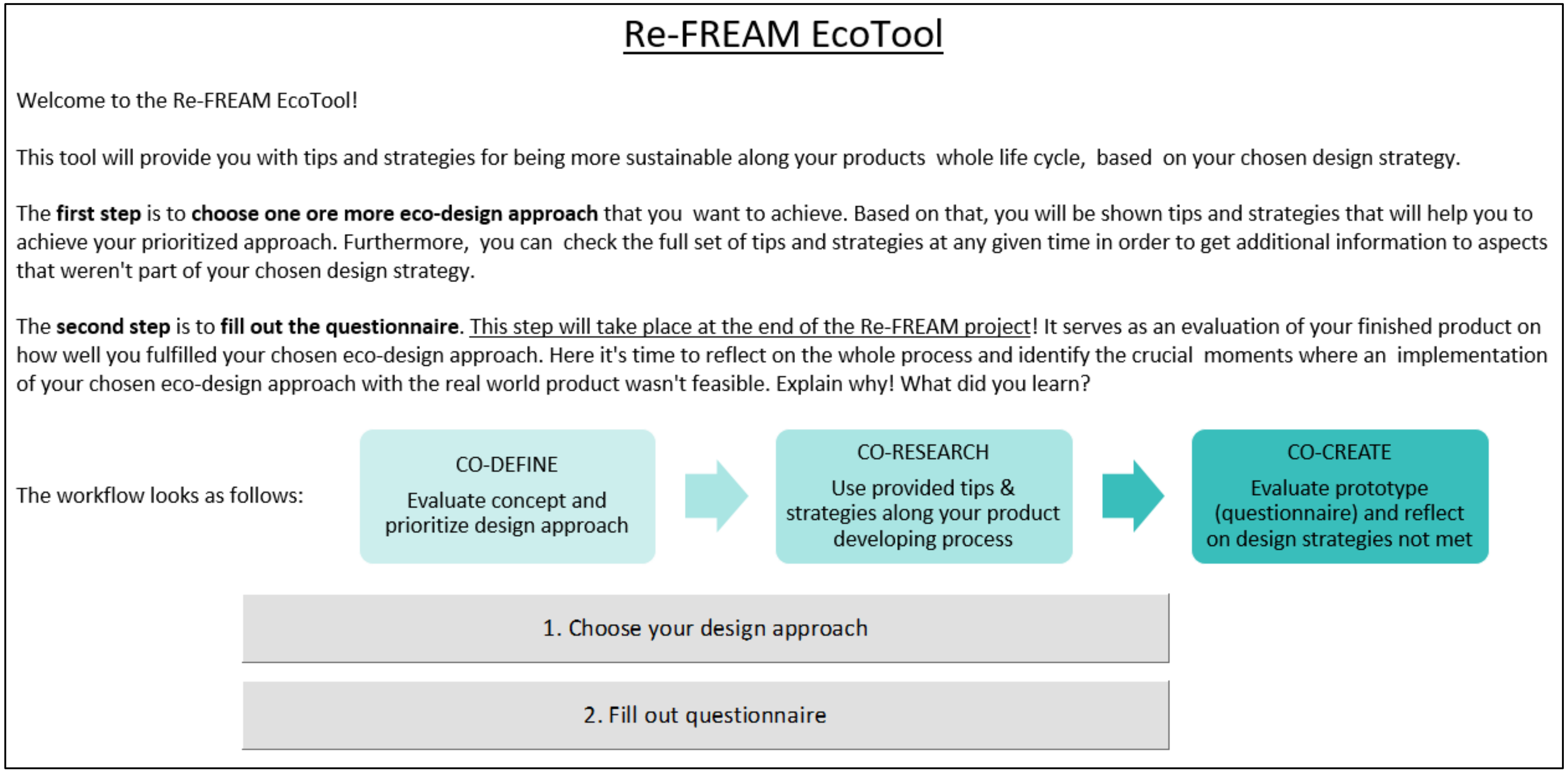


Figure 8: Introduction page of the Re-FREAM EcoTool

The next page shows the four different design approaches the artists can choose from (Figure 9). They can select one or several approaches by double clicking on the respective cell. Before choosing a design approach users should evaluate their design concept in order to identify environmental “hot spots”. They should prioritize design approaches which help to mitigate those “hot spots”. Tools to identify environmental “hot spots” are listed in section 2.2.2.2 on page 17. By clicking on the button „Show list of tips & strategies“, the user will be guided to the next page that provides a list of tips & strategies that are part of the chosen design approach (Figure 10).

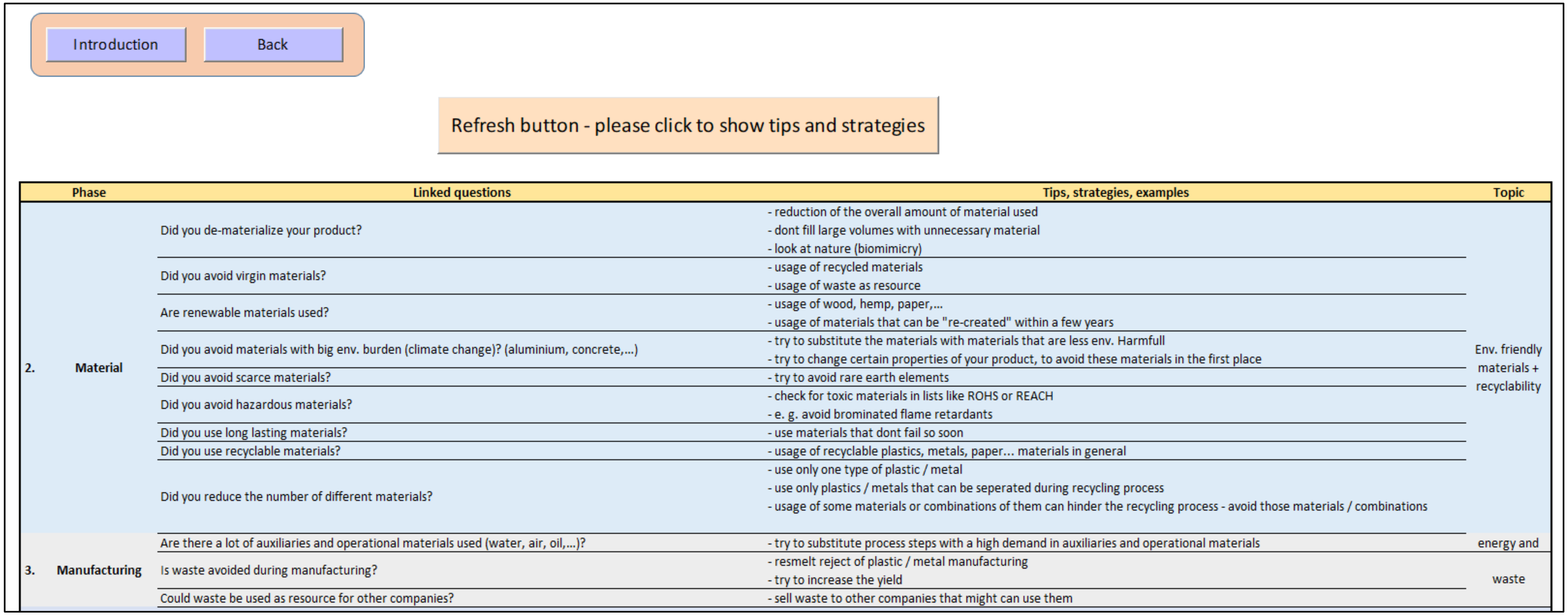
Introduction

Design approach...	...for easy repair and maintenance	...for improved material consumption	...for improved energy consumption	...for improved end of life
	- providing easy and safe access in general - facilitate exchange of failed components - enabling safe access to critical / toxic components - avoiding an exchange of larger sub-assemblies, if technically not needed - speed up the process of taking a product apart - ...	- use less materials for the manufacturing of the product - use less materials during use phase - use less materials for packaging - use more sustainable materials - ...	- use less energy during the manufacturing phase of the product - use less energy during the use phase - enabling usage of more ecological energy sources - check for efficient means of transportation - ...	- enabling of recycling - usage of fewer different material types - avoidance of toxic materials - ...
Choose here (double click) →		x		

Show list of tips & strategies

Figure 9: Choice of design principles, that the artist wants to fulfill

Being on that page, the first thing to do is clicking the “refresh” button, to show the list of tips & strategies based on the chosen design principles. The list of tips & strategies are shown in a table, linked to the respective life cycle phases and higher questions that the artists should ask themselves. The last column summarize the tips and strategies into one overarching strategy.



Introduction Back

Refresh button - please click to show tips and strategies

Phase	Linked questions	Tips, strategies, examples	Topic
2. Material	Did you de-materialize your product?	- reduction of the overall amount of material used - dont fill large volumes with unnecessary material - look at nature (biomimicry)	Env. friendly materials + recyclability
	Did you avoid virgin materials?	- usage of recycled materials - usage of waste as resource	
	Are renewable materials used?	- usage of wood, hemp, paper,... - usage of materials that can be "re-created" within a few years	
	Did you avoid materials with big env. burden (climate change)? (aluminium, concrete,...)	- try to substitute the materials with materials that are less env. Harmfull - try to change certain properties of your product, to avoid these materials in the first place	
	Did you avoid scarce materials?	- try to avoid rare earth elements	
	Did you avoid hazardous materials?	- check for toxic materials in lists like ROHS or REACH - e. g. avoid brominated flame retardants	
	Did you use long lasting materials?	- use materials that dont fail so soon	
	Did you use recyclable materials?	- usage of recyclable plastics, metals, paper... materials in general	
	Did you reduce the number of different materials?	- use only one type of plastic / metal - use only plastics / metals that can be seperated during recycling process - usage of some materials or combinations of them can hinder the recycling process - avoid those materials / combinations	
3. Manufacturing	Are there a lot of auxiliaries and operational materials used (water, air, oil,...)?	- try to substitute process steps with a high demand in auxiliaries and operational materials	energy and waste
	Is waste avoided during manufacturing?	- resmelt reject of plastic / metal manufacturing - try to increase the yield	
	Could waste be used as resource for other companies?	- sell waste to other companies that might can use them	

Figure 10: Tips & strategies based the chosen design approach

When scrolling down, the user might see a note, that his / her chosen design principles didn’t cover all life cycle phases. That will be indicated by a red note (Figure 11).

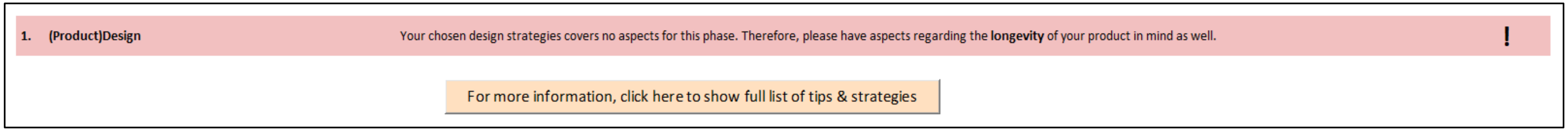


Figure 11: Red indication that will be shown if the chosen design approach didn’t cover all life cycle phases.

To see tips & strategies for the missing life cycle phase, the user has to click on the button on the very bottom. A page will open, that provides all tips & strategies, regardless of the chosen design approach. This list can be used any time along the project.

During the creation process of the product, the artist should try to fulfill the strategies and tips based on their chosen design approach. In the second part of the tool (the assessment), they have to justify themselves if they didn’t fulfill the chosen design approach.

2.3.2 Co-Research

In the Co-Research phase the artists should use the list of tips & strategies based on his / her chosen design approach. It helps them to get an overview of eco-design aspects and where to start with the research. They should go through the provided tips & strategies along the life cycle phases and doing research on how to reach their chosen design approach. The artist should use the list frequently to ensure they don’t miss out on any aspect. A major goal in this phase is to enhance the artists’ awareness on environmental impacts that he / she can influence by design decisions.

2.3.3 Co-Create and Prototype

During this phase the artists are still using the list of tips & strategies based on his / her chosen design approach. Every time a design decision for the product will be made, they should check if it’s in conflict with one of their eco-design approach.

If the prototype of the product is finished, the assessment of the product will take place. The assessment is structured like a questionnaire and is going through all life cycle phases of the final product. The user will access the questionnaire by clicking on the “2. Fill out the questionnaire” button at the introduction page (Figure 8).

Figure 12 shows the start page of the assessment. The user has to click on one of the life cycle buttons to start the questionnaire. It’s recommended to start with the first life cycle phase “1. (Product)Design)” and from there on, go through all six phases.

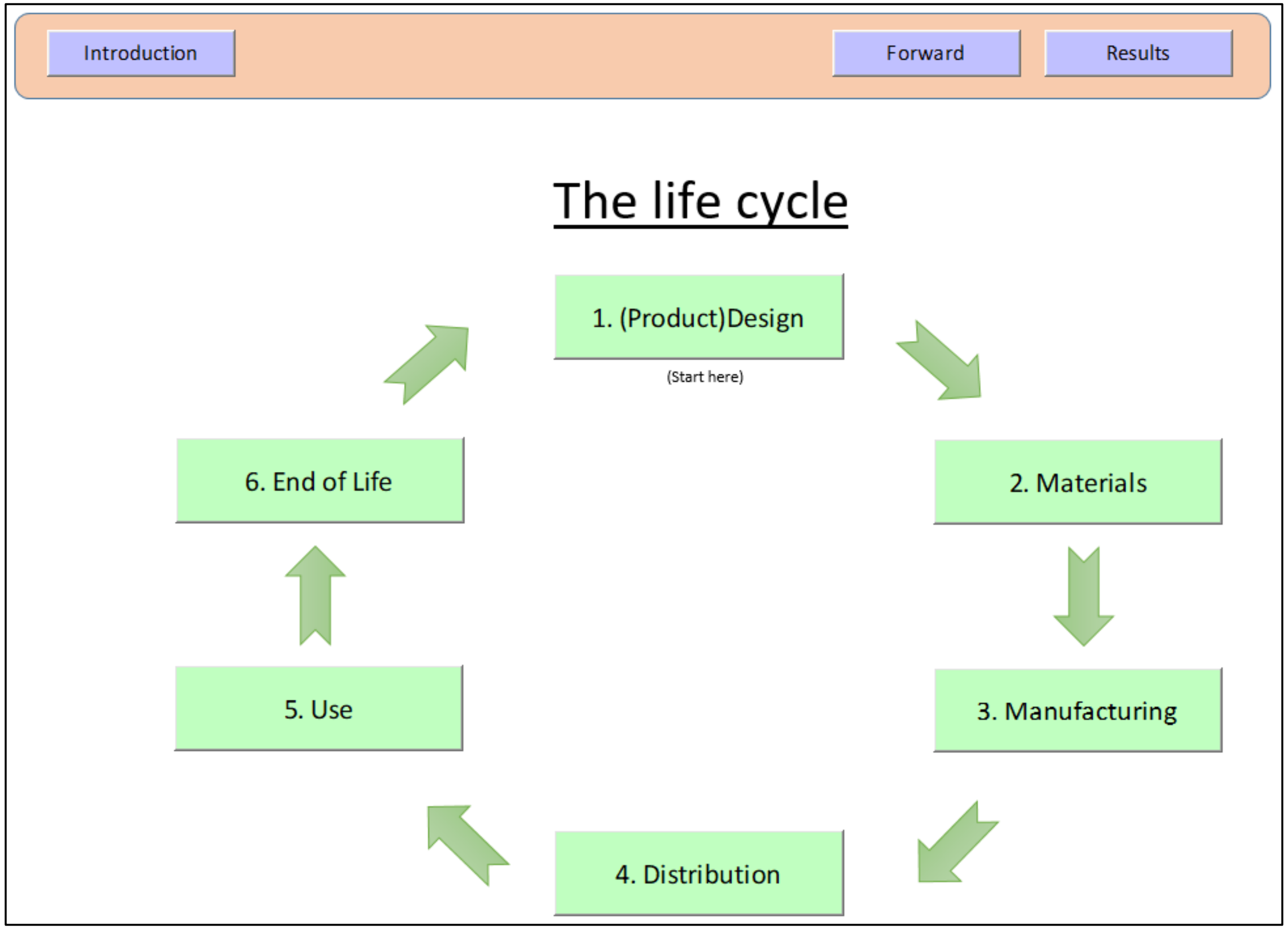


Figure 12: Start page of the assessment / questionnaire

Figure 13 shows exemplary the questions for the use phase.

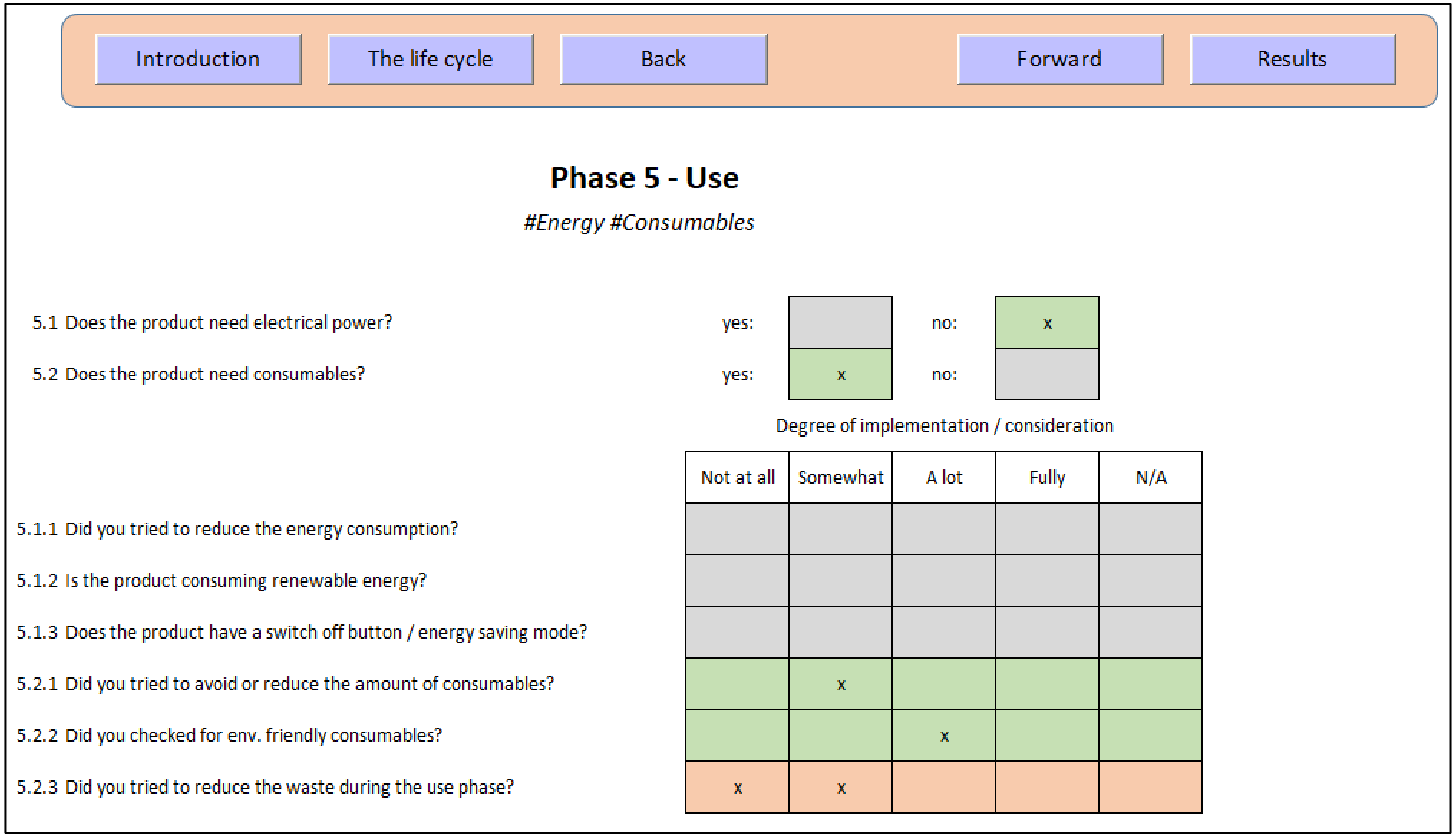


Figure 13: Questions exemplary for the phase 5 "Use"

The user has to evaluate the degree of implementation / consideration for each question. He / she can choose between four distinct options of consideration, depending on how much he / she considered the asked aspect. To choose a cell, the user has to double click on it to mark it with an "x". Thereupon the row turns green. In Figure 13, two entries have been made for question 5.2.3 mistakenly. The respective row turns red, because only one "x" is allowed per row. Double clicking on an "x" again will delete it. The use phase is the only phase with two "knock out" questions, 5.1 and 5.2. If clicking "no" at one of them, the linked questions underneath turn grey – they are not applicable and therefore don't have to be filled out. Should a question not fit for the artist's product, option N/A (not applicable) should be used. The questions should be answered as honest as possible to get the most accurate results. Depending on the answers, the user will receive points, with 3 points as the maximum and 0 points as the minimum. The final results will be shown in a radar char at the end of the questionnaire or by clicking on the "Results" button.

Figure 14 shows the "results" page. Depending on the answered questions, the user reached a final score for each life cycle phase. The chart will help to identify phases with need of improvement. To see how well the artist considered his own eco-design approach based on the chosen eco-design approach in the beginning, he / she has to click on the "Show final tips & strategies" button.

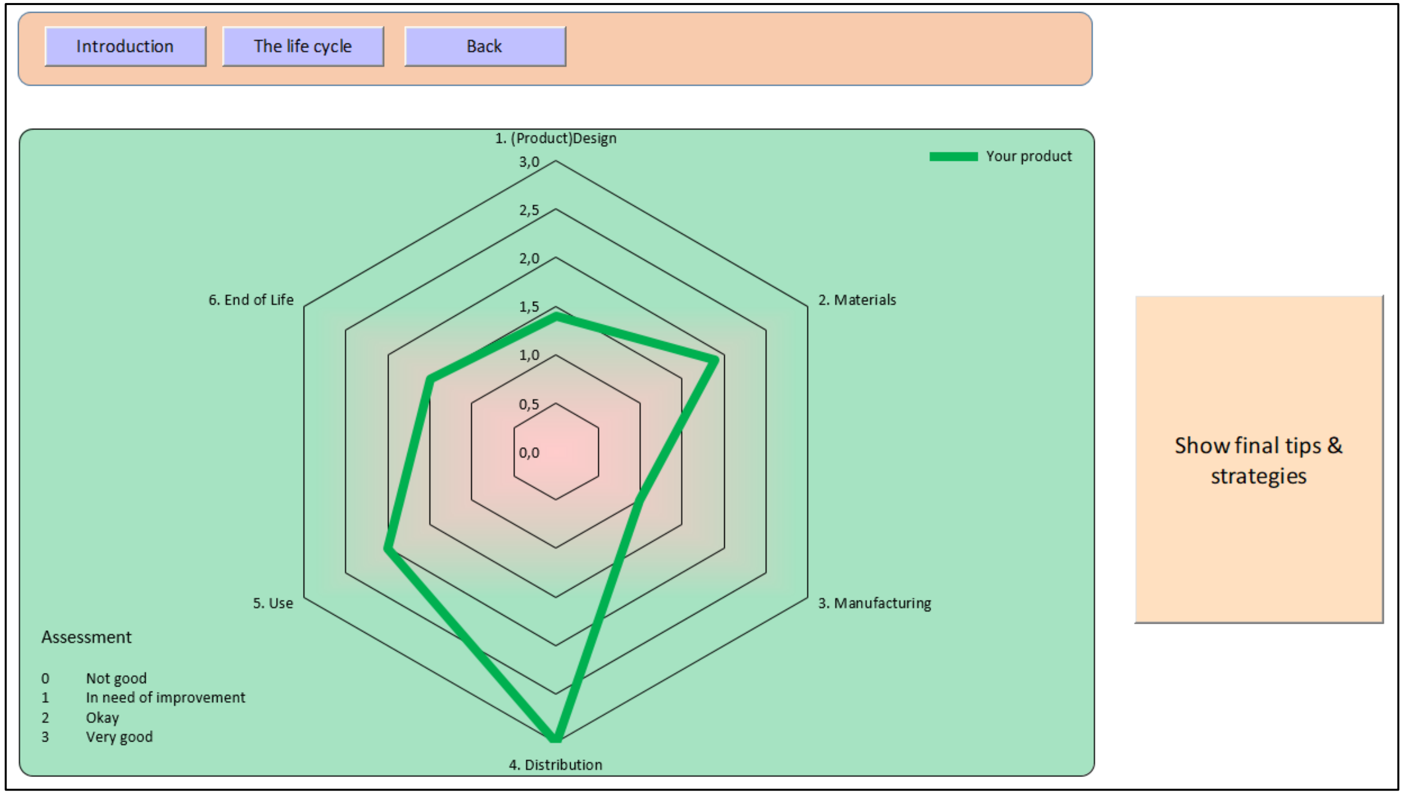


Figure 14: The results - a radar char is indicating how well the user considered environmental aspects for each life cycle phase

Figure 15 shows the final page, with those answers where the user received low points. After clicking on the “refresh” button, all the aspects with a low score will be shown. Very important are the aspects shown in the lower part under the pink header. There, all eco-design aspects are shown for which the artist received low points but have been part of his / her chosen eco-design approach in the beginning. These are the aspects related to the chosen design approach which he/she “failed” to reach. At this point, the artist should reflect on his / her creation process and identify reasons why these eco goals hasn’t been reached. The simplified eco-design process ends with this final reflection.

Introduction | The life cycle | Back

Refresh button - please click to show aspects where you received low points

Aspects, not part of your chosen design strategy

Phase	Question	Your answer	Tips, strategies, examples	Topic
3. Manufacturing	Did you had the energy consumption of your facility in mind?	Somewhat	- usage of energy efficient manufacturing processes - try to substitute high energy consuming process steps with less energy consuming processes - use a solar energy powered factory - can process steps be done manual with men power - check if manufacturing place is ISO 14001 certificated	energy and material reduction
	Is the production facility be shared with others?	Somewhat	- use something like a maker space - shared facilities can save resources, energy, space and might be beneficial for the business wise as well	
6. End of Life	Is another life cycle possible?	No	- think about potential users / companies that could reuse your product - think about easy refurbish / remanufacturing processes to enable a second life cycle	second life cycle
	Can spare parts be reused for same or other purposes?	Not at all	- try to build your product in a modularly way - think about possible new applications for spare parts	
	Does the product has toxic materials incorporated that needs to be disposed of separately?	Somewhat	- check for toxic materials in lists like ROHS or REACH - e. g. avoid brominated flame retardants	disposal

Aspects that were part of your chosen design strategy - please explain why they haven't been fullfilled

Phase	Question	Your answer	Tips, strategies, examples	Topic
2. Material	Did you avoid virgin materials?	Somewhat	- usage of recycled materials - usage of waste as resource	Env. friendly materials + recyclability
	Did you avoid scarce materials?	Somewhat	- try to avoid rare earth elements	
3. Manufacturing	Are there a lot of auxiliaries and operational materials used (water, air, oil,...)?	Somewhat	- try to substitute process steps with a high demand in auxiliaries and operational materials	energy and
	Is waste avoided during manufacturing?	Somewhat	- resmelt reject of plastic / metal manufacturing - try to increase the yield	waste
	Could waste be used as resource for other companies?	Somewhat	- sell waste to other companies that might can use them	
5. Use	Did you tried to avoid or reduce the amount of consumables?	Somewhat	- try to avoid consumables at all if its not necessary - try use less consumables if possible	consumables consumption
	Is waste generated during the use phase?	Not at all	- check if the waste can be used as product for other companies / users	

Figure 15: The final page, showing the users answers with low points.

ANNEX I Short describtion of tools

Table 3: Overview of tools

Short describtion of tool	PHASES			
	ENVISION	CO-DEFINE	CO-RESEARCH	CO-CREATE
Presentation of basic concepts and methods Short introduction of basics and methods regarding eco-design.	X			
Circular System Design: Tool to prototype circular system around a product integrating design, service, and business aspects as well as partners in order to close loops. https://sustainabilityguide.eu/methods/system-design/ https://sustainabilityguide.eu/wp-content/uploads/2018/12/Learning-Factory-Ecodesign-Manual_EN_14.pdf			X	
Circular Flows At its core, a circular economy means that products no longer have a life cycle with a beginning, middle, and end, and therefore contributes less waste and can actually add value to their ecosystem. Getting acquainted with different ways of being circular (biological and technical cycles). Checking of different loops and understanding their relevance and achievability for what you are designing. (https://www.ellenmacarthurfoundation.org/assets/design/Circular_Flows_Final.pdf)		X	X	
Circular Opportunities Making your product, service or organisation more circular can start small. Consider what you have direct influence over and start there. Keep an eye on the big picture, and as you build small successes, scale your solution over time. (https://www.ellenmacarthurfoundation.org/assets/design/Circular_Opportunities_Final.pdf)		X	X	
Brief on ○ *How does the concept transport the idea of sustainability?* ○ *Which environmental goals should be reached (e.g. reduction of hazardous substance, reduction of CO2 Emissions)?* ○ *What do we still need to find out?*		X		

Short describtion of tool	PHASES			
	ENVISION	CO-DEFINE	CO-RESEARCH	CO-CREATE
Re-FREAM EcoTool Excel tool to prioritize ecodesign approach, identify eco-design strategies and evaluate final design		X	X	X
Eco-design strategies and checklist (see ANNEX Ip 28)	X	X	X	
MECO Matrix: http://orbit.dtu.dk/files/3996106/mpu-elektronisk-uk.pdf This is a 7 step approach were one product will be evaluated. The first 6 steps isolate the environmental task and focus on identifying environmental effects. Step 7 provides a framework for an action plan and the basis for systematic integration of the proposed environmental improvements into the product development process.			X	
EcoDesign Pilot: http://pilot.ecodesign.at/pilot/ONLINE/ENGLISH/PDS/INDEX.HTM Improving an existing product by means of appropriate ECODESIGN measures. There are 5 different measures for products with different main environmental impacts.			X	
Circular Economy Toolkit - Assessment Tool: http://www.circulareconomytoolkit.org/Assessmenttool.html This toolkit provides materials to companies to help create more sustainable products, services and business models.			X	
Biomimicry: - https://www.circulardesignguide.com/post/biomimicry, - https://toolbox.biomimicry.org/methods/process/ Biomimicry is the design of products and systems that are inspired by and modelled on existing biological processes, which have feedback built in.			X	
Smart Material Choices: - https://sustainabilityguide.eu/ecodesign/materials-parts/ - https://www.circulardesignguide.com/post/materials These steps will help to make better choices about what materials go into products as well as their impact on the wider system.			X	
Open LCA databases: data on environmental impacts of different materials and processes (e.g. global warming potential in CO_2 equivalents) - Probas (German Envrionment Agency) for energy generation, materials, waste processes, acriculture processess, transprt, electronics and metals: www.probas.umweltb undesamt.de/php/index.php - PlasticsEurope Eco-profiles for polymers and semi-finished chemicals www.plasticseurope.org/en/resources/eco-profiles - Open LCA Nexus: nexus.openlca.org			X	

Short describtion of tool	**PHASES**			
	ENVISION	**CO-DEFINE**	**CO-RESEARCH**	**CO-CREATE**
Methodology for the Ecodesign of Energy-related Products (MEErP) – EcoReport Tool: https://ec.europa.eu/docsroom/documents/5309/attachments/1/translations/en/renditions/native The ErP EcoReport tool facilitates the environmental impact analysis of Energy-related Products.				X
Ecolyzer. http://ecolizer.be/ The Ecolizer is an ecodesign design tool and is aimed at all designers and companies who want to know and tackle the environmental impact of their products.				X

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ANNEX II Eco-design checklist and strategies

Table 4: Tips and strategies related to the life cycle phases

Phase		Question	Tips, strategies, examples	Topics
1.	**(Product)Design**	Is the product built in a modular way?	- design of the product in a way, that parts of the product can be changed easily, quickly and safe - upgradability of the product should be emphasized	Longevity
		Are there spare parts available on the market?	- check the market for potential sellers of parts - check if you are able to sell parts	
		Is access in a non-destructible way possible?	- avoidance of glued, welded or other permanent connections - usage of removable connections like screws or clips - provide information for an easy dismantling	
		Is it easy to access parts that likely need maintenance?	- only a few and common tools needed for disassembly - usage of common types of screws - labelling of parts - provide information for an easy dismantling	
		Is avoidance of direct contact to hazardous materials during disassembly possible?	- incorporate hazardous materials in safe casings - try to avoid usage of hazardous materials at all	
2.	**Material**	Did you de-materialize your product?	- reduction of the overall amount of material used - don't fill large volumes with unnecessary material - look at nature (biomimicry)	Env. friendly materials + recyclability
		Did you avoid virgin materials?	- usage of recycled materials - usage of waste as resource	
		Are renewable materials used?	- usage of wood, hemp, paper,… - usage of materials that can be "re-created" within a few years	
		Did you avoid materials with big env. burden (climate change)? (aluminium, concrete,…)	- try to substitute the materials with materials that are less env. Harmful - try to change certain properties of your product, to avoid these materials in the first place	
		Did you avoid scarce materials?	- try to avoid rare earth elements	

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		Did you avoid hazardous materials?	- check for toxic materials in lists like ROHS or REACH - e. g. avoid brominated flame retardants	
		Did you use long lasting materials?	- use materials that don’t fail so soon	
		Did you use recyclable materials?	- usage of recyclable plastics, metals, paper... materials in general	
		Did you reduce the number of different materials?	- use only one type of plastic / metal - use only plastics / metals that can be separated during recycling process - usage of some materials or combinations of them can hinder the recycling process - avoid those materials / combinations	
3.	**Manufacturing**	Did you have the energy consumption of your facility in mind?	- usage of energy efficient manufacturing processes - try to substitute high energy consuming process steps with less energy consuming processes - use a solar energy powered factory - can process steps be done manual with men power - check if manufacturing place is ISO 14001 certificated	energy and material reduction
		Are there a lot of auxiliaries and operational materials used (water, air, oil,…)?	- try to substitute process steps with a high demand in auxiliaries and operational materials	
		Is the production facility be shared with others?	- use something like a maker space - shared facilities can save resources, energy, space and might be beneficial for the business wise as well	
		Is waste avoided during manufacturing?	- re-smelt reject of plastic / metal manufacturing - try to increase the yield	waste
		Could waste be used as resource for other companies?	- sell waste to other companies that might can use them	
4.	**Distribution**	Did you try to avoid long distances between material extraction, production and consumer?	- centralized place for resources, manufacturing and sell	transport
		Did your transport companies act env. friendly?	- does the means of transportation use green or renewable energy sources - check if delivery chain is ISO 14001 certificated	
		Is the transport organized efficiently?	- use the whole space of transportation vehicles - adapt clever stacking to reduce unused volume	

		Did you consider your packaging material?	- try to avoid packaging material as much as possible -> every packaging material is a product for itself(!) - try to reduce weight and volume - use reusable packaging material - use less packaging material or use material from renewable resources (wood, paper, carton, …) - use recycled / recyclable plastics as packaging materials	packaging
5.	**Use**	Did you try to reduce the energy consumption?	- try to avoid electrical energy at all if it's not necessary - implement less energy consuming parts into your product	energy consumption
		Is the product consuming renewable energy?	- try to power the product self-sufficient with a solar panel	
		Does the product have a switch off button / energy saving mode?	- implement some sort of switch off button or energy saving mode for idle times	
		Did you try to avoid or reduce the amount of consumables?	- try to avoid consumables at all if it's not necessary - try use less consumables if possible	consumables consumption
		Did you check for env. friendly consumables?	- try to substitute consumables with env. friendly consumables	
		Is waste generated during the use phase?	- check if the waste can be used as product for other companies / users	
6.	**End of Life**	Is another life cycle possible?	- think about potential users / companies that could reuse your product - think about easy refurbish / remanufacturing processes to enable a second life cycle	second life cycle
		Can spare parts be reused for same or other purposes?	- try to build your product in a modularly way - think about possible new applications for spare parts	
		Is the product recyclable?	- usage of recyclable plastics, metals, paper... materials in general - label material of parts	disposal
		Does the product has toxic materials incorporated that needs to be disposed of separately?	- check for toxic materials in lists like ROHS or REACH - e. g. avoid brominated flame retardants	
		Is a safe disposal possible?	- check if reuse or recycle is possible - check if the product can be landfilled or incineration in a safe way	

ANNEX III Eco-design Strategy Wheels

Lifecycles

Design
Human-centred design approach to understand the users needs and environmental impact. Define the problem By looking at the whole system - Lifecycle thinking.

Materials & Parts
Use of fewer components, parts and materials. Recycled, greener and long lasting materials. Removal of hazardous substances. Reduce material and energy consumption throughout the lifecycle.

Manufacturing
Optimized processes to minimize negative environmental impacts; Conserve energy and natural resources. Remanufacturing improvement around assembly, reparability and disassembly. Industrial symbiosis.

Product
Design for Longevity and Trust. Durability, easy maintenance and reparability. Modularity for upgradeability, standardization & compatibility.

Distribution
Optimization of distribution systems & transport infrastructure. Reusable packaging. Reduced package waste. Full circle supply chain.

Sales & Marketing
Circular economy business models. Product life extension. Portfolio planning. Lease-rent-share. Sustainable Retail.

Use
Design for ease of maintenance, reparability, upgradability and adaptability. Efficiency in use and maintainability. Optimization of initial lifetime. Reuse, second life.

End of life
Optimization of end-of-life systems. Takeback programs. Recovery & recycling. Waste management. Design for Dis- and Reassembly. Dematerialization. Up-cycling. Reverse logistic.

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Design

1. Start with People - design for purpose
Apply Human-centred design approach to understand the users needs and behaviour. Discover user motivations, challenges and desires. Identify network partners and understand their needs.
Clarify and simplify the functions and make it valuable and desirable.

2. System Design
Start with the system. Look at the systemic full life cycle impacts. Design for circular value and supply chains. Define the problem by looking at the whole system+ Lifecycle Thinking. Waste: designing it OUT from the start. Design for longevity, modularity, reparability, upgradability, compatibility, recyclability.

3. Design & Innovation-New concept development
Think new ways to use and reuse the product already in the design phase in product and service design. Solving sustainable challenges stimulates new eco-innovations. Technical, material and social innovations for closing the lifecycle loops.

4. Digitalization (→ service/ product)
Incorporate digital technology. Open innovation platforms. Collaborate to create joint value. Track and optimize resource use and strengthen connections between supply chain actors through digital, online platforms and technologies.

5. Rethink the business model
New Circular Business model innovations. Build on the interaction between products and services – product as a service. Discovering economic business models, and understanding societal behavior.

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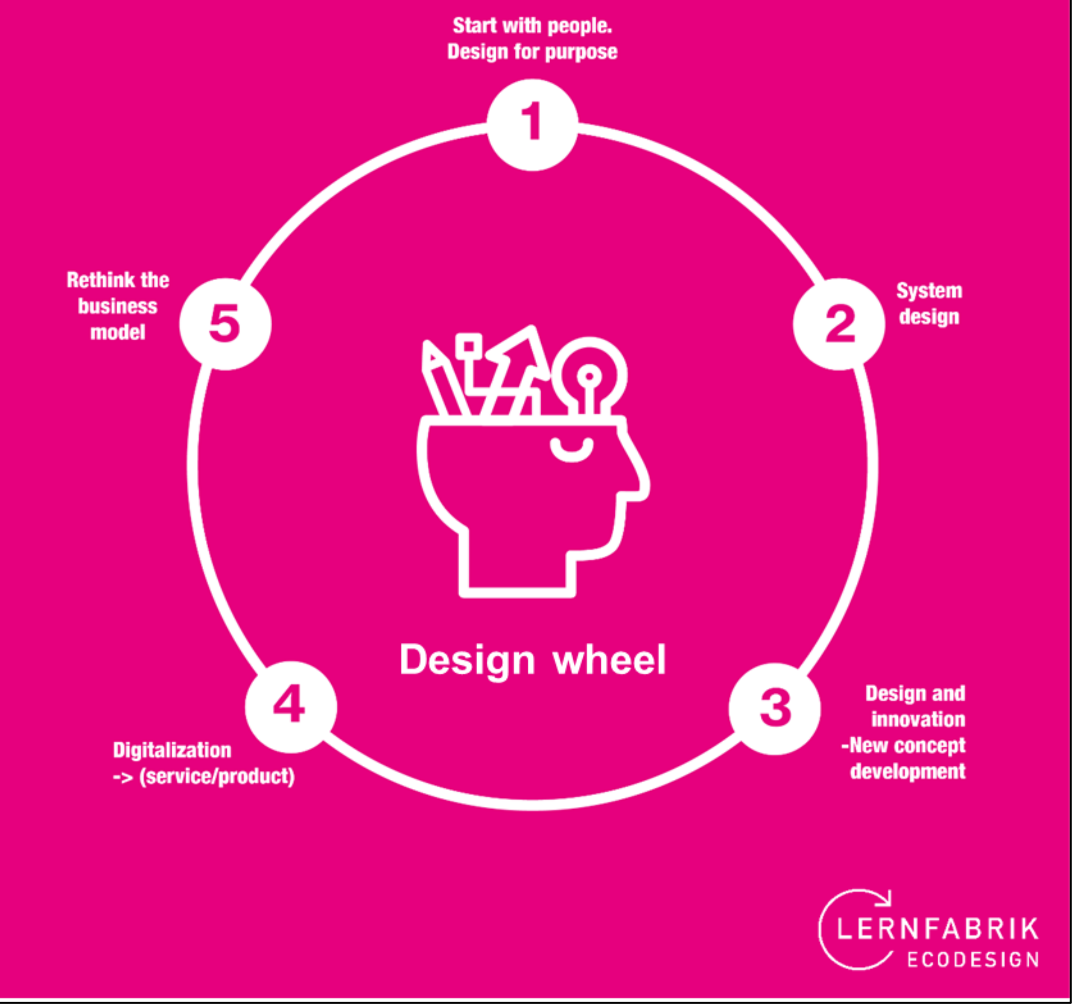

Material

1. Use of smart, greener materials

Renewable, recycled materials. Designing for use of materials that have a lower environmental impact in manufacturing, use or disposal. Design for recyclability.

2. Use of fewer materials, components & parts

Modularisation/ standardisation Designing to reduce the materials required to create a product. Reduction of material usage and reusing components. Labelling to identify materials. Reduce of raw material.

3. Material properties

Use stronger long lasting materials- gracefully aging. Light weight, reduction in weight and size. Durable, indestructible structures. Shock, water, dustproof.

4. Material health

Clean materials, removal of hazardous substances. Safe in manufacturing and use.

5. Low energy content materials

Use components with low energy consumption throughout the lifecycle also in use.

6.Sustainable manufacturing

Smart production techniques. Reduce complexity. Optimised supply chains, reduction in (transport) volume.

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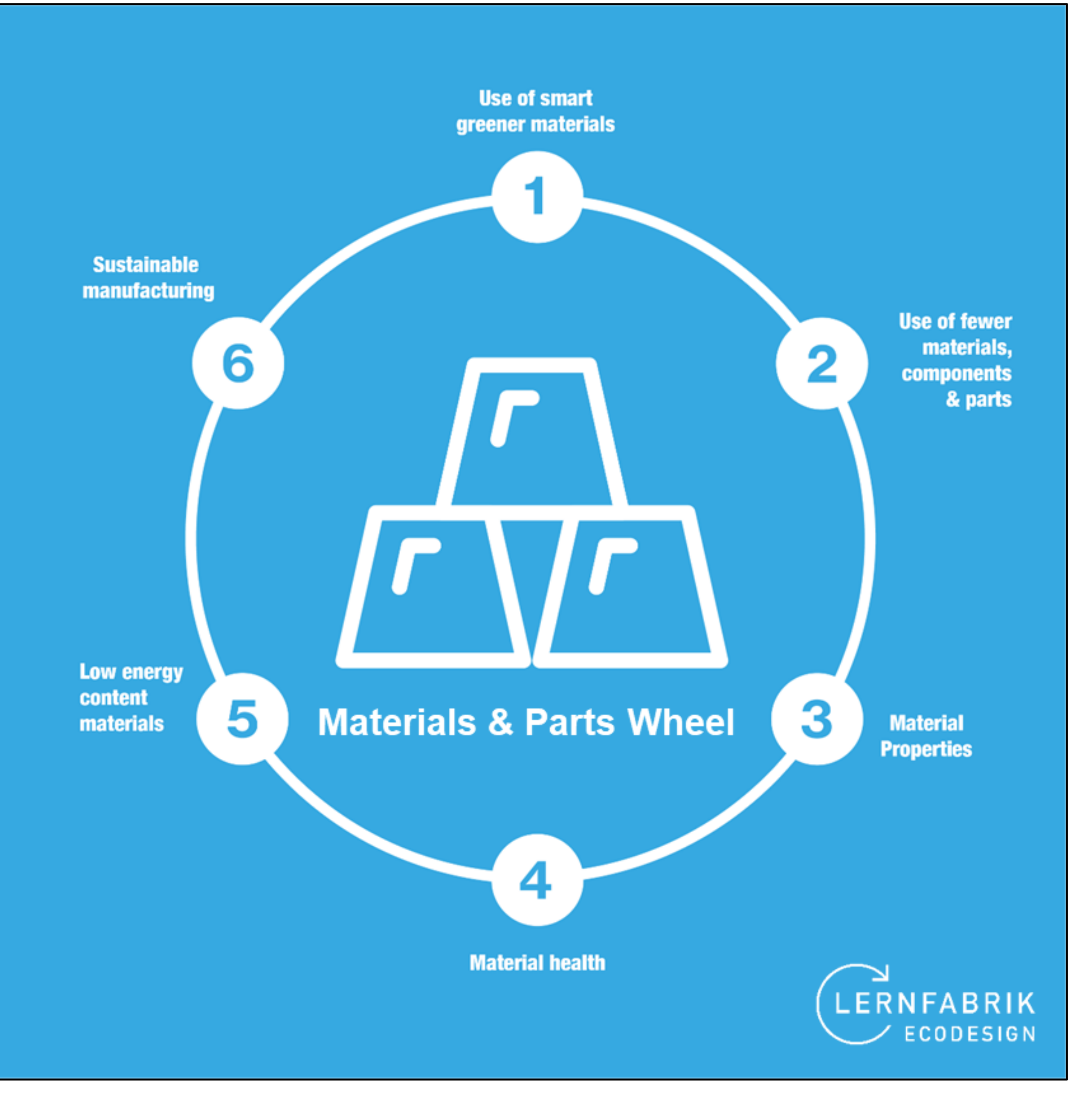

Manufacture

1. Sustainable manufacturing

Optimized processes that minimize negative environmental impacts; conserve energy and natural resources it also enhances employee, community, and product safety.

2. Optimization of production processes and techniques

Lean optimized production methods and operations by continuously improving performance. production quality control, fewer production steps. Manufacturing innovations, IOT, automatization, 3D print. Lower production and labor costs and greater efficiency.

3. Increased energy efficiency

Low/ clean/ renewable energy consumption. Minimize energy use in production.

4. Producing less pollution, emission and waste

lower waste disposal costs. Cleaner and safer working environment.

5. Industrial symbioses

Industrial symbiosis emulate sustainable natural cycles in industrial networks, where all discarded materials from one are resources for others to use. 'Industry 4.0' production systems prototyping new manufacturing setup.

7. Design for Remanufacturing

Disassemble it into useful parts that can be directly reused in another product. Improvement around assembly, reparability, refurbishment and disassembly.

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Product

1. Design for Product Attachment and Trust

Creating products that will be loved, liked or trusted longer. Timeless classic design. Practical – fit to purpose and what people need. Enhanced personalization. Optimization of initial lifetime.

2. Design for Longevity

Design for easy maintenance, reparability, with a strong consumer-manufacturer relationship, Developing products that can take, wear and tear without breaking down. Design for Durability- products that last longer.

3. Modular Design

The modular design of product, facilitated by an open source approach. Modular and reusable, they are also modifiable. Embrace open source modularity, and drive the transition to a circular economy.

4. Design for Standardization & Compatibility

Creating products with parts or interfaces that fit other products as well to bring longevity into product but also flexibility. Future Upgradability and compatibility to past.

5. Design for dismantling

Design for disassembly, deconstruction and reparability. Reversible interconnection technologies, e.g. screws better than glues. Labeling the parts.

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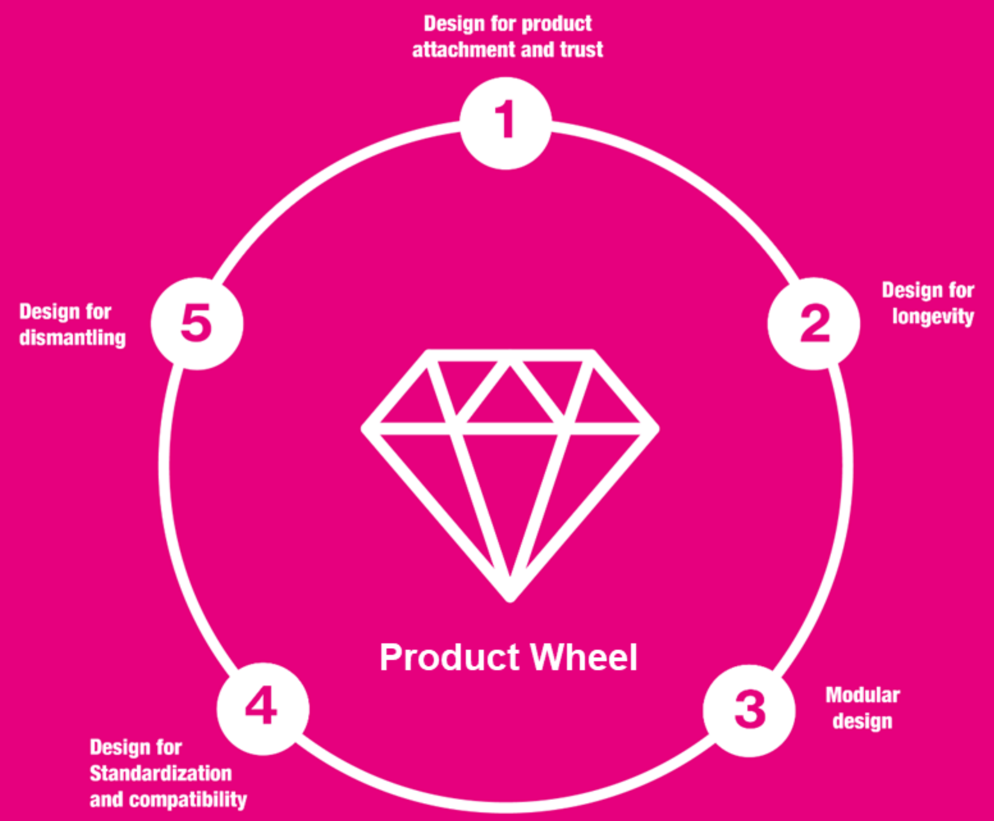

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Distribution 1

1. Sustainable distribution

Improved logistic transportation / hauling of goods between vendor and purchaser with lowest possible impact on the ecological and social environment, and includes the whole distribution process from storage, order processing and picking, packaging, improved vehicle loadings, delivery to the customer or purchaser and taking back packaging.

2. Optimizing transport infrastructure

By local manufacturing and distribution the distance that products travel can be reduced. Localized supply chains, shifting from roads to rail or from air to sea. Optimizing vehicle loads and implementing intelligent transportation management systems. Future cleaner energy efficient & flexible transportation modes. Near zero emission trucks, electronic cars, drones, autonomous cars.

3. Sales and Marketing

Green marketing to generate and increase sustainable purchasing. Differentiate your business "*Sustainability is quality that gives your customers a better experience*" story telling. Sustainable retail and point of sales.

4. Full circle supply chain

Collaboration with supply chain is critical – both up and downstream. Thinking whole supply chains, value chains and new business models. Reverse logistic reclaiming used packaging as well as unsold and end-of-life products that have to be disposed in order to make materials and components available for recycling or reuse.

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Distribution 2

1. What kind of packaging is needed?
Understand the needs of customer, sales, transportation whole supply chain. Take in to account function and brand.

2. Select the right materials
Reduce - minimize and optimize packaging materials. Reduced package waste. Use recyclable lightweight materials, biodegradable, compostable materials, renewable resources. Avoid mixed or composite materials? Check material contamination (toxicity).

3. Reduce components in packaging
Remove - eliminate unnecessary packaging, extra boxes or layers. Do product need Primary, secondary and transportation packaging? Reduce use of material, weight, size and dimensions.

4. Re-use
Use materials over and over when economically feasible. Re-use packaging. Can same package use with other products? Make packaging functional and valuable for additional use e.g. store some accessories, parts.

5. Innovation
New emerging materials and technologies. Functional Package as a product e.g. Puma shopping bag. Smart packaging e.g. IoT trackable.

6. After use
Reuse – Packaging. Recovery and recycling materials. Energy recovery. Packaging can be folded together to save space.

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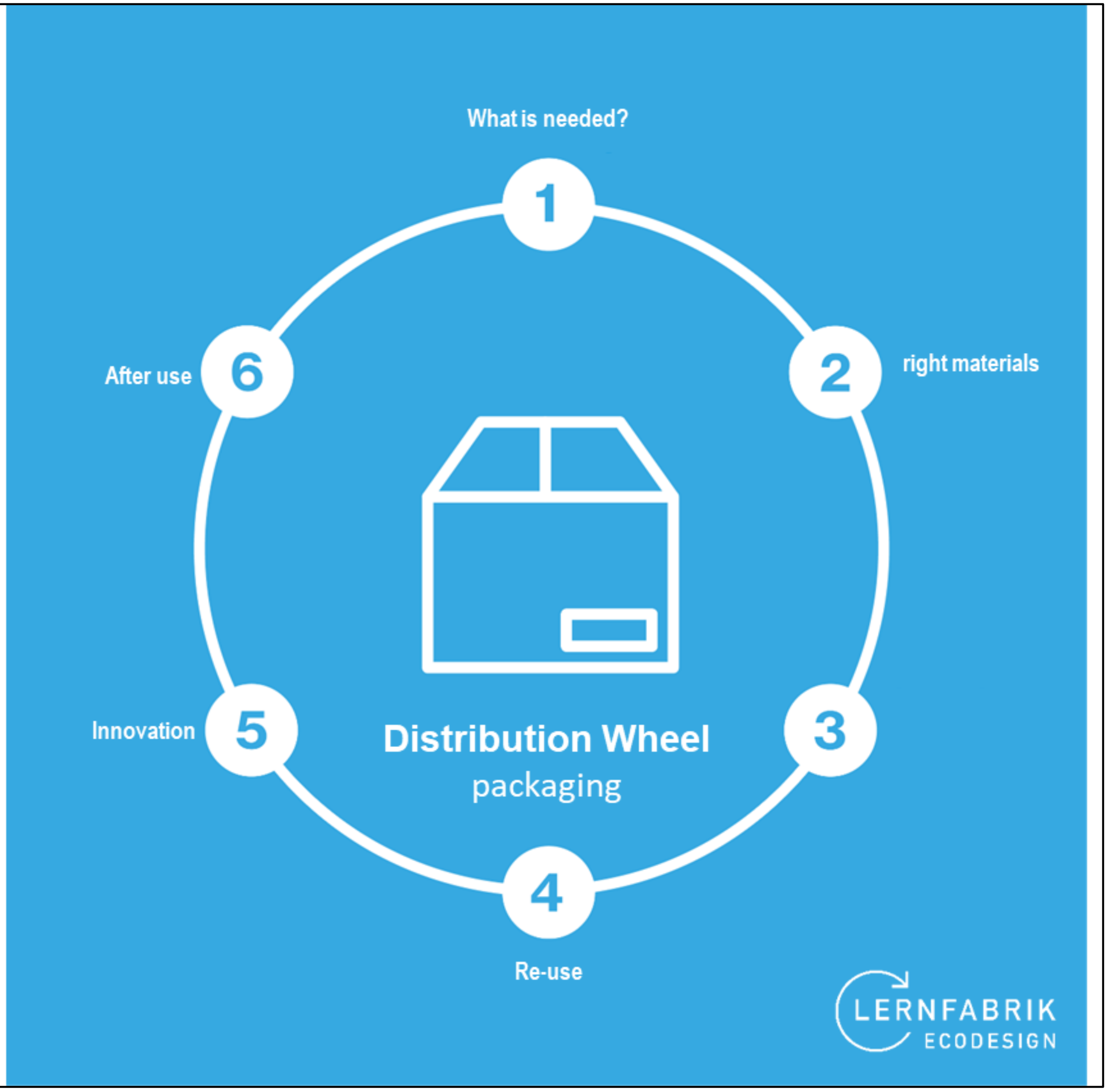

Use

1. Persuasive design

Understand how you can increase people's ability and motivation to behave sustainable.

2. Design for ease of maintenance and repair

Optimization of initial lifetime by offering extended-life products that are multifunctional, easy to maintain and repair. Optimizing the function of products and ensuring most suitable service life.

3. Efficiency in use

Designing products that require less resources during operation. Energy efficiency- a major source of environmental impact is the energy consumed by a product during its use. Ensuring that products use fewer resources cause less waste and pollution when they are used by end customers.

4. Design for Upgradability & Adaptability

Allowing for future expansion and modification. Product life extension- keeping alive and relevant (modernization). Personalization.

5. Product as a service. Product life extension- lease – rent- share

Sharing platform, renting, swapping, collaborative consuming, cloud computing etc. Product as a service- service based business models.

6. Reuse

Second life, alternative use of product, e.g. old phone as burglar alarm. Second hand markets.

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End of life

1. Recyclable materials

Designing using organic, recyclable, renewable, non-toxic, reusable materials. Processing at the point of recycling.

2. Design for Dis- and Reassembly

Ensuring products and parts can be separated and reassembled easily. Design for quick disassembly into separate components for faster processing at the point of recycling.

3. Design for End-of-Life-collection and take-back programs

Eco-labeling and guidance how to recycle and dispose.
Use prepaid return shipping labels.

4.Full circle supply chain

Thinking whole supply chains, value chains. Closed loop industry with Industry symbiosis.

5. Up-cycling

Transforming by-products or waste materials, into new materials or products of better quality or for better environmental value. Reverse logistic.

6. End of life-waste

Recovery and recycling - waste management and energy recovery. Optimize recycling routes for high recycling and recovery rates. Keep track of waste, avoid illegal export.

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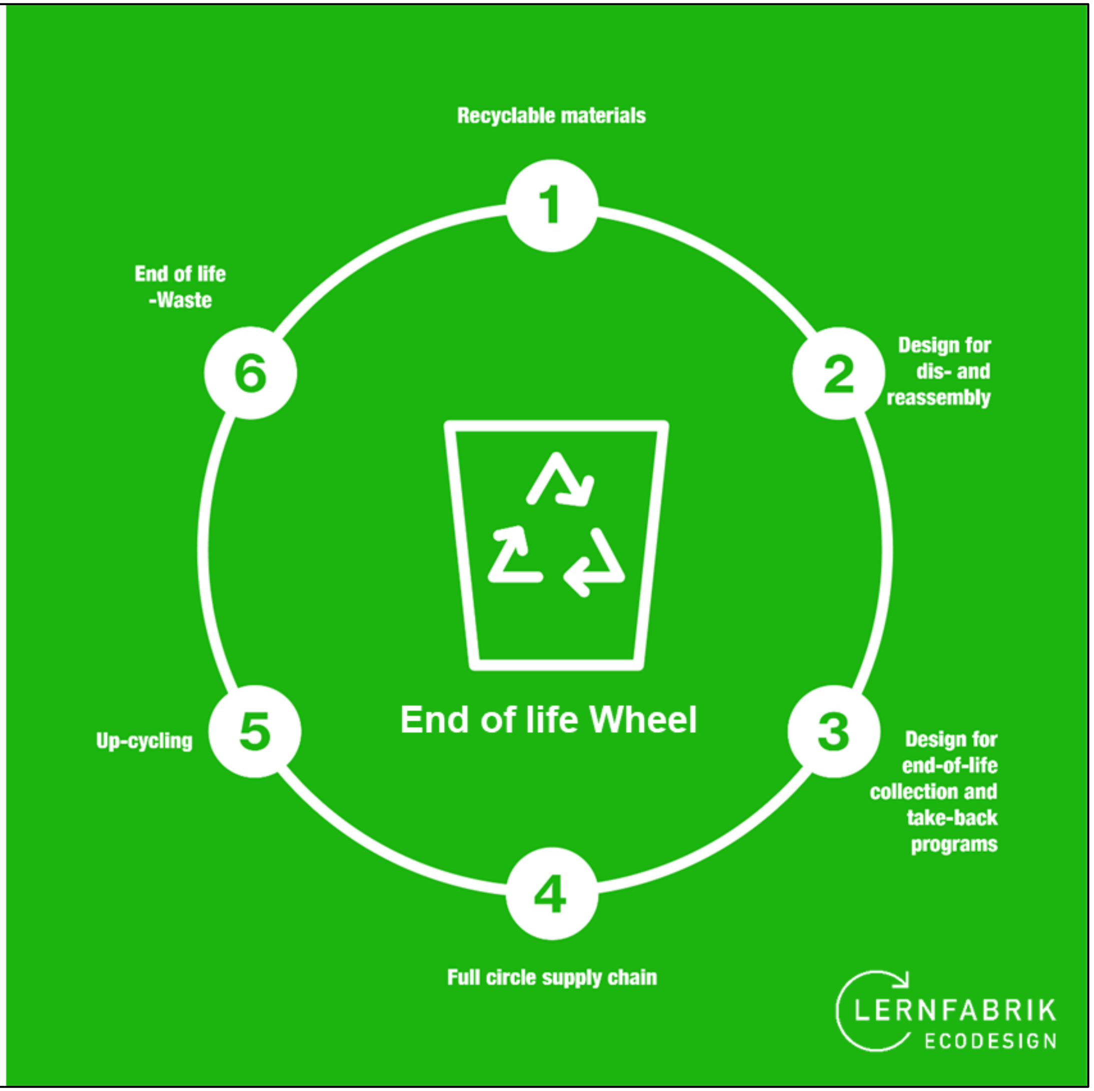


Business Models

1. Provide and Perform
Providing the capability or services to satisfy user needs without needing to own physical products

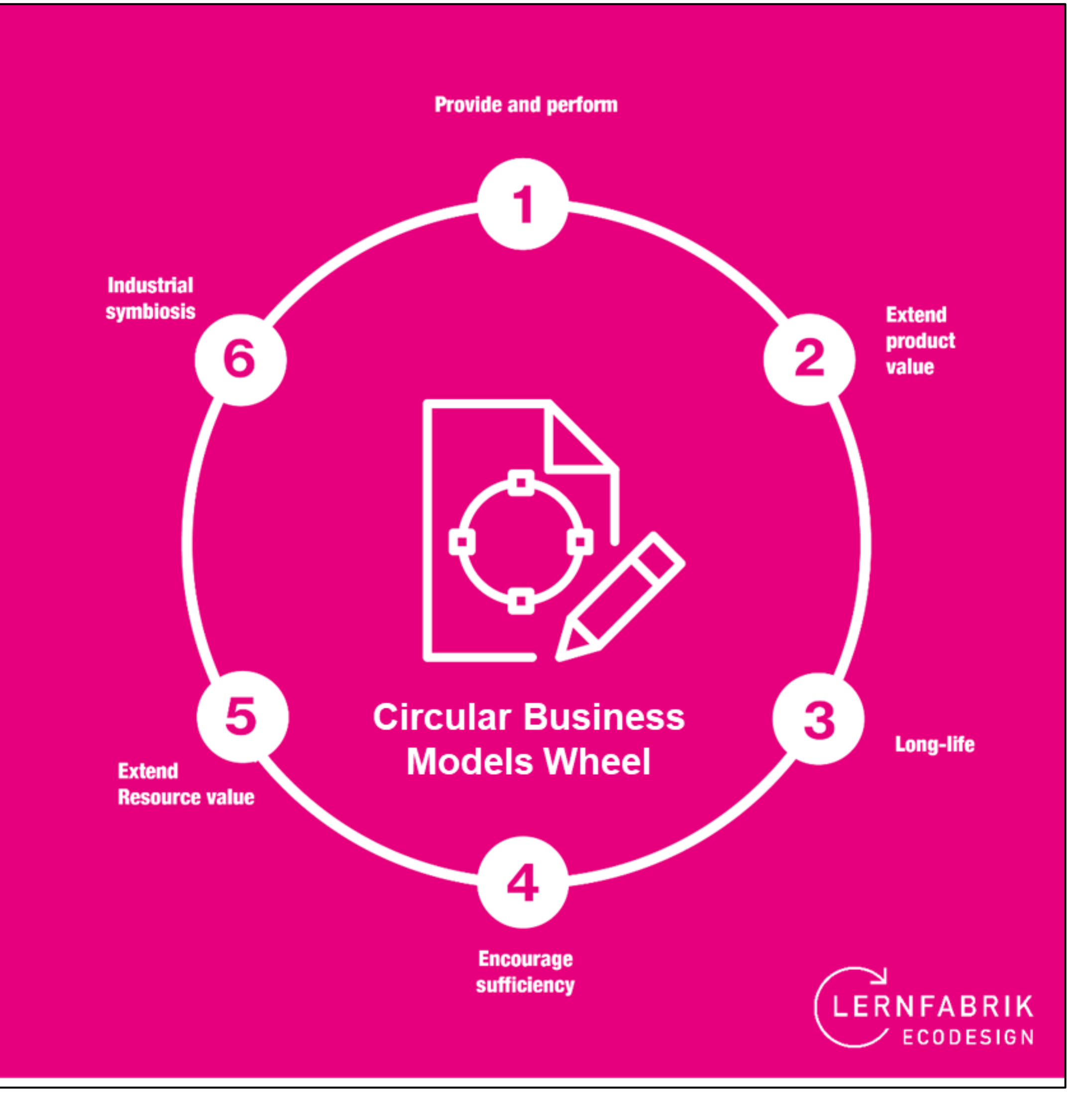
2. Extend product value
Exploiting residual value of products – from manufacture, to consumers, and then back to manufacturing – or collection of products between distinct business entities

3. Long-life
Business models focused on delivering long-product life, supported by design for durability and repair for instance

4. Encourage sufficiency
Solutions that actively seek to reduce end-user consumption through principles such as durability, upgradability, service, warrantees, reparability and a non-consumerist approach to marketing and sales

5. Extend resource value
Exploiting the residual value of resources: collection and sourcing of otherwise “wasted” materials or resources to turn these into new forms of value

6. Industrial Symbiosis
A process-oriented solution, concerned with using residual outputs from one process as feedstock for another process, which benefits from geographical proximity of businesses



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