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PRODUCT DESIGN AND
RESOURCE SCARCITY

PRODUKTGESTALTUNG DER RESSOURCENKNAPPHEIT

Bachelorthesis Produktgestaltung and der
Hochschule für Gestaltung Schwäbisch Gmünd
von Jan Sagasser und Raphael Jung.

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Bachelor thesis Product Design at the
University of Applied Sciences Schwäbisch Gmünd
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Produktgestaltung ist beeinflusst durch Faktoren der Umwelt, der Kultur sowie der immer neuen Bedürfnisse, hervorgerufen durch die voranschreitende Technologisierung. Sie ist eine Disziplin im stetigen Wandel.
Ein Wirkungsbereich des Designs ist dabei auch das Feld der elektronischen Konsumprodukte, in dem, mit zunehmender Komplexität der Produkte, in den vergangenen Jahren die Reparier- und Recycelbarkeit stetig abnahm.
Die Folgen für die Umwelt werden dabei spätestens bei der Entsorgung dieser sichtbar. Nicht nur, dass die Entsorgung, wenn korrekt durchgeführt, wie auch der gesamte Herstellungsprozess sehr energieaufwendig ist, auch dass durch eine Herstellung, bei der nicht auf die Rückgewinnung wertvoller Rohstoffe geachtet wird, solche Prozesse äußerst komplex sind. Wodurch ein Großteil des Elektroschrotts nicht fachgerecht recycelt wird, sondern auf Deponien endet oder in andere Länder exportiert wird, in denen die Auflagen für die Entsorgung andere oder erst gar nicht existent sind.

Dazu wird ein Thema in den letzten Jahren und in 2022 durch den Ausbruch des Krieges in der Ukraine zunehmend relevanter: Die Abhängigkeit von fossilen Brennstoffen und des hinsichtlich der Umweltbelastung immer dinglicher werdenden Wandels hin zu erneuerbaren Energien, um einerseits die Ziele des Pariser Klimaabkommens zu erreichen und um andererseits auf die bevorstehende Erschöpfung der Erdöl- und Erdgas-Quellen vorbereitet zu sein. Dieser Umstieg bedarf jedoch genau der kritischen Rohstoffe, die in den meisten Elektronikprodukten verbaut sind und bei denen es sich ebenso um endliche bzw. schwer zugängliche Rohstoffe handelt.

Product design is influenced by environmental factors, culture and the ever-changing needs brought by the ongoing technological development.
It is a discipline in constant change. One area influenced by design is the field of electronic consumer products, in which the reparability and recyclability of products has steadily decreased in recent years as their complexity has increased.
The consequences for the environment become apparent at the latest when the products get disposed. Not only is disposal, if carried out correctly, very energy-intensive, but the entire manufacturing process is extremely complex due to a production process that does not take into account the recovery of valuable raw materials.
As a result, a large part of e-waste is not recycled properly, but ends up in landfills or is exported to other countries where the requirements for disposal are either different or non-existent in the first place.

In addition, one issue has become increasingly relevant in recent years and in 2022 with the outbreak of war in Ukraine: The dependence on fossil fuels and the increasingly urgent shift towards renewable energies in terms of environmental impact, in order to achieve the goals of the Paris Climate Agreement on the one hand and to be prepared for the imminent exhaustion of oil and natural gas sources on the other.
However, this change requires precisely the critical raw materials that are built into most electronic products and which are also finite or difficult to access.

Es muss ein Umdenken stattfinden, in dem vollumfänglich hinterfragt wird, wie Produkte gestaltet sind, um in einer Zeit, in der die Rohstoffe, die uns alltäglich umgeben, knapp werden. Auch wie sich das Konsumverhalten der westlichen Welt entwickeln muss, um nicht nur selbst einen nachhaltigeren, ressourcensparenderen Lebensstil zu erreichen, sondern auch um eine Vorbildrolle einzunehmen.

In dieser Arbeit werden die Ereignisse der Vergangenheit und die Entwicklungen, die zur gegenwärtigen Situation führten, ausführlich beleuchtet, um die Nachvollziehbarkeit des von uns erstellten Designguides zu gewährleisten.
In diesen Guidelines wurden Maßnahmen aufgelistet, die bei der Gestaltung von elektronischen Konsumgütern, im Zeitalter der Ressourcenknappheit, höchst relevant sind. Zudem wird dargelegt, wie die Anwendung dieser auf konkrete Produkte aussehen kann und welche Denkprozesse und Entscheidungen den resultierenden Produkten zugrunde liegen.

We need to change the way we think about how products are designed in order to be more sustainable at a time when the raw materials that surround us every day become scarce. We also need a change in consumer behaviour in the western world, not only to achieve a more sustainable, resource-efficient lifestyle ourselves, but also to set a good example.

In this thesis, the events of the past and the developments that led to the current situation are examined in detail in order to ensure the comprehensibility of the Design Guide we have created. These guidelines listed measures that are essential in the design of consumer electronics in the age of resource scarcity.
It also explains how to apply these to concrete products and which thought processes and decisions underlie the resulting products.

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PROBLEM ANALYSIS

RESOURCES

1

The following section of the problem analysis relates specifically to the role of resources in the megatrend of resource scarcities.
This section discusses the importance of resources, resource scarcities, and the resources affected concerning electronic consumer goods. Previous developments and the current state of the relevant factors are considered.

1.1 HUMANS AND RESOURCES

Resources are essential for the existence of humans and every other species.
We require oxygen to breathe, water to drink, food to eat, and space to inhabit.
The development of the human species is closely linked to the discovery and use of materials.

The first use of tools by human ancestors is believed to have occurred 3.3 million years ago, in the Stone Age (Gimbutas, 2022).
The following ages of humanity were the Bronze Age and Iron Age - the foundation of the development of humankind - named after materials.
In the late 20th century, humanity arrived with the digitalization of the globe in the Silicon Age.
Modern life depends on products, systems, and infrastructures that would not function without silicon metals.Although resources have such an existential role for humanity and are therefore of such great value, our use of them is an exploitative one. In the development of not only reaching the top of the food chain but also gaining more and more control over resources, humanity not only drove species into extinction but is also responsible for the destruction and degradation of nonrenewable resources. Our current and most likely future behavior results in the same impacts. As is stated in ‚The globalized thought process in relation to natural resources‘ by Swing, short-term economic demands have come to take priority over nearly all other long-term aspects of our existence (Swing, 2019, p.1).

The disintegration of our ecosystem is progressing faster with a growing population and increasing consumption. In 1950, the world population was estimated at around 2.6 billion people (United Nations, n.d.). In 2022 over 7.9 billion people will inhabit the world (World Population Review, 2022). Additionally, the world GDP in 1915 was around 4,7 trillion US dollars; a hundred years later, it was already at around 108 trillion US dollars (Roser, 2013). These developments have resulted in high demand for resources, and it can be assumed that this development will not depart in the near future.

Fig.1 Flint

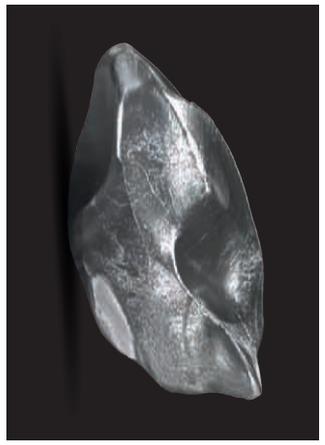


Fig.2 Indium

1.2 MEGATREND RESOURCE SCARCITY

Having an exponential population and economic growth while being faced with limited resources will inevitably lead to system failure if nothing is changed.
Due to the abovementioned factors, humanity is experiencing the megatrend of resource scarcity. Megatrends are global, profound, and long-term developments with significant impacts on ecology, politics, society, economy, and technology (Evolutionizer, n.d.). Resource scarcity is one of them. In the report ‚Narratives of scarcity: Framing the global land rush' Scoones et al. (2019) present three framings of scarcity:

Absolute scarcity (1) The understanding of absolute scarcity, mainly proposed by ecological economists, resource economists, and demographers, is that an unchangeable physical limitedness of raw materials faces increasing demands of humanity.
It is argued that the increasing impacts of human activity are more substantial than the capabilities of our natural environment.
As predicted in the Club of Rome's report ‚Limits to Growth' by Meadows et al. (1972), the result will be a ‚rather sudden and uncontrollable decline in both population and industrial capacity' (Meadows et al., 1972, p.23). This understanding of resource scarcity is that resource scarcity is inescapable, physical, and real (Scoones et al., 2019).

Relative scarcity (2) This framing understands scarcity as something relative. Society has economic, institutional, and technological responses in the face of scarcity. Relative scarcity is mainly proposed by agricultural, new institutional, and neoclassical economists (Scoones et al., 2019).
It is suggested that scarcity is relative to demand. Limits in resource availability can be compensated through science, economy, technology, and innovation.
The source of the problem is not a lack of physical availability but underproduction (Scoones et al., 2019).

Political scarcity (3) The third framing, ‚political scarcity', is mainly proposed by political ecologists, economists, and sociologists. Political scarcity is considered artificially made and perceived to suit particular interests (Scoones et al., 2019). Geographically limited resource availability, relations of power, and historical inequalities affect resource distribution, with ‚real winners and losers in the resource struggle' (Scoones et al., 2019, p.223).
An example is China's long-term strategy for controlling natural resources, which resulted in a strong dependency on China over critical natural resources (Kuo & Tang, 2015). A current example of the usefulness of such dependencies is seen in the Russia-Ukraine conflict. The EU's dependency on raw materials from Russia required for the Energy production, limits the scope of action in terms of even stricter sanctions.

1.3 MATERIALS IN CONSUMER ELECTRONICS

Consumer electronics consist of three main elements: The enclosure, the skeleton, and the electronic components (screen, battery, motherboard, ...). Some have additional elements, e.g., the stand of a monitor or the keys on a keyboard.

The enclosure: The enclosure has four main functions. It isolates the electronics inside, protects the electronics, e.g., from physical impacts, water, and dirt, provides portability, and forms the outside shell, thus defining the appearance and haptics. There are four main manufacturing options, each of which specifies a material selection (Ye, 2020):

CNC milling: This manufacturing option allows for precise and highly complex shapes, with the downside being relatively slow and costly. Materials commonly used for electronic enclosures are:

1. Aluminum
2. Steel
3. Stainless steel

Injection molding: This method is used to mass-produce simpler plastic enclosures. It is suitable for versatile shapes and is a ubiquitous production method. Its downside is the high starting investments in tools, which only pay off when used for mass production. Materials commonly used in this method are:

1. ABS
2. Polycarbonate
3. Acrylic
4. TPE

Sheet metal forming: This method is affordable and allows the production of durable and easy-to-make electronic enclosures. Its downside is the limited options in in terms of its aesthetics and haptics. Materials commonly used in sheet metal forming enclosures are:

1. Aluminum
2. Steel
3. Stainless steel

3D printing: This method is currently not suitable for the production of larger quantities. It is practical and cheap option to produce one-off products. Materials commonly used in 3D printing enclosures are:

1. ABS
2. PLS
3. Polycarbonate

The skeleton is in the interior of the enclosure and holds the electronic components in place. In many products, the skeleton is already included in the enclosure. Plastic or suitable steel for higher stability requirements is usually used depending on the application.

Electronic components vary depending on the type of product. Examples include screens, touch screens, batteries, sensors, and antennas. These parts are often recyclable and contain rare materials with high economic and societal value. The EU lists such materials as critical raw materials (CRM).

1.4 CRITICAL RAW MATERIALS (CRM)

The Critical Raw Materials (CRM) are a selection of raw materials grouped by the European Union. These materials are of high strategic and economic importance for the European economy and at risk in concern to their supply (Bonollo & Ferro, 2019).

Not only are they used across all industries and supply chain stages, but they are also critical for sustainability-linked technology required to tackle our climate crisis (e.g., energy storage) (European Commission, n.d.). The current development of new technology results in a growing number of materials required for our consumer electronics production.

Fig.3 Bayan-Obo-Mine

The two main parameters used to analyze the criticality of materials for the European Union are the economic importance and the supply risk (European Commission, n.d.). The economic importance of a material is the added value of that material for EU manufacturing sectors and economic importance, in concern to end-use applications.

Additionally, the economic importance parameter includes the performance of substitutes for these materials.

The parameter ‚supply risk' reflects which concentration of raw material producing countries source these, considering trade aspects and their governance performance (European Commission, n.d.). As of 2020, 30 raw materials are considered critical. The following materials are part of that selection (European Commission, n.d.):

Antimony
Baryte
Bauxite
Beryllium
Bismuth
Borate
Cobalt
Coking Coal
Fluorspar
Gallium ›

Germanium
Hafnium
Heavy Rare Earth Elements
Light Rare Earth Elements
Indium
Lithium
Magnesium
Natural graphite
Natural rubber
Niobium
Platinum Group Metals
Phosphate rock
Phosphorus
Scandium
Silicon metal
Tantalum
Titanium
Tungsten
Strontium
Vanadium

Since its first mention, the list of CRMs has been extending over time. In 2014, 17 materials were considered critical raw materials; in 2020, the number rose to 30 materials (Deloitte Sustainability et al., 2017). This development - driven by our consumption behavior - displays the need for a trajectory change in our relations and actions towards resources.

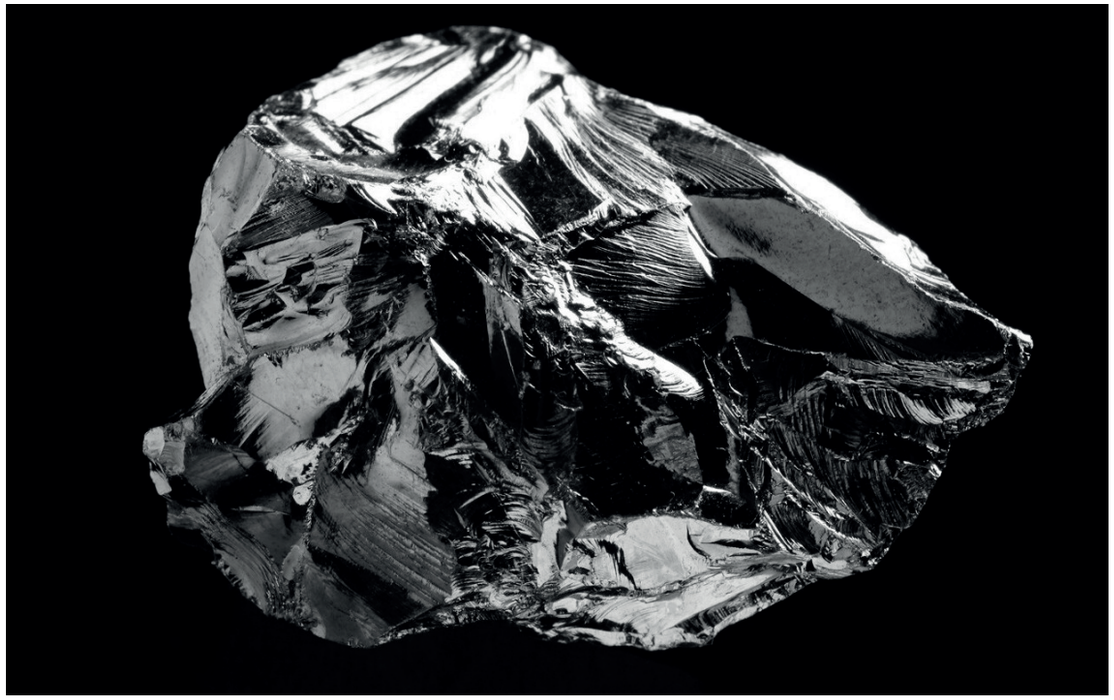


Fig .4 Silicon

1.4.1 IMPORTANCE FOR SUSTAINABILITY TRANSITIONS

Additionally to the already existing supply risks and economic importance, a high quantity of critical raw materials is essential to complete necessary sustainability transitions, e.g., the transition towards more environmentally friendly energy production (the so-called energy transition).

Dolega et al. (2021) state that until 2050, the demand for lithium could, due to the use in car batteries, face a 45-fold increase, and the demand for cobalt, a 15-fold increase, and nickel, could increase by four times. This is just one example of the rising demand for CRMs due to their use in green technology.
This underlines the urgency to manage the usage of these resources strategically.

1.4.2 STRATEGIES

In order to transition towards a more sustainable system, ‚migrating actions' , as talked about by Bonollo and Ferro (2019), are required in concern to the sourcing, the usage, and the end-of-life management of CRMs.
The use of these materials needs to be reduced; if possible they should be substituted by noncritical materials and recycled at the end of their life as an element in a product.

Behavior changes (1) Changing our behavior towards less consumption, better caring for and repairing products, and properly disposing of them at their end of life can significantly impact our demand for CRMs. Other behavior changes with an impact are, e.g., the making of conscious decisions on which products to consume and which services to use.

Substitution (2) In some applications, CRMs can be replaced with other materials without losing their function. An example is the substitution of natural graphite with synthetic graphite in batteries. A substitution can have side effects with a strong negative impact, e.g., the production of synthetic graphite requires a high amount of energy (Dolega et al., 2021).

Material efficiency (3) Decreasing the use of CRMs by using them more efficiently in products. Material efficiency is usually pursued in the development phase of products due to its close link to economic efficiency (Dolega et al., 2021).

Innovation (4) Innovations that improve the sourcing and processing of CRMs can reduce the amount required to fulfill the demand still. This option might create unintended and opposing side effects. Dolega et al. (2021) give the example of an improved energy density in power tools, which instead of smaller batteries, resulted in high demand for such batteries for new applications (drills, chainsaws, etc.).

Recycling (5) Currently still inefficient in CRM, recycling is crucial for a stable long-term resource supply. Improved product design, consumer awareness, and infrastructure are essential for improving the impact recycling can make in using CRM. Additionally, improved technologies and innovations are required.
Momentarily the costs of recycling processes are not compensated by the value of the recovered material.
With rising material costs, recycling can become a more attractive option.

Policies (6) Regulations and policies can help steer the system around the use of CRMs toward a circular economy and can be an incentive for improving recycling rates, e.g., by introducing mandatory recycling content quotas (Dolega et al., 2021). The Committee on Industry, Research, and Energy of the European Union (2021) developed a European strategy for critical raw materials.

1.5 CASE STUDY INDIUM

LCD screens (e.g., computer screens and televisions) and touch screens (e.g., smartphones and tablets) use a transparent conductive layer consisting of indium tin oxide. For the production of indium tin oxide - as by 2012 - up to 75% of all globally refined indium was used (Ylä-Mella & Pongrácz, 2016). As the production of such end-use appliances drastically increased, so has the demand for indium.

By now he number of screens globally has passed the double-digit billion mark. In 2020 alone, 3.2 billion flat-panel displays were produced (Deloitte, 2020). With new product categories containing such screens being established in the market (e.g., smart watches, smart fridges), the dependence on the indium of the consumer electronics market stays strong. Additionally, indium plays a crucial role in producing thin-film photovoltaic systems.

These systems are the second generation of photovoltaic systems and are more efficient due to low production costs and low material and energy demands, thus gaining increasing importance in the energy transition.
The cost of solar power has fallen by 90% this century, and a reduction of another 15% to 20% will likely occur in the next decade (Flowers, 2021). Operational improvements will likely increase the generation capacities, while inverters will improve the overall footprint.
As Ravi Manghani in Flowers's interview (2021), it is expected that by 2030, solar power will be competitive at wholesale prices in most power markets. These developments make solar power central to the energy transition and create an even higher demand for indium.
It is stated by Ciacci et al. (2018) that the global demand for indium will have an annual growth of 5% to 10%. Nevertheless, the supply is at risk due to the following reasons stated by Lokanc et al. (2015):

Small markets (1) Indium is traded in amounts so small that it is not traded in any metal exchanges.
The disruption by a single supplier can, therefore, strongly impact the price of indium. Between 2002 and 2005, indium prices increased by ten times due to the closure of one refinery (Stevenson, 2019).

Production as a byproduct (2) Indium is almost exclusively produced as a byproduct of zinc. This results in shared production costs, thus much lower costs as if it were produced by itself. The rise in demand will require production by itself, thus higher production costs (Lokanc et al., 2015). Additionally, its quantity in the production as byproduct is so low that indium sourcing might not only be dependable on the demand and supply of the primary products but also might not be recovered by the refineries (Ylä-Mella & Pongrácz, 2016).

Scarcity (3) Indium has a low average abundance in the Earth's crust; thus, it is one of the scarcer elements.
The American Chemical Society lists indium as one of the nine elements with a seriously threatened supply within the next 100 years (Stevenson, 2019). Additionally, 72,70% of indium is distributed by China (Zhang et al., 2015). This creates a high dependency on this country.

The high economic and sustainability-related value combined with the high supply risks requires strategies to tackle this problem. One promising way is the recycling of end-of-life products containing indium. In 2016, less than 1% of indium was recycled (Ylä-Mella & Pongrácz, 2016), while methods exist which allow a recycling rate of 86% in LCD screens (Zhang et al., 2015).
The first major problem with the recycling rate of indium is high dissipative losses. The dissipation rate of indium in 2016 was 90%. The global substance flow analysis of indium by Yoshimura et al. (2013) states three categories of dissipation.
The first one is dissipation in the sourcing (responsible for over 93% of indium lost due to dissipation), losses during the recovery process (responsible for around 6% of indium lost due to dissipation), and the discard of end-of-life products.
The refining efficiency has significantly improved over the past years (Ylä-Mella & Pongrácz, 2016) and will likely improve further with new technologies in place and the increasing demand. ›

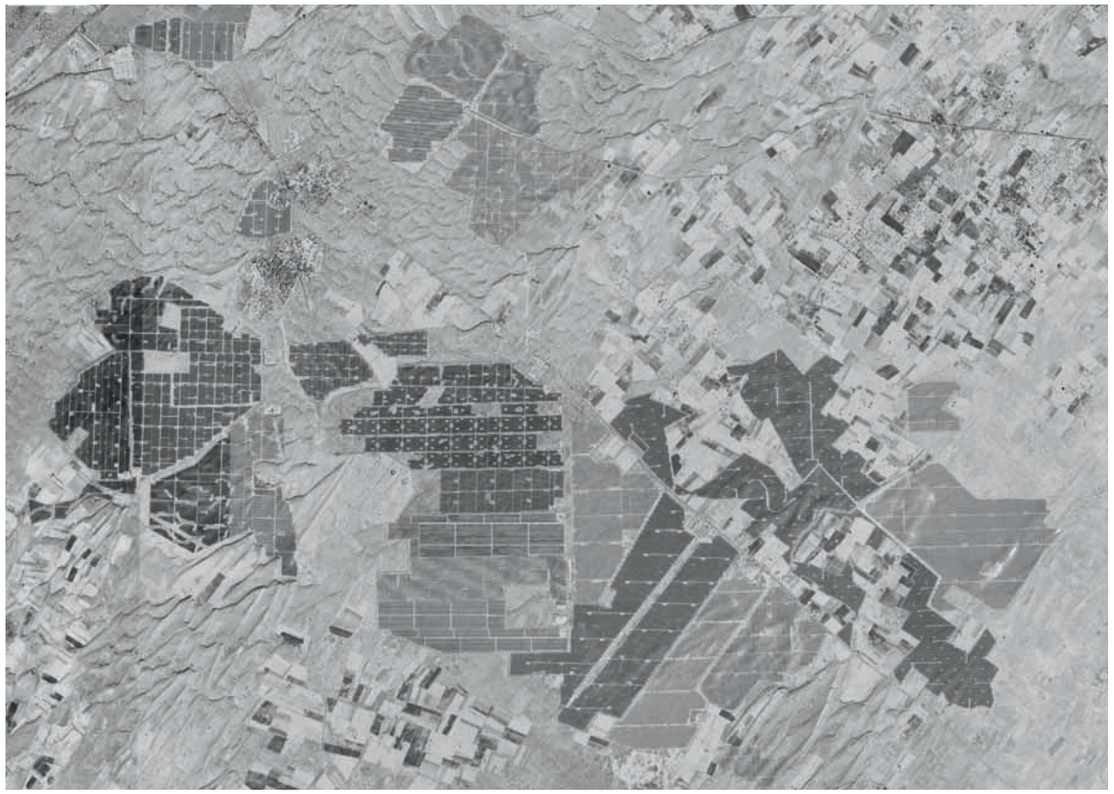


Fig.5 Solarpark Bhadla I

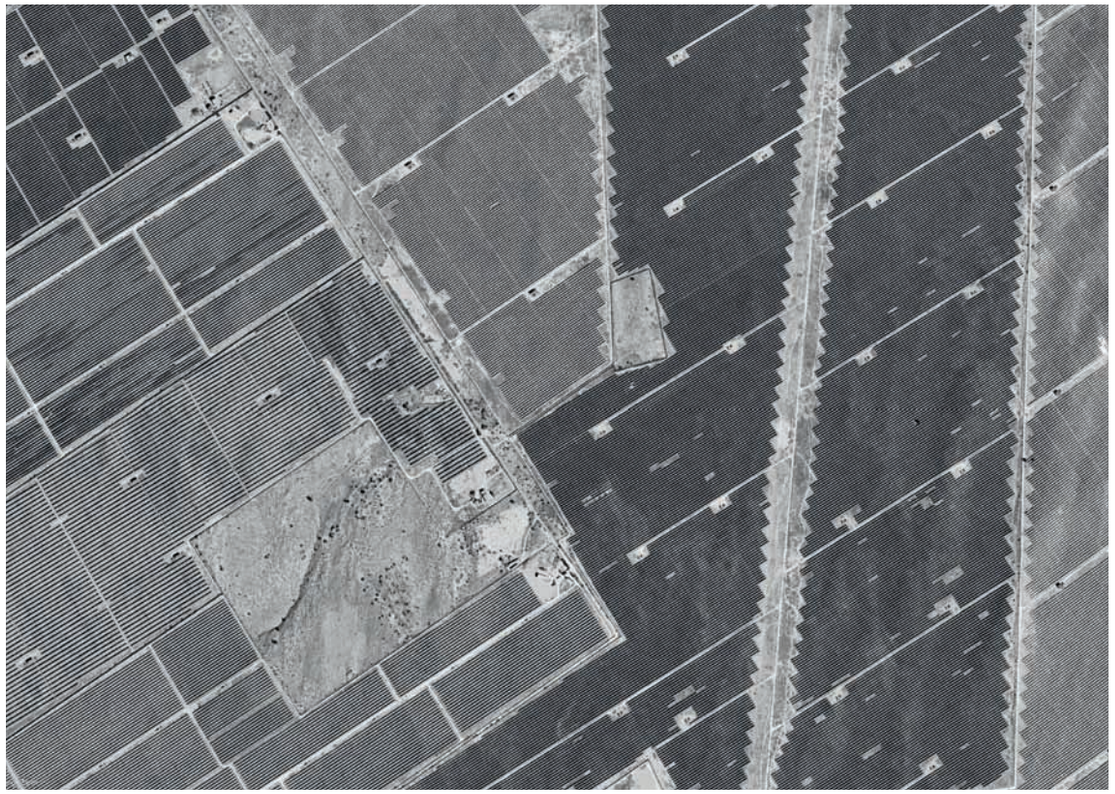


Fig.6 Solarpark Bhadla II

In order to improve upon the other categories, better end-of-life management and improved recyclability are key. The current problems with closing the loop are, among other things, the following:

1. „Product design that makes disassembly and material separation difficult or impossible“ (Ylä-Mella & Pongrácz, 2016, p.5)
2. „Low awareness levels about the loss of resources. “ (Ylä-Mella & Pongrácz, 2016, p.5)
3. „In industrial countries, many goods such as small electronics are “hibernating” in drawers and closets.“ (Ylä-Mella & Pongrácz, 2016, p.5)
4. „Recycling technologies have not kept pace with complex and diverse modern products.“ (Ylä-Mella & Pongrácz, 2016, p.5)

These aspects are system and design problems that lie within the competencies of a product designer. By reducing the use of indium in products by leaving unnecessary displays and touchscreens to consider the end-of-life and recyclability of products actively, designers can create a substantial impact on the development of usage and relationships with indium.

1.6 PLASTICS AND METALS

Besides the electronic components, most materials used in consumer electronics are plastics and aluminum, the main application being the enclosure of the electronic components. This section discusses the properties of the most commonly used materials and their relation to resource scarcity.

1.6.1 PLASTIC RECYCLING

The average consumer electronic plastic content is 28% in small equipment and 15% in large equipment (Slijkhuis, 2020). With 40 to 60 million metric tonnes of WEEE (waste of electric and electronic equipment) annually (Schwesig & Riise, 2016), 7.5 to 15 million metric tonnes of plastic waste comes from WEEE produced annually.
The most commonly used plastics are:
Research from 2015 states that only 50 years of crude oil is left in the reserves (MET-Group, 2021). With over 99% of plastics made from chemicals sourced from fossil fuels (Center for International Environmental Law, 2019), the need to recycle plastic and use it effectively is urgent.

Acrylonitrile Butadiene Styrene (ABS): ABS is one of the most cost-effective plastics today. It is durable and provides a high impact and heat resistance, but it is mainly suitable for indoor use since it is not very UV stable.
Its low melting point makes it very useful in the injection molding manufacturing process (Polycase, 2021).
ABS is mainly suitable for high quantity production or low material costs.

Recycling of ABS: In 2020, ABS made up 17% of all plastic recycled from WEEE (Waste from Electrical and Electronic Equipment) (Slijkhuis, 2020). ›

Under the right circumstances, 100% of ABS can be recycled (Vihaan, 2022). As the study of Fisher and Ford (2019) shows, recycled ABS (rABS) can be a fully functional substitute for virgin ABS in consumer electronic enclosures, just requiring the right product design.
This concludes that ABS has both good recycling properties, and its recycling makes sense. In order to make the final product well recyclable or even potentially circular - the slightly different properties of rABS, easy disassembly, and the use of mono-material rABS need to be considered by the product designers.

Polyamide (PA): Polyamide is a material suitable for outdoor use due to its good heat resistance (Early, 2015). It is tough, wear-resistant, and an excellent electronic isolator. Humidity proposes a problem for PA since PA absorbs water (OKW Enclosures Inc., n.d.). Polyamide is long-lasting. The downside of this property is that PA remains in the environment for a long time if discarded. Around 10% of all garbage in the ocean is composed of PA (Vanden, 2020b).

Recycling of PA: PA is well recyclable. It is long-lasting, meaning it can be reprocessed multiple times. This makes it suitable for circular systems (Vanden, 2020b).

Polycarbonate (PC): Polycarbonate is tough, impact-resistant, thermally stable, transparent, and easy to color. It can be used both in- and outdoors with good UV resistance (OKW Enclosures Inc., n.d.). Overall, polycarbonate is a versatile and high-performance material with many use cases.
It is gaining more and more popularity (Vanden, 2020b).

Recycling of PC: In 2020, PC made up 12% of all plastic recycled from WEEE (Waste from Electrical and Electronic Equipment) (Slijkhuis, 2020). Under the right circumstances, 100% of PC can be recycled (Vanden, 2020b). Recycled PC can be used as a substitute for virgin PC.

PC/ABS Blends: PC/ABS is an engineering thermoplastic created from blending ABS and PC. Its properties depend on the ratio of the two components. It is more cost-effective than PC and offers heat resistance and toughness with the processability and ductility of ABS (Fast Radius, 2021).

Recycling PC/ABS Blends: Separation of PC/ABS blends into PC and ABS for recyclability is difficult. Until 2018, PC/ ABS was only used for incineration, not recycling. MGG Polymers (2019) claim that they have been able since 2018 to separate and refine PC/ABS blends in serial production.

Other plastics commonly used for electronic enclosures but not further discussed here are High Impact Polystyrene (HIPS), Polypropylene (PP), and Thermoplastic Elastomers (TPE).

When consumer electronics reach their end of life, most are dismantled and sorted, and the metals removed. After shredding the remaining content is called electronics shredder residue (ESR).
ESR consists of various materials, with plastics making up 86% of European ESR (Schwesig & Riise, 2016). Due to the following factors, recovering plastic from ESR for recycling is challenging (Schwesig & Riise, 2016):

*Many different plastic types in ESR
*Non-plastics make up a significant amount
*Coatings and Paints
*Problematic substances in ESR mix
(e. g. flame retardantsand heavy metals)
*High requirements for the resulting materials
when used as a substitute for virgin materials

Mechanical recycling is the most environmentally friendly option in this case, compared to incineration and chemical recycling (Barthes et al., 2012). ›

Due to the complex nature of the recycling process of WEEE, simplifying that process by blending increases the recycling rate and decreases the waste volume over the short term (Barthes et al., 2012).
Since blends need to be separated after their end of life, a complicated process, it is questionable whether the increase in recycling rate and decrease of waste volume also occurs over the long term.

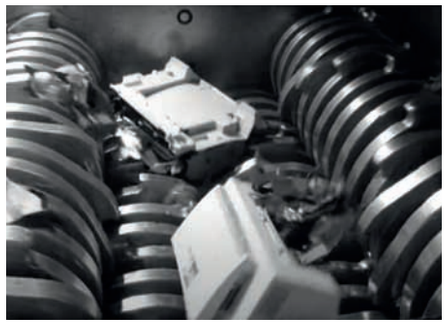


Fig.7 Shredder

1.6.2 METAL RECYCLING

Metals account for 60% of WEEE in weight (Cesaro et al., 2018). With 49000 mg/kg, Aluminum is one of the metals most commonly found in WEEE. The other most common metals are Iron, Copper, Zinc, Lead, and Antimony. Even though precious metals are only found in small quantities, they have very high economic value. Precious metals are i.a., gold, silver, platinum-group, palladium, and rhodium. Used in printed circuit boards in small quantities, their concentration in these circuit boards is generally much higher than in mineral ores, thus offering an economic incentive for recycling WEEE (Cesaro et al., 2018).

Aluminum: Since most metals are only present in electronic components and are commonly found in consumer electronic enclosures, Aluminum is chosen here for further examination.
Aluminum is lightweight but strong; thus, it allows for durable products. It is by many considered as a a more ‚premium 'material in concern to plastics while being more cost-effective than other metals. Additionally, it dissipates heat better than other alternatives, which is helpful for electronics that heat up quickly. On the downside, it blocks signals.

Recycling of Aluminum: Aluminium is 100% recyclable, with only 5% of the energy needed for recycling than for producing virgin Aluminum (Ugreen, 2021).
Europe has the world's highest recycling rate of Aluminum, with 81% of all Aluminum used being recycled (Quartz Business Media, 2020).

Fig.8 Aluminium recycling

1.7 LEVERAGE POINTS RESSOURCES

The following leverage points emerge from the problem analysis for the product design of electronic consumer goods concerning resource scarcity.

Offering counter-designs for negative product trends (1) Creating designs outside of existing trends with negative impacts or steering the existing trends with product design into directions with improved impact helps shifting the widespread understanding of "good design "toward improved environmental impact.

Designing for longevity (2) The more extended the product's life, the later it needs to be replaced; thus, fewer products are produced. This saves energy required for producing products and materials, the emissions for transport, and fewer raw materials are required. This also means that easy repairability should be possible.

Designing for disassembly (3) When a product comes to its end of life and enters the waste stream, in order to have good recycling properties, disassembly must be possible and easy. That easy disassembly is possible; it must already be considered in the design phase of a product.

Optimizing material use (4) The quantity of material should be used as optimized as possible. Regarding quantity, products should contain the least amount of material possible to meet the properties and requirements. This improves the product's impact on resource scarcity and is the best way for the economy.

Considering the right materials (5) Since ABS, PS and PP make up about 55% of the plastic in WEEE, their recycling is the most lucrative and, therefore, the most efficient (Sliz, 2019).
In contrast, other materials such as PC or PMMA are only present in small quantities (1-2%); thus, their recycling is economically uninteresting. Therefore, materials that are as common as possible should be chosen (Sliz, 2019).
When considering materials in the design of a product, the following points should be considered when deciding which materials to use: Suitability, recyclability, scarcity, the energy required for production and transport, durability, and other applications materials.

Designing for the use of recycled materials (6) The properties of recycled materials vary in comparison to their virgin counterparts. Products should be designed in a way so that recycled materials can be used.
It must additionally be considered that WEEE plastics are sorted for recycling with near-infrared detection (NIR).
This technology only reliably detects light-colored plastics. Dark ones are detected unreliably or not at all but make up 60-80% of WEEE plastics (Sliz, 2019).

Using mono-materials (7) A big issue when recycling is the pureness of materials. The use of composites and other multi-materials is therefore problematic concerning the recyclability of a product. If possible mono- materials should be used in as many building parts as possible. Additionally, coatings and paints are often problematic since they are hard to remove and impair product purity.

PROBLEM CONSUMPTION ANALYSIS

2.

The second section of the problem analysis will look at consumer behavior in the western world. These developments have led to current consumption patterns and the effects of this behavior on newly designed products and people.

What role does consumption play in everyday life and the social environment, and how does this influence consumption and the products that get bought.

2.1 EVOLUTION OF OUR CONSUMPTION BEHAVIOR

The development that led to the prevailing consumer behavior began as early as 1950, during the industrial revolution and the increasing prosperity in many social classes. The driving factors were the motives of belonging, self-esteem, and enjoyment. Demand increased as the population of modernizing societies grew, prices for food and clothing fell, and more money remained for other purposes.

The liberalization that had already begun in the 19th century supported this consumption even more; the lower social classes realized that by working more, they could enjoy the same resource-intensive lifestyle that had previously been the privilege of the aristocracy.

Thus, the traditional external constraints (having to work) were transformed into self-constraint: The spread of consumerism and the fear of social de-integration that this development brought with it can be transferred to large parts of our society today.

Even more, distinctive consumption (consumption to separate oneself from a specific social group) increasingly tied people's identity to symbolic consumer goods (Stengel, 2011). Another step in the intensification of consumerism began with the collapse of the planned economy, making capitalism alternativeless and finally global. Emerging countries, which gained a competitive advantage by producing goods cheaply, helped the people living there to new prosperity. Although this development towards better living standards for all once again legitimized capitalism, it also pushed the ecological crisis.

As products could now be sold even more cheaply in the industrialized countries due to the lower production prices, the people in the former emerging countries were now seeking the same consumption goals as the European industrialized countries; France, Germany, and Great Britain.

Fig.9 VW Beetle - a symbol of economic growth

After 1990, the consumption of fossil fuels and natural resources increased steadily. The overproduction of the self-dynamic market economy was already considered an ecological problem then, but it was tolerated to overcome the deficient society.

At the beginning of the 21st century, many people in industrialized countries enjoyed material prosperity that had already gone far beyond subsistence (Pfister, 1995).

Nowadays, the Western world lives in abundance in which the production of the multitude of goods surrounding us has become a threat to nature and, thus, a threat to human beings. Moreover, by stimulating the market, the major economies have encouraged the purchase of more consumer goods.

This attempt to overcome the economic crisis maneuvered the consumption society into a systematic dilemma (Stengel, 2011). Manufacturers flood the market with ever-new versions of their products, but the innovations are merely minimal improvements to the product or the software. This leads to a reduction in the useful life of raw material- and energy-intensive products. This, in turn, triggers the imminent shortage of raw materials and the amount of electronic waste (Wang et al., 2009).

2.2 IMPACT OF OUR CONSUMPTION BEHAVIOR

Over-consumption, driven by over-production, has shaped our lives since the 1990s and is now visible in many environmental problems, including the shortage of raw materials. The deforestation and pollution of our oceans and climate change are leading to biodiversity loss. Biodiversity is essential for the creation and preservation of complex ecosystems which are fundamental to life on earth. Once destroyed, they cannot be reproduced by humans (Gupta et al., 2020).

The civilized society destroys everything humans cannot reproduce to maintain its standard of living, which is based on reproducible goods and environments (cities, villages...). This includes reefs and forests, the habitats of animals that depend on them, and habitats of natives who lived together in harmony, considerately with nature.

However, soil erosion and acidification are a much more immediate threat to us. This is linked to several factors, including the deforestation mentioned above to mine underground resources, the conversion of more natural land to cultivation, and the intensive use of fertilizers. This development affects and more directly as the cultivation of our food will no longer be possible on these soils in the long term if this development continues (Gryschko et al. 1997).

2.3 DRIVERS OF OUR CONSUMPTION BEHAVIOR

We live in a world where greater satisfaction and happiness are closely linked to greater material wealth. Consumption allows us mobility, a diverse diet, more convenience, many individual choices, and personal comforts. As a result, the idea prevails that the more we consume, the better off we are.

The consumer society functions based on the constant urge to satisfy the needs created by advertisements. Political incentives also increase this satisfaction (scrappage bonus when purchasing new cars in Germany, new energy efficiency classes), which ensures increased consumption. According to Max Neef, actual human needs are small and universal, in contrast to the insatiability of desire (Ekins et al., 1992).
He thus addresses the dual function of many material objects. Most of the time, they are essential to us because of their direct practical use and what they mean to us and others. In his report on "Motivating Sustainable Consumption," published in 2005, the environmental economist Tim Jackson lists various theories contributing to understanding our behavior. In the first place, human needs are very general and not focused on consumption.

Well-being
Property and ownership
Privacy
Impartiality
General usability (of information technology)
Trust
Autonomy (of decisions)
Accountability
Courtesy
Environmental protection and sustainability
Identität
Tranquillity ›

The fulfillment of these needs can be classified into two aspects. Material needs (subsistence and protection) and social-psychological needs (self-esteem and belonging). In addition, a differentiation is made between needs and satisfiers, which opens up the discussion that not all satisfiers satisfy the underlying needs equally.

An example would be food, which is a life-sustaining need, but not all foods have the same nutritional value, nor are many harmful to us, even in small quantities. Regardless of the satisfaction of basic needs, many 'false' and 'unnatural' needs have been created for commercial interest (Jackson, 2005). Actual consumer spending in Germany has almost doubled in the last 30 years (Statistisches Bundesamt, 2021), whereas satisfaction with the living situation has hardly changed (Donovan, 2002). So we consume in a way that does not benefit our mental health and harms our environment. So if neither psychological nor social needs are satisfied by modern products and goods, Jackson (2004) concludes, it should be possible to live better and reduce our environmental impact by consuming less. In other words, the theories he points out attempt to answer the fundamental question:

If the products we consume do not make us happier (satisfy us), why do we continue to consume?

2.3.1 IDENTITY AND BELONGING

Our behavior as consumers is closely linked to our personal and collective identity. We are what we own. Certain consumer goods such as clothes, music, or food play an essential role in the process of identity formation. People wear the latest fashion to identify with a particular social group, position themselves within that group, distinguish themselves from other groups, and show which ideals they follow.

Fig.10 Punk

The ideals that a product symbolizes can also be attributed to social meaning so that consumers contribute to identification with a group and, in terms of society as a whole, to reach a certain status (Jackson, 2005).

2.3.2 SOCIAL CONVERSATION

Symbols are inherently social constructs whose value is constantly renegotiated within a cultural context. Consumer goods thus play a vital role in the social and cultural dialogue and narratives holding together society.

Thus, their role is not limited to creating and maintaining personal identity; according to Douglas and Sherwood (1996), they can be seen as a non-verbal medium for creativity. In addition, material goods, in particular, can provide a labeling service beyond display consumption. ›

Fig.11 Bourgeoisie

They help maintain exchange within a social group, enhance social resilience in the face of cultural change, preserve social identity and negotiate inter-group relations (Jackson, 2005).

2.3.3 HABITS

We consume many things out of habit without realizing it. We do not question certain purchases if it was already the habit of our parents or if society, in general, reflects it as usual to own or consume these products. This is known as the lock-in effect: Societies become socially and materially dependent on certain consumer goods.

This can take the shape of cultural dependency, which is when we become accustomed to a certain level of material possession (car, smartphone, branded clothes, dishwasher...), or technological dependency (Belz, 2007), which also means that social organization becomes dependent on technical devices such as computers or mobile phones (Jackson, 2002).

Fig.12 Cup of coffee

2.3.4 DESIRE

Tastes and preferences are shaped by desire, which is used directly and indirectly through sexual connotations in advertisements. It is a very real and widespread association between material goods and sexual selection (competition for sexual partners).

Fig.13 Shop window

Desire is not associated with 'rational' effort - to align the functional character of goods with our specific personal or social needs, but rather with emotional solid or sexual drives and motivations. (This suggests a biological basis for consumption, which puts the task of changing behavior in an even more daunting light).
However, evolutionary theory also explains cooperative and moral behavior, for example, the individual sexual and social status.
Evolutionary theory holds that animal behaviors are the result of evolutionary adaptation under the pressure of natural selection (competition for scarce resources's choice between competitive and cooperative behavior is strongly dependent on the social climate (Belk et al., 2003)

2.4 WHY THE FALSE CONSUMPTION DOES NOT MAKE YOU HAPPY

It is widely known that a higher income does not necessarily make people happy. One reason is the time stress that earners of higher incomes suffer (Hamermesh & Lee, 2005) since leisure time is necessary for subjective well-being. If one now asks whether more consumption makes people happy, it can be argued that the income achieved for higher consumption is mostly achievable with more significant time commitment, thus less leisure time. However, psychologically and neurobiologically, there are far more reasons why consumption does not make us happy, apart from the sheer quantity of consumer goods we want to acquire.

The neurobiological peculiarity of humans preferring immediate rewards to delayed rewards (Prinz & Pawelzik, 2006) is interesting for this thesis since this phenomenon is almost ordinary. We consume without consuming; we buy without using. The hedonistic act of buying causes our brain's reward system to release endorphins.
If our hedonistic pursuit is purely directed towards consumption, it results in our hedonistic pursuit dropping so low after taking possession of the consumer good that, according to Wayne Hoyer and Deborah MacInnis (2004), consumption no longer takes place.

Fig.14 Black Fiday 2017

This rush of happiness of (what should be) successful satisfaction of needs wears off through increased consumption, so hardly any rush of happiness is caused by expectable satisfactions (Prinz & Pawelzik, 2006).
A psychological aspect that challenges the theories that we consume to distinguish ourselves from a social class, according to Pelzmann and Tinbergen (2006), is that the status competition fought out with the amount spent on consumption is not matched by a hedonistic equivalent. Thus, consumption can improve one's status, reducing the status of at least one other person.
Consumption, however, is a fighting tool without an equivalent intrinsic value. However, it does not necessarily have to be used as a tool in battle; it is enough that we constantly have the feeling that we have to keep up.

2.5 EFFECTS OF CONSUMER BEHAVIOUR ON NEWLY DEVELOPED PRODUCTS

There is a clearly defined categorization of perpetrators and victims in the media on the question of responsibility for the obsolescence of modern products. The manufacturers of products are exclusively responsible for the rapid wearing out of formerly long-lasting products.

However, this narrative only reinforces the consequences of this development. This is important as this representation of the cause can impact consumers' perceptions of their role.

In a study by sociologist Melanie Jaeger-Erben (2019), when asked about the end of life of a device, most respondents stated that it had broken down due to the expected signs of use, except for smartphones and notebooks. Consumers classify this end of life as 'rather expected'.

These consumers expect their products to be functional for a shorter period due to deliberate faulty design. Moreover, they do not see this short lifespan as problematic, but see the broken appliance as a welcome occasion to buy a new one.

The new appliance is associated with quality of life, as already shown on the previous pages, and people like to show off in their social environment. Producers also point to their customers' wish for new products that are as cheap as possible and their disinterest in durability (Spinney et al., 2012).

However, it is not only customer perception that plays a role in the obsolescence issue; usage practices are also crucial. For example, most users do not know how a lithium-ion battery should be charged appropriately or how and when a washing machine needs to be maintained.

According to Friedrich von Borries (2016), "[t]he human being [...] is not up to the task in the world he has created, the new machines, the fast production, the rapid technological developments [...] and their handling.
Man's designs overwhelm his ability; he can no longer act with competence in the world he has created." (translated by the author)

Much of our actions are based on implicit, practical knowledge, which in most cases is not questioned; moreover, not enough time is given to the professional care and maintenance of products in our everyday lives. Time or dependence on products also has a significant role in users' unwillingness to repair defective products.
For many users, the reason for not repairing a product is that they cannot do without it. Moreover, replacements are available in working condition (most likely cheaper) (Jaeger-Erben, 2019). This at least questions the common explanation that buying new is mainly based on the appeal of the new and a high fashion or status consciousness. ›

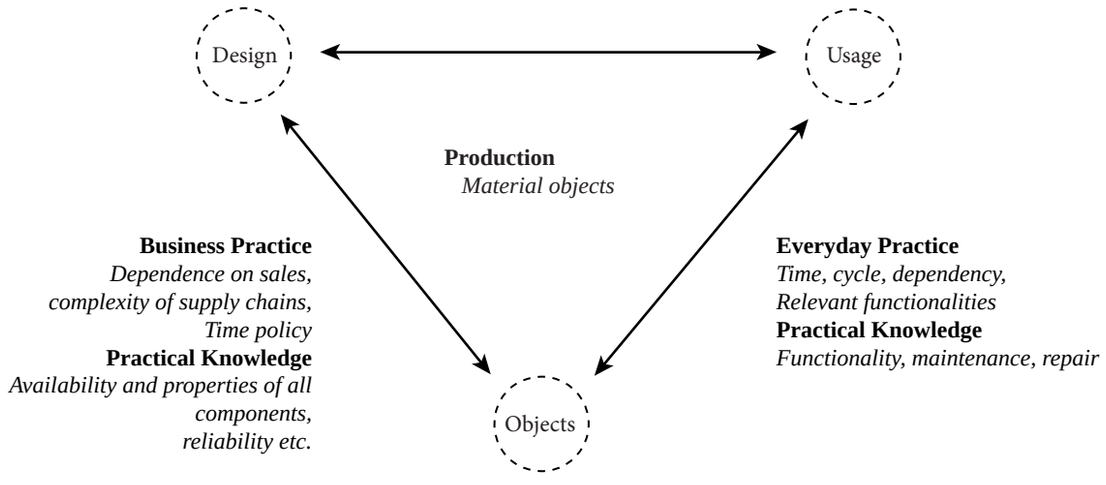


Fig.15 Triangular relationship in the production of obsolescence expanded to include aspects relevant to human-object relationships

In contrast to the public discourse, where a linear relationship between the actors has been used until now, the triangular relationship shown in Figure 4 is used as a reference. It shows that we directly influence the obsolescence of products with our consumption behavior.

In addition, our requirements and behavior patterns significantly influence the development of new products (Jaeger-Erben, 2019).

2.6 LEVERAGE POINTS CONSUMER BEHAVIOR

The following leverage points have emerged from the initial problem analysis of the development of consumption, the impact on people, and the factors influencing the design of new products.

Products should be satisfied through use (1) or associated with an activity that satisfies. Since experiences fade quickly in everyday life, it cannot be generally argued. 'Experiences are better than objects.' This is because the pleasure of the purchase can last longer, depending on the product, and thus have a disproportionately greater value (Oberhuber, 2016).
Those who buy a nice bicycle and ride it on nice tours have long and often deep satisfaction.

Products should help reinforce values and perspectives within a social group (2) Beyond showcase consumption, products are means of communication that help a social group maintain exchange within the group and thus defend its values externally.
If we assume a group that already consumes responsibly, products and the exchange about them help defend themselves against the influences of society's mass consumption. If these products can be the focus of a meeting of the group, this improves the effect.

The ideals and values of a product should be visible to the outside (3) After communicating internally, products can also have communicative aspects externally.
If products are seen to be different through their form, materiality, use, or branding (e.g., Veja shoes), they become the medium of the new ideals. Even more, using these objects can have an educative effect on others, stimulate thinking and thus influence other social groups.

New products should be created to be complete (4) These products can exist somewhat detached from innovations. Many new products are constantly replaced to keep up with the pace. Old things are closed, they often no longer have a "real" function, but they still carry a strong symbolism.
The completeness characteristic stands in strong contrast to a rapid change of life and helps to come to rest and decelerate life.

The frequency of use of products should be taken into account when redesigning products (5) We only build a bond with products that we need and use, which brings an appreciation for the effort of using and maintaining them.
The Norwegian industrial designer Roar Høyland already addressed this in 1938. He gave the example that improving the milk carton was more important than improving another expensive chair (Fallan, 2011).

Consume less and consume right. (6) If consumption does not make us happy, we should rethink how we consume. Owning fewer products means taking responsibility for fewer products that take time to use (if we use them) and maintain.

To change our consumption patterns in general and save resources; give up on them, we need to change not only the products but also our consciousness.

This awareness must be passed on from the individual to the social environment, to the descendants, to ensure the continuation of the civilizational project.

1.+2. CONCLUSION OF THE PROBLEM ANALYSIS

We must consume to ensure our survival and satisfy our basic needs. We consume to integrate ourselves into a social group, separate ourselves from other groups, and increase our well-being. We consume so that others see that we are doing well and envy us. We, in return, consume because we envy others and feel we need what they have. Our social environment strongly influences our consumption behavior.
The feeling of belonging to a group, but also the status in the whole society, is associated with the products we own (the clothes we wear, the cars we drive, the trips we go on, ...). Resources form an essential livelihood for humankind.
While resources and our capabilities to extract them are limited, the growth in population and demand seems limitless. This development results in the megatrend of resource scarcity.For consumers, the unlimited consumer possibilities lead to an overwhelming overload of experiences that we cannot process.

This is reflected, for example, in the fact that bought products are not used because there is not enough time to do so; thus, we tend to surround ourselves with products that offer us an option to use them. The many products, in turn, make us compare what we have bought more with other options available and regret the purchase.
The spiral into which this generates, in which more and more products are purchased, the satisfaction and the endorphin release decrease, so that in order to compensate, at first even more is consumed until the expected satisfactions hardly cause a rush of happiness anymore, leads to even greater frustration about the products.
Conscious consumption can prevent effects like this, which frustrates and psychologically burdens people and contributes to the waste of resources.

The most critical ones, the critical raw materials (CRM), are widely used in consumer electronics. Both the rising numbers of consumers and current product trends (e. g. larger screens in smartphones) result in increasing demands for CRMs.

Additionally, the technology required for sustainability transitions (e.g., photovoltaic panels or energy storage) requires these materials urgently. With the CRMs supply at risk, this poses a significant threat to the system and humanity.
The other primary materials focused on in consumer electronics are plastics and metals. With plastics making up 15% to 28% of the waste of electric and electronic equipment (WEEE), most of it requiring crude oil for its production and the synthesis of virgin plastics being more energy-intense than the recycling of plastic, the recyclability of plastics in consumer electronics, is necessary.
Other reasons for advocating for effective plastic recycling are reduced demand for other raw materials and reduced end-of-life plastic disposed of in landfills.

With metal making up the majority of WEEE in weight, their recycling is also highly interesting. With high energy required for producing virgin metals and ofter way less energy required for recycling, e. g. in aluminum, collection and recycling is essential. Concerning the high value of precious metals like gold and silver, and a concentration generally a lot higher than in mineral ores, they can provide an economic incentive for recycling WEEE.

This shows the importance of considering resource scarcity in product design. Product design is often part of the problem but can also be an essential part of the solution.
Considering resource use after the end-of-life in products, the types, quantities, and qualities of materials used, the lifetime of a product designed, and the design of ‚good examples‘ (to guide product trends) can make a significant impact in concern to resource scarcity.

INTERVE NTIONS AND METHOD S

3.

3.1 POSSIBLE TRANSITION PATHWAYS

The multi-level perspective (MLP) (Geels & Schot, 2007) visualizes socio-technical transition pathways. The MLP distinguishes between three levels: The socio-technical landscape, the socio-technical regime, and niche innovations.
The socio-technical landscape is the overall environment concerning the transition in question. It is beyond the direct influence of the actors from the regimes and niches.

Examples are macroeconomics, environmental developments, and deep cultural patterns. Landscape developments can exert pressure on the socio-technical regimes; this landscape pressure can facilitate transitions.
The socio-technical regime comprises the six regimes industry, science, culture, policy, markets and technology. The regime comprises the dominant and established social communities, industries, practices, views and standards. Examples are design and engineering practices, consumption patterns and dominant companies.

The niche innovation level is where novelties are created. Radical new ideas are created by small networks consisting of dedicated actors.
The niches on this level develop and protect novelties against the selection in the mainstream markets. These novelties are not established with the chance of entering the regime level in the course of a transition.

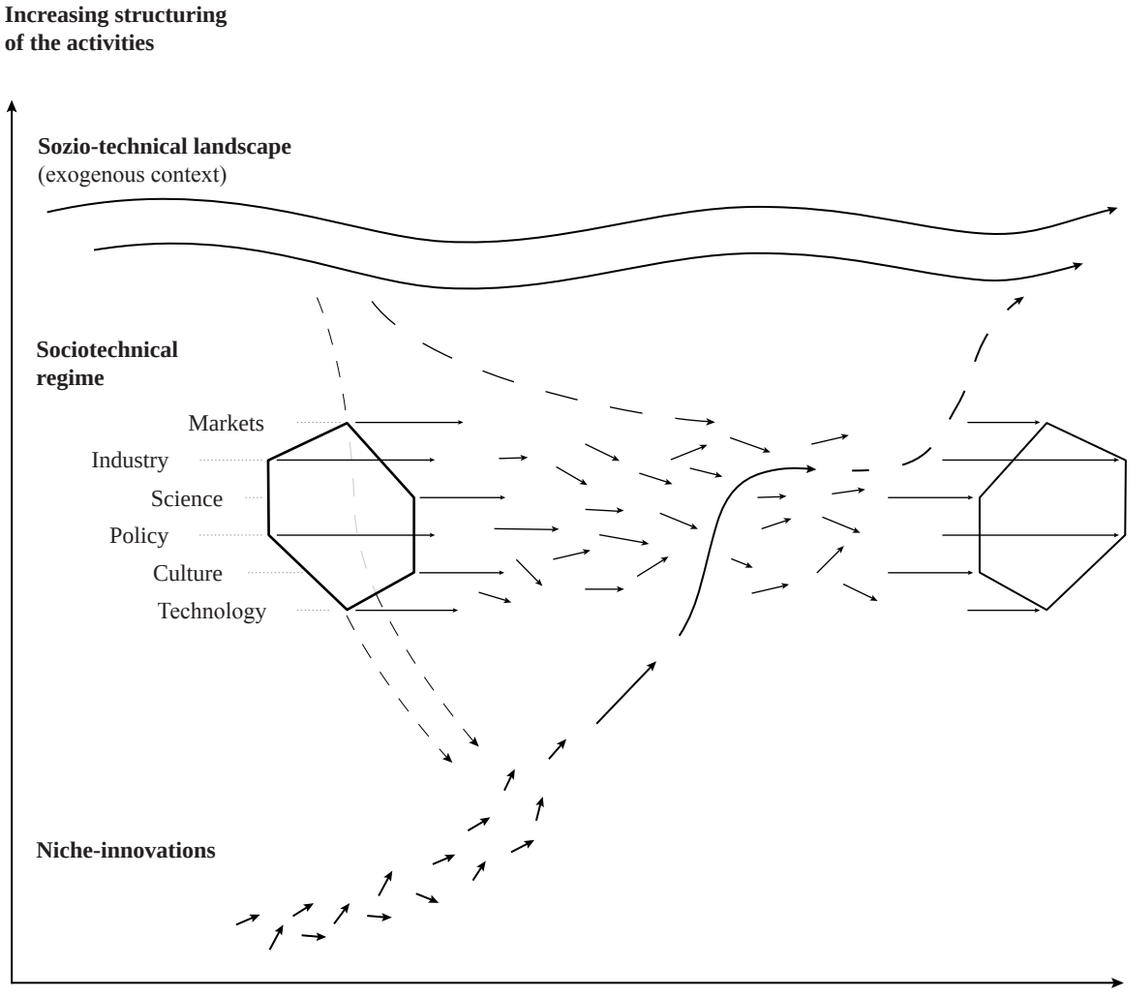


Fig.16 Multi-level perspective on transitions (adapted from Geels und Schot, 2017, p. 407).

Geels and Schot (2007) make a distinction between four different types of transition pathways: The transformation path, the de-alignment and re-alignment path, the technological substitution and the reconfiguration pathway.

Transformation path (1) This transition pathway occurs when the landscape changes in one direction moderately, at a time when niche innovations are not fully developed.
Existing regime actors will react to the landscape pressure by adjusting the direction of developments and incorporating nice innovations (Geels & Schot, 2007).

De-alignment and re-alignment path: When landscape changes are extensive, sudden, and diverse in a time where niche innovations are not fully developed, the regimes break apart.
This creates a window of opportunity for a multitude of niche innovations co-existing in the newly forming regime; at some point, the most dominant ones will establish themselves forming the new core of the regime (Geels & Schot, 2007).

Technological substitution: When the landscapes experience a substantial change resulting in much landscape pressure at a time when novelties from niches are fully developed, they will break through and replace the existing old regime (Geels & Schot, 2007).

Reconfiguration pathway: Niche innovations are adopted in the regime to solve small problems. This adoption triggers further adjustments, which change the core architecture of the regime (Geels & Schot, 2007).

For our project, a transition towards a system with sustainable resource use is desired. Possible transition paths are selected and analyzed to understand further what is required for such a transition to happen. The mega trend of resource scarcity is a major and long-term landscape change with the factors of physical availability of materials, prices for resources, changing dependency on resources, and political and societal purpose of materials.

3.1.1 TRANSFORMATION PATHWAY IN RESOURCE SCARCITY

Suppose resource scarcity develops in a steady direction towards less and fewer resources, higher resource costs, higher resource demand, and stronger resource-related dependency of regime actors on other regime actors. In that case, the landscape development will be steady and one-dimensional, creating pressure on the regimes to find substitutes, reduce resource consumption, and introduce circular use.

The resulting transition will fit into the type ‚transformation‘ pathway described by Geels & Schot (2007).
This means attention needs to be drawn to adverse effects; protest must be voiced against problematic practices and solutions demanded (e.g., stricter regulations).

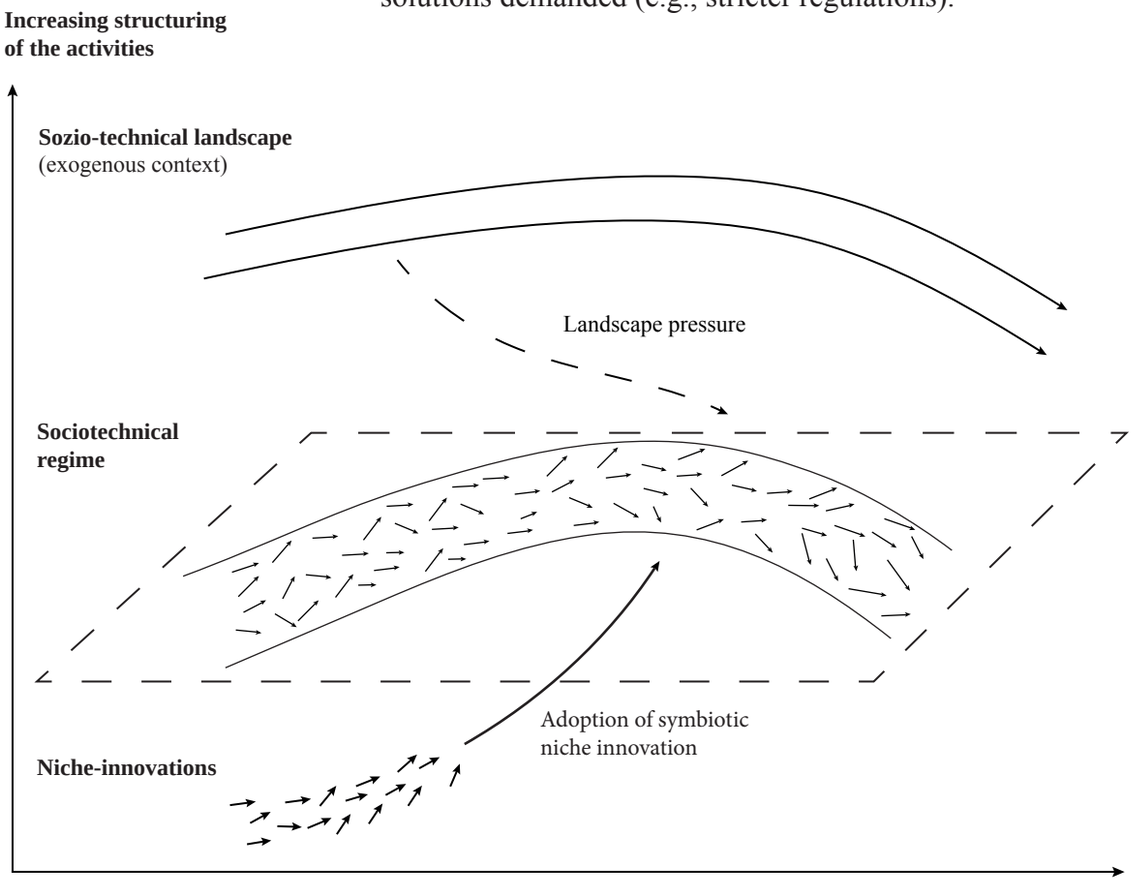


Fig.17 Transformation pathway (adapted from Geels und Schot, 2017, p. 407).

The role of product designers, in this case, is the development of alternative practices and technologies and create products that are viable alternatives in order to influence regime actors to reorient activities and adopt niche innovation

3.1.2 TECHNOLOGICAL SUBSTITUTION PATHWAY IN RESOURCE SCARCITY

Suppose the environment around the topic of resource scarcity experiences a shock-like development (e.g., by a war with a country controlling high quantities of certain materials). In that case, this shock creates a high demand for alternatives, breaking up the existing regime, which creates a window of opportunity for niche actors to enter the regimes. The incumbent regime actors will try to defend themselves by investing in improvements.

If niche innovations replace former technology, a domino effect will occur, and a broader co-evolution process will follow.

Fig.18 Mariupol, Ukraine, February 2022

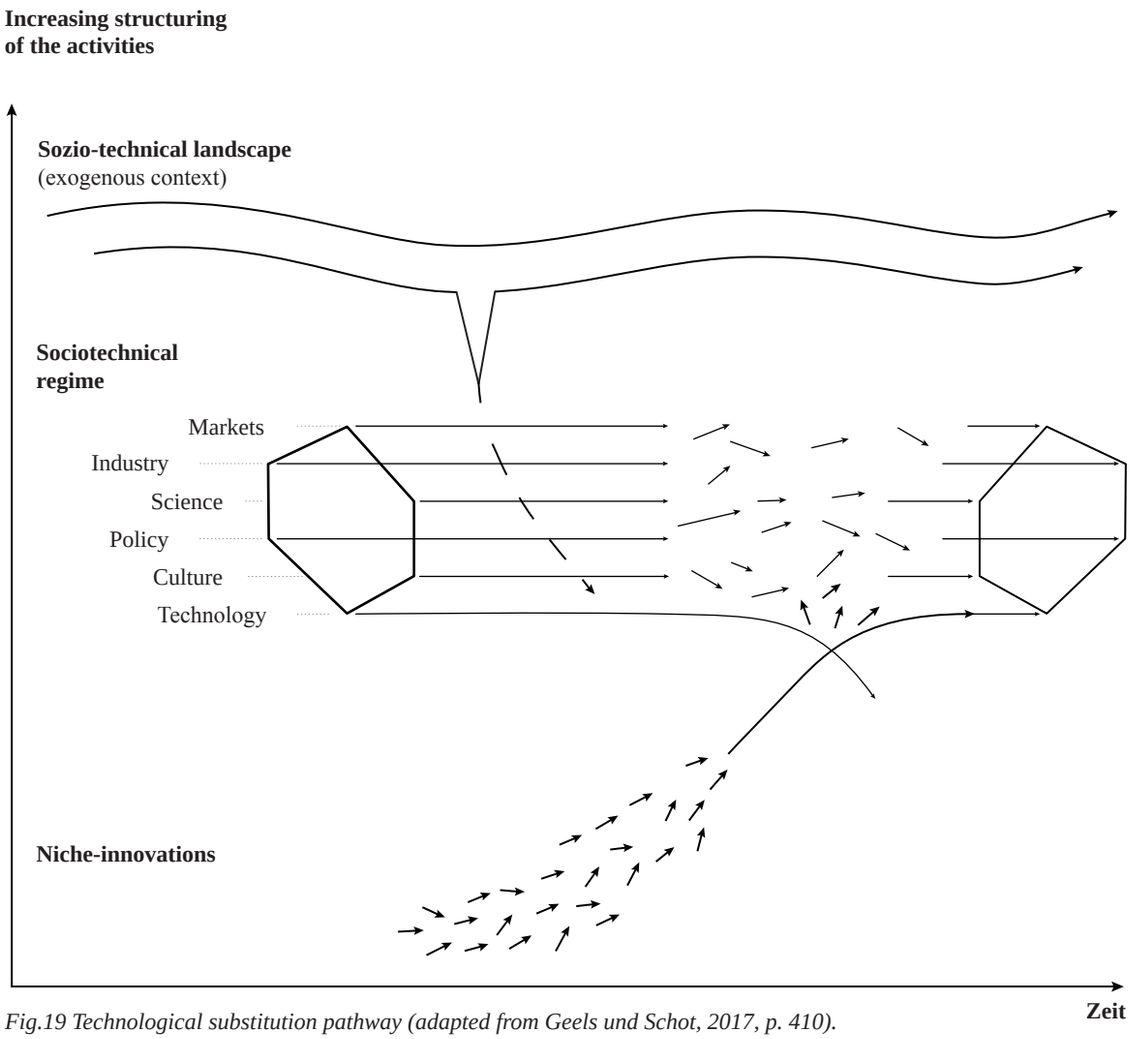


Fig.19 Technological substitution pathway (adapted from Geels und Schot, 2017, p. 410).

Currently, a disruptive and one-dimensional change is occurring in the availability of many resources. Due to demand from a steadily growing population, more consumption, and the role of these materials in increasingly important areas such as green technologies, combined with their increasing scarcity, the disruptive environmental change can be considered nearly inevitable. A transition is, therefore, definitely required to cope with these changes.

For product designers, that means that product design needs to involve careful considerations regarding resource usage. For the involved regime actors, ›

best practice of product design tackling resource scarcity can mean that they are not overtaken by competitors in the course of this development and cushion the impact of resource scarcity on their agency.

Due to the vulnerability of the supply of critical raw materials, the landscape may experience shocks. The types of shocks can be highly diverse, from the closing of refineries, wars (e.g., between China and Taiwan), resource costs exceeding the threshold of what is the economically feasible or intense use of resource allocations as political levers.

> The result would likely be a transition following the technological substitution pathway. In this case, the best practice of product design tackling resource scarcity can mean for regime actors to dampen the effects of the shock on their agency and be prepared to compete with niche innovations pushing into the market. For niche actors, such a product design helps them make the best use of the window of opportunity created by the shock and establish themselves in the market. It also helps them compete with other niche actors and the old regime's defending their position.

For society and our environment, sustainable resource use is essential for survival. As Meadows et al. predicted, the result of unlimited growth with limited resources will be a ‚rather sudden and uncontrollable decline in population and industrial capacity‘ (Meadows et al., 1972, p.23). Additionally to the competitive advantages of resource-oriented design, it also offers a way to evade system failure and maintain a healthy environment.

3.2 USING CONTEMPORARY LUXURY CONSUMPTION PATTERNS

Luxury products are defined by Wang (2018) as products that are both expensive and exclusive and that differ from regular products in concern to their sensory appeal, exquisite design and craftsmanship and their distinct socio-cultural narratives.
As Wang (2018) states, an essential part of the use of luxury products are luxury competencies in their users.

> These competencies are sensitivity to luxury symbolism, aesthetic taste, and expertise. The luxury competencies are closely linked to the luxury features named above.
> Sensory appeal correlates with aesthetic taste, exquisite design and workmanship is linked to luxury expertise, and socio-cultural narratives correlate with sensitivity to luxury symbolism. ›

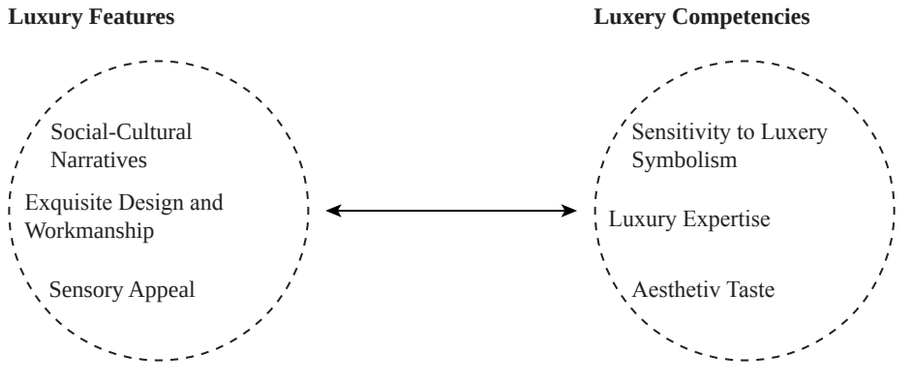


Abb.20 Luxus-Merkmale und Luxuskompetenzen

Users with a competency-based consumption of luxury goods are more open to novelties, thus new types of product categories enter the contemporary luxury market, e.g., coffee machines, blow dryers and other home appliances. Additionally, traditional luxury products are often considered non-inclusive and wasteful (Wang, 2021).
This far-spread understanding results in traditional luxury products being shamed, and contemporary luxury and the status symbols it presents are closely linked to signaling values, sophistication, and intellect (Wang, 2021).

This contemporary understanding of status symbols can be of good use when introducing resource-oriented designs in a market. As stated in the problem analysis, the impact of a product creating awareness is essential when it comes to implementing behavior changes for improving resource consumption.

Fig.21 Freitag Backpack

The interaction with a product, e.g., the sensory stimulation of its appearance or function, must have an educational effect and represent the values behind the product.
This effect does not only apply to the user but to everyone who interacts with it. An example are , Freitag' bags, using disposed truck tarps as textile for bags, backpacks etc. With every bag being unique due to the different prints on truck tarps, the patina of the tarps, and the prints themselves, they communicate that they are made from recycled material to their users and everyone who looks at them. The prices between 190€ and 320 € for an everyday backpack are higher than the average everyday backpack. The product communicates that its user likely cares about sustainability and has a sense of individuality and fashion.
These factors help to connect factors that are positive for the product's sustainability impact with positive factors for the product quantity being sold and used and the price accepted.

This contemporary consumption behavior creates a market for more resource-efficient products and further underlines the importance for product designers to intensely communicate the positive impact of well-designed and resource-efficient products.

3.3 PRODUCT ATTACHMENT

With a continuous rising amount of waste of electric and electronic equipment (Statista, 2021b) and studies showing high amounts of products being discarded while still functional (e.g., 52% of hand mixers discarded (Prakash et al., 2016), the creation of a stronger product attachment in users is desirable. In their work ‚Maßnamen gegen psychologische Obsoleszenz' (translated by author: Measures against psychological obsolescence) Hegele and Hilbert (2022) developed measures for targeting this type of obsolescence. A selection of these measures is shown here:

The creation of an information base (1) For consumers, comprehensive information about a product is an important basis for purchasing decisions. Important information for a well-founded decision of what to buy is the impacts of the products (e.g., energy consumption), their comparability to other products, and information on the product's lifespan.

Strengthening the competence of users (2) If users' knowledge is concerned with the components, structure, and technology of a product helps improve their capability of caring for, maintaining, and repairing products.
This competence helps increase the lifespan of products and improves the alignment of expectations for a product and its actual capabilities.

Creating product loyalty (3) If a strong connection of a user to a product is present, the product will be better taken care of, maintained, and remains longer in the lifecycle. Such connections can be both rational and emotional. Knowledge, information, association, experiences, function, ergonomics, haptics, and aesthetics are factors.

Utilizing the aging process (4) In the western culture, newer is often considered better. Aging-related flaws are considered problematic and are either excepted with resentment, ›

repaired, or the product is exchanged with a new one. Creating awareness of the natural aging process of materials and considering the aging process when designing is a measure to target the obsolescence of products.

Improving the adaptability of products (5) Changes and developments are omnipresent in the system products are embedded. In order to stay functional and of interest for the longest time possible, products need to be able to adapt, fit into changing environments and to be upgradable.

Developing services to maintain and increase value (6) Services for preserving the value of products can be, for example, devices that focus on maintenance and repair of products or services that allow for customization of products to fit an individual's wishes and use scenarios.

Consideration of these measures can improve user-product loyalty. These measures are closely related to the motivations behind the consumption of current luxury products. Thus, taking these factors into account means creating options for market entry and improving product loyalty.

Implementing such measures is therefore also relevant when designing for all other target groups besides the users of modern luxury goods. Since many options for the economic success of resource-oriented consumer electronics, e.g., targeting the group of LOHAS or the aforementioned users of luxury products, go hand in hand with the acceptance of high product prices, it can be criticized that such strategies only include a small group of potential users and leave the majority out.

For a transition towards sustainable resource use, the majority of users and the majority of products need to change. It is therefore important to recognize that the market entry options discussed can only be a first step in facilitating the establishment of resource-use enhanced products.

The measures mentioned by Hegel and Hilbert (2022) are suitable for a wide range of products and should therefore be considered as a general and highly relevant framework for improving product retention and combating psychological obsolescence.

3.4 PATHWAY TOWARDS SUSTAINABLE USE OF RESOURCES

With this method, a vision of sustainable resource use was developed. This vision consists of multiple factors. For the backcasting, the major factors relevant to product designers were chosen, and a pathway was developed.
The main points which will need to be targeted by product designers are awareness and behavior change, materials and the physical nature of products, and the creation of „good examples “ to showcase best practices.

3.4.1 VISIONS

For the backcasting method, a vision of the future in relation to resource scarcity was developed, which, in our understanding, is aspirational. This vision is not meant to be a forecast but rather a goal to work towards. The developed vision consists of 14 factors that turned out to be relevant to the discussed topic.
On the one hand, these factors represent concrete goals for the socio-technical regimes, but on the other hand, they are also more general goals related to the environment and society. Due to the high complexity of the topic, these 14 factors do not claim to be exhaustive for all relevant factors that will play a role in the future concerning raw materials. They are only a selection of the most relevant factors and should help characterize the vision of an optimal future and make it more tangible.

1. Net-zero emissions in production

2. Total circularity globally

3. Raw material extraction rate is lower than resource generation rate

4. Decentralized resource and energy sourcing and production

5. Equally spread resource distribution

6. Non critical and regenerative substitutes for critical raw materials are used

7. 100% renewable feedstock used,
0% fossil feedstock used

8. Widespread awareness of the importance of sustainable resource use

9. Reduced and aware consumption

10. Buffer zones and reserves to tackle potential resource scarcities are installed

11. Landfills are dismantled and nature is reclaiming destroyed areas

12. Resource demands in green technologies are fulfilled

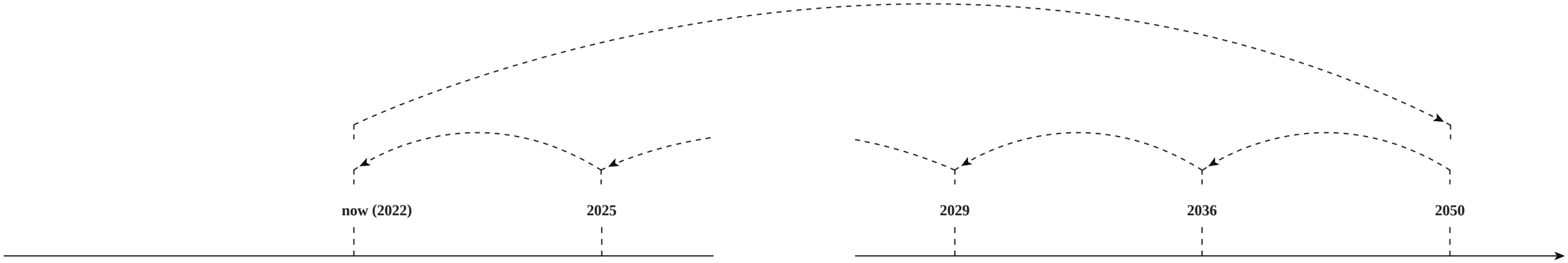
13. Globally present regulations and policies ensure sustainable resource use

14. Quality of ecosystems (e.g.soil and oceans) improves steadily

Fig.22-35 are the representations of visions 1-14

3.4.2 POINTING OUT A PATHWAY WITH THE BACKCASTING METHOD

With this method, a vision of sustainable resource use was developed. This vision consists of multiple factors. For the backcasting, the major factors relevant to product designers were chosen, and a pathway was developed. The main points that will need to be targeted by product designers are awareness and behavior change, materials and the physical nature of products, and creating „good examples” to showcase best practices. ›



	now (2022)	2025	2029	2036	2050
Awareness and Behavior Changes	Little awareness of the importance of sustainable resource use *63 % of the population considers sustainability an important criterion in purchase and consumption of consumer goods*	Awareness of the importance of sustainable resource use grows, limited actions are taken *70 % of the population considers sustainability an important criterion in purchase and consumption of consumer goods*	70% of the population is aware of the importance of sustainable resource use, moderate action is taken *85 % of the population considers sustainability an important criterion in purchase and consumption of consumer goods*	95% of the population is aware of the importance of sustainable resource use, widespread action is taken *98 % of the population considers sustainability an important criterion in purchase and consumption of consumer goods*	100% of the population is aware of the importance of sustainable resource use. *100 % of the population considers sustainability an important criterion in purchase and consumption of consumer goods*
Materials and Physical Nature	Around 240 million tonnes of CO2 emissions from the industry anualy *Global recycling rate of WEEE at around 17.4 %* *30 materials are listed as critical raw materials*	Emissions from the industries are reduced to around 200 million tonnes of CO2 annually Global recycling rate of WEEE at around 25 % and first circular systems for electronics in some countries *30 materials are listed as critical raw materials*	Emissions from the industries are reduced to around 120 million tonnes of CO2 annually Global recycling rate of WEEE at around 40 % and first circular systems for electronics globally *27 materials are listed as critical raw materials*	Emissions from the industries are reduced to around 70 million tonnes of CO2 annually Global recycling rate of WEEE at around 50 % circular systems become the norm *15 materials are listed as critical raw materials*	100% of all products are consumed in circular systems 100% aller Produkte werden in Kreislaufsystemen verbraucht *100% of critical raw materials are subsidized with non critical and regenerative materials*
Good Examples	The implementation on new regulations are implemented slowly, 'good examples' are lacking in the industries	Good examples appear on the market, pushing policymakers to implement new regulations and policies for ensuring more effective resource use	Regulations and policies ensure sustainable resource use are implemented in parts of the world pushed by 'good examples' across the industries	Regulations and policies ensure sustainable resource are implemented further across the globe	Globally present regulations and policies ensure sustainable resource use

Fig. 36 Backcasting - The desired future of resource-based product design

(The most important factors)

3.5 WAYS TO MORE CONSCIOUS CONSUMPTION

Before asking what a change can look like, it must be clarified under which circumstances it can come about. Matthias Horx (2020) sees a fundamental change in the way people, the economy, culture, and politics think as a sign of a BIG SHIFT, i.e., alienation from the world around us. The old has not yet ended, and the new has not yet begun. Horx sees the world currently facing such a change, the change from the industrial to the ecological age.

> This is because our established socio-ecological system is exhausted, and we are facing a crisis of complexity that requires a higher level of solution. One such crisis is the climate crisis - industrial or national strategies can no longer solve the problem of global warming; instead, global cooperation and radically different modes of production are needed.
> The imminent change can also be seen in the resistance that is building up, from wind power haters and speed limit opponents to climate deniers; according to Wolf Lotter (n.d.), the simplified thinking about the situation is thereby consciousness-reducing drugs, which can be seen in populism, hysteria in the media and the polarization of the debate about the future. When the new is imminent, the power of the old temporarily increases." (Horx 2020)

A movement brought to public attention as early as 2000 by the study of sociologist Paul H. Ray and psychologist Ruth Anderson is LOHAS - Lifestyle of Health and Sustainability. The 'Trend Report Target Group LOHAS - How the Green Lifestyle is Conquering the Markets' (titles translated by the author) published in 2007 assigns 30% of the German population (similar to the USA) to this group (Glöckner et al., 2010).

> According to Wenzel et al. (2007), LOHAS sees itself as "a new elite of aspirations that defines itself along with key concepts such initrinsic value, authenticity, quality of life, and well-being. LOHAS describes the 'lifestyle of as well as.'
> The post-material, value-driven intrinsic value, authenticity, quality of life, and well-being. LOHAS describes the 'lifestyle of as well as.' The post-material, value-driven orientation is at the core of this lifestyle.

At the same time, a sense of responsibility intersects with a positive attitude to life and a fun-oriented lifestyle design. The central aspect of their actions is strategic consumption, which aims to change and influence the environment through new values such as authenticity, information, honesty, and sustainability that influence the purchase of new products.
The great opportunity is that these values reach the broad, middle-class. With their purchasing power, they are in a position to change the economy. Changing their purchasing criteria can encourage the economy to bring complementary products onto the market. As Glöckner et al. (2010) show with their positioning of LOHAS in the Sinus Milieus:

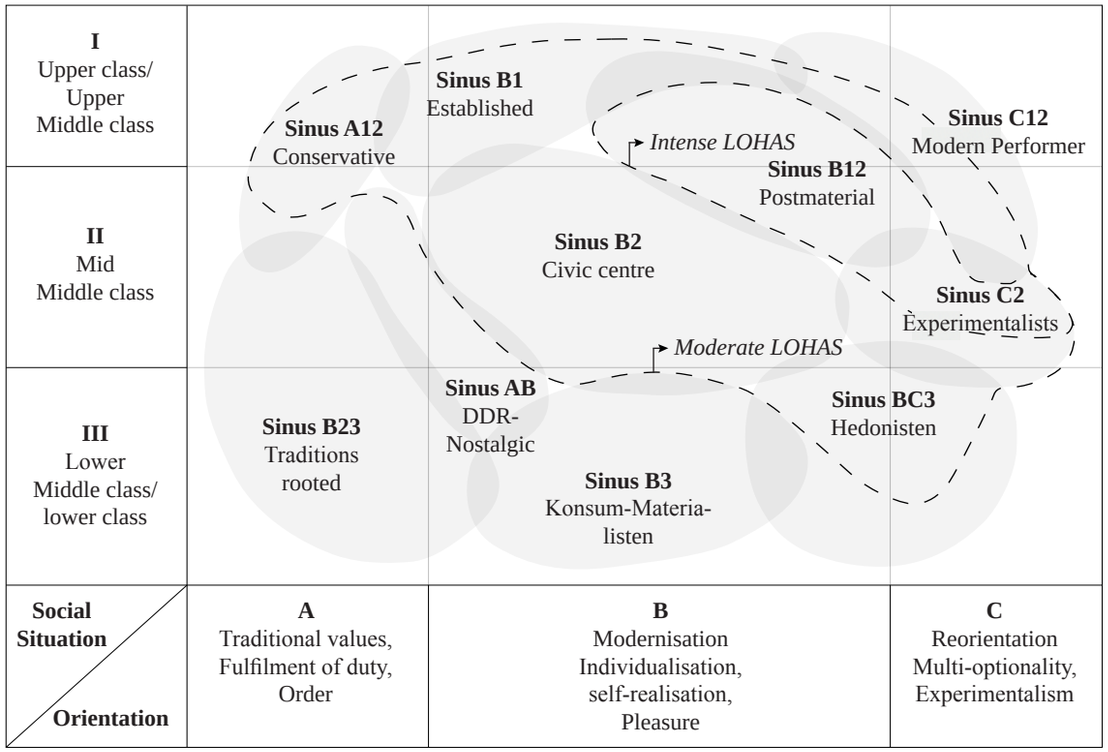


Fig. 37 Location of LOHAS in the Sinus Milieus

The Future Institute does not describe LOHAS as a target group defined by market research but rather as a social change movement whose beginnings are visible in the Sinus Milieus. Wenzel et al. go so far in their description as to say:

> "With LOHAS we are not describing a temporary fashionable hype, a short-term consumer whim, but a long-lasting process of social value change that substantially alters our reality (and of course our consumer realities)".

How the spread of such a value system can be supported is described by Matthias Horx describes with the Blue Revolution, in which ecology is not seen as a and renunciation but rather as liberation from too much. The current idea of green ecology is based on three pillars:

1. dogma of existential scarcity
2. romanticisation of nature
3. logic of guilt toward nature

These aspects lead to avoidance becoming the basic idea of life in this view. But this ideology of scarcity creates distribution struggles: Who has to renounce? Who is still allowed to have things? For such a movement to be successful, it must be linked to openings and new freedoms that give hope for the new, the better.
Therefore, a paradigm shift from scarcity to fullness must be at the center of such a change. Matthias Horx (2020) explains it with an example.

"Pathological obesity is not uncommonly the result of the feeling of "not getting enough." However, on a different, an emotional level. Food, as we all know, is a damn good comforter, a great "compensate."

> So we eat more than is good for us. We shift a lack on one level to an experience of overabundance on the other. However, in doing so, we remain stuck on the lack. Paradoxically, we never become fulfilled, even though we are in a state of abundance. This trance-like state is similar to the whole of industrial civilization in relation to oil and its derivatives: we cannot get enough of it BECAUSE we are constantly afraid of running out. "

A change can only work if we free ourselves from the fear of not getting enough, not through green asceticism but the recognition of fullness. In this way, a new freedom of renunciation can emerge in which we do not have to miss anything. He cites the example of Copenhagenisation, which refers to the displacement of cars from cities.

> If looked at this from a lack perspective, it only reduces the possibility of moving around the city by car. However, when entering a city like Amsterdam or Copenhagen, the mindset changes; cars are not missed at all; it is instead enjoyed what is possible without them. It is similar to the smoking ban in restaurants and planes, which is a clear restriction of freedom at first glance.
> When this regulation was introduced, it seemed like a release.
> A new social abundance was created in which smokers could meet new people outside the door and not have to feel bad about smoking up others.

Blue ecology means adopting a different way of thinking in which new fullness can be experienced through liberation from too much. To reach this blue horizon, new technologies, movements, and ways of thinking are needed that show that was consciously deciding against the use of specific resources and products or the discontinuation of habits has nothing to do with lack but happens in favor of experiencing a new diversity of possibilities.

3.6 AESTHETICS AND SUSTAINABILITY

The design of resource-saving and sustainable products introduces a new set of aesthetics. Influential factors here are the material used, which visually already occupies a very dominant position; in addition, other factors have a significant influence on the aesthetics indirectly.

3.6.1 RECYCLABILITY

True recyclability and, thus, the avoidance of waste influences the aesthetics in the shape of mono-materials, and the authenticity of these (no coloring) and not combining plastics with different degrees of solidity changes, for example, the approach to how contact surfaces on products are designed. In order to provide grip surfaces with a non-slip, simply softer plastic or a natural material such as cork, elements should be fixed with connections that can be detached before disposal.

These detachable connections, other than adhesive or non-destructive detachable connections, affect the complexity of the design, which can be seen in both volume and visual characteristics. The impact the recyclable design has is also a feature of sustainable aesthetics.

3.6.2 UPGRADEABILITY/REPAIRABLE REPARABILITY (OPEN PRINCIPLE)

Although this thesis focuses on durability, it is nevertheless impossible to imagine our time without technological change. In order to avoid replacing entire products, possibilities should therefore be created to replace individual elements that may wear out (reparability) or replace components where innovation is predictable (upgradeability). Thus, should more powerful electric motors with lower energy consumption be introduced to the market, installing them in the system should be possible.

Fig. 38 Karl Clauss Dietel with one of the first designs of the SR51 scooter

Excursus: A historical example of this type of design is the design principle described by Karl Clauss Dietel and Lutz Rudolf as "The Open Principle", which was intended to ensure lasting functionality and usability. This principle was applied for the first time to the Heliradio rk3, which set itself apart from conventional, closed wooden sound furniture through simplification and increased objectivity. ›

The innovation lay in the consistent emphasis on the technical character and the separability of the individual components. The best-known example in Germany, which is still the first motorbike many people drive today, is the Simson S50. The individual components are positioned so that anyone can replace them, regardless of innovation, defect, or changing aesthetic requirement

However, in order not to create a new chain of needs or to avoid generating another waste product by replacing the existing component (motor), it must be ensured right from the initial assembly that the replaced component is reusable (returns to the cycle) or can be completely recycled.
In this context, companies have new responsibilities; products are not fundamentally reworked and brought to market as a new version; instead, information about upgradeability is always provided, necessary components (e.g., adapters) are offered, and components and devices are taken back, repaired, and offered again.
The direct effects on aesthetics can be: a larger construction volume to allow space for easy reparability and the exchange of components (with various dimensions). Increased use of (non-destructive) detachable connections, whereby the connections should not be too easy to detach, as frequent use of, for example, snap connections, out of curiosity, will damage them and thus limit the longevity of the component/product. Simple tools (e.g., coin, card, spoon, pin) are possible to unlock these connections.

3.6.3 COUNTERACT TRENDS

Styling and following the ever-emerging trends in terms of color, shape, and materials not only creates ever new needs, which is not sustainable per se given the current production standards, the materials used in combination with the unwillingness to repair/recycle products, but in times of ultra-thin 4K TVs and the general trend towards flatter-is-better also brings with it design aspects that make sustainability challenging to implement.

Adapting trends in shape and color to newly designed products becomes questionable if looking at the shape development of the iPhone generations. Without even mentioning the fashion industry, it can be said that trends usually return in a slightly modified way. A change in aesthetics is often based on maximizing profits by exploiting our consumer behavior. Especially the aspect of the social significance of the products is exploited.

The rounded iPhones of the 6th generation, with modifications of the size, the camera as well as the buttons, formed the standard from 2014 to 2021. In 2014, it was a strong contrast to its predecessor with angular edges. The result: with over 200 million units sold, this is still the most sold iPhone generation. The strong contrast made it easier to tell whether a already new or still an old iPhone is owned. The modifications of the following models increased sales slightly until April 2021, when the iPhone 12 (square edges) drastically increased sales again, with over 120 million units sold after only half a year on the market (Oiku, 2021).

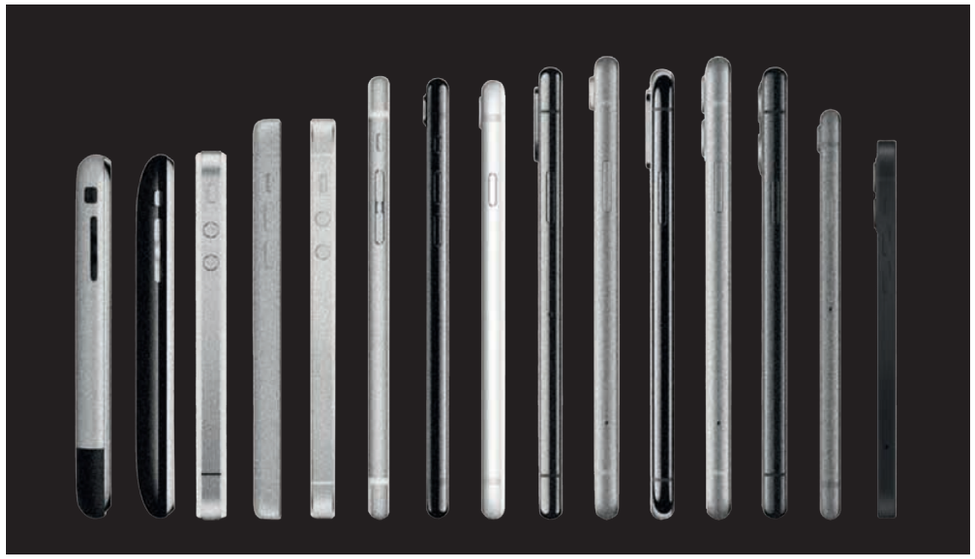


Abb.39 Apple iPhone Shape Development

A simple and unobtrusive design should be chosen to avoid this consumer behavior. For smartphones, the actual color is usually hidden/modifiable by changing the cover and can thus be kept simple. In the case of products designed for real longevity, the choice of color should be possible through exchangeable elements. In this way, either a part can be exchanged for individualization or, in the case of repair, the product can be given a new aesthetic by replacing a component, and thus, similar to Kintsugi, the broken can be repaired and improved at the same time.

Another example of using an Apple product shows the difficulty of counteracting the trend of thinner-is-better: the first reports and forum entries on the 2021 MacBook generation were filled with criticism that it is thicker and heavier than the predecessor model.

That this might be a necessary development to make products more resistant never occurred (In Apple's case, it is due to the higher cooling power needed to drive the new chips, not to improved resistance). However, this is one of the aspects that will shape the design of the next few years, not only in terms of durability but also to enable the use of recycled materials. For example, recycled ABS (rABS) has a higher stiffness, making the product more fragile using the same shapes, wall thicknesses, and stiffeners as ABS. Therefore, even more concerning the future use of bio-plastics,

a development towards more voluminous shapes is recommended. Although more material is needed for them, this additional usage is amortized by the more extended durability and the use of recycled raw materials/bio-plastics.

3.6.4 MATERIAL DIFFERENCES

The materials from which many products are made today are mostly dyed or painted. Both require additional raw materials and energy. Avoiding the general dyeing process and taking the raw material as it is or not re-dyeing the recycled materials will save resources and energy.
Dyeing also means that the material is contaminated, which can be recycled less often.
The production of a (materially) uniform product aesthetic can no longer be guaranteed.

However, this does not have to be seen as a disadvantage.
The desire of many consumers for individualization/personalization of their products is made possible by this, as by the already mentioned replacement of individual components with colored components. In addition, authentic materials have a strong symbolic power, which, as already mentioned, is necessary to establish the aesthetics of this materiality.

DESIGN GUIDELINES

4.

This design guide has the purpose of offering designers an overview of the aspects relevant for designing products with an improved impact on resource scarcity. Currently, consumer electronics still rely on critical raw materials and other non-renewable resources. In order to maintain our quality of life, basic needs, and a stable system, rethinking our use of resources is essential. Product designers and manufacturers, along with the consumers, play a significant role in this topic.
It is the twenty-first century's designers' responsibility to work towards a transition of sustainable resource use. This design guide offers an overview of implementing positive changes to be part of the mentioned transition. The established guidelines are relevant for designers, manufacturers, and other actors in the system around the design, manufacture, distribution use, and waste management of consumer electronics.

4.1 MATERIALS AND PHYSICAL PROPERTIES

4.1.1 Create longevity
4.1.2 Plan for disassembly
4.1.3 Select materials
4.1.4 Use recycled materials
4.1.5 Optimize material use
4.1.6 Optimize material quality

4.2 BEHAVIOR AND AWARENESS

4.2.1 Create satisfaction through use
4.2.2 Strengthen values and perspectives
4.2.3 Make ideals and values visible
4.2.4 Strive for completeness in products
4.2.5 Consider frequency of use
4.2.6 Change consumption

4.3 COMMUNICATION AND MARKET POSITIONING

4.3.1 Offer counter-designs for negative product trends
4.3.2 Know the target group
4.3.3 Convince customers
4.3.4 Use contemporary luxury consumption patterns
4.2.5 Market ‚aesthetics of sustainability'

4.1 MATERIALS AND PHYSICAL PROPERTIES

The guidelines listed under the category of ‚materials and physical properties' directly impact the designed product's physical nature. They were created to improve the impact of the physical properties (e.g., the types and quantities of materials) to improve the direct impact of the feedstock and the end-of-life factors required for products.

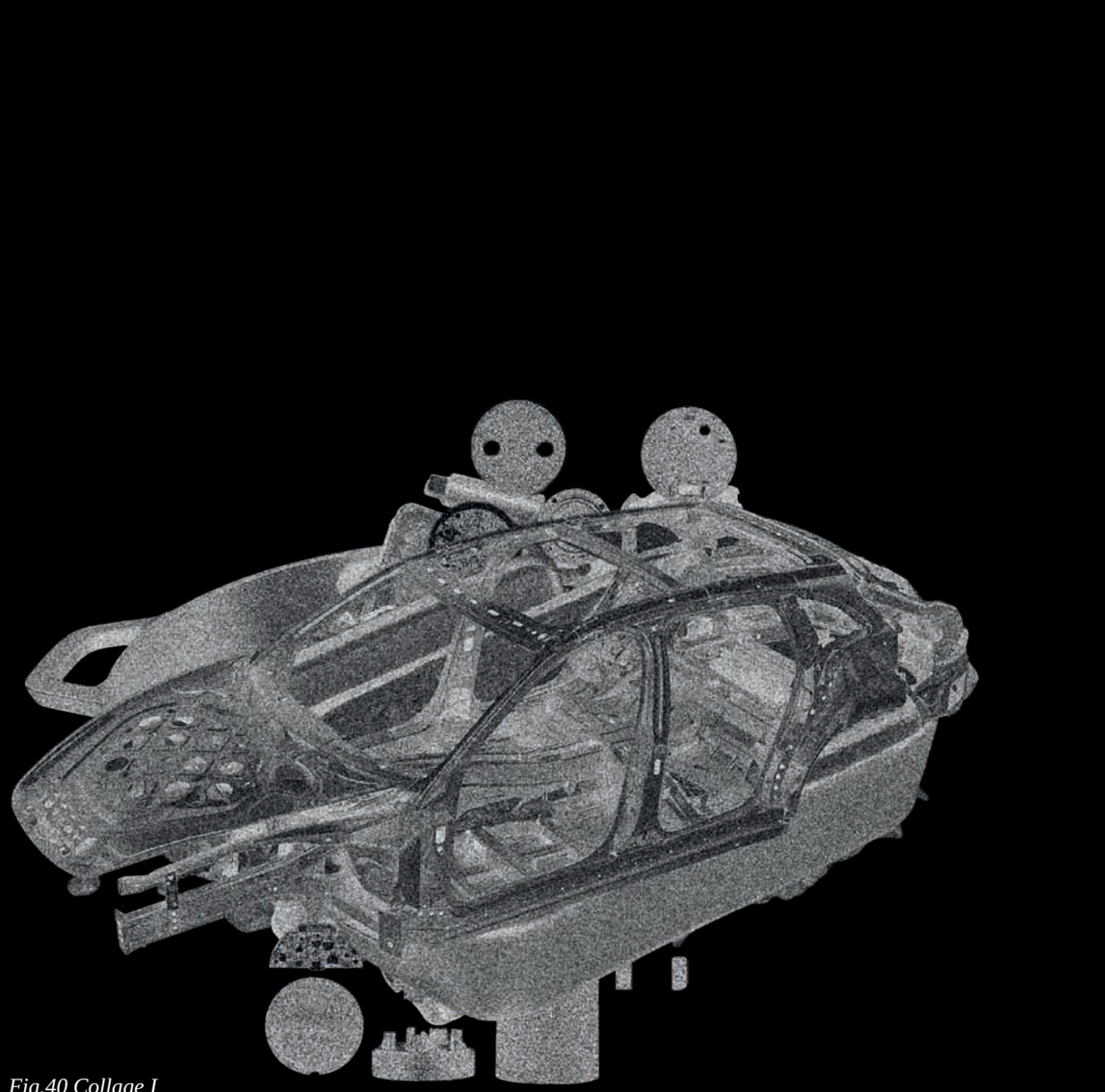


Fig.40 Collage I

4.1.1 CREATE LONGEVITY

The longer the product life, the later it needs to be replaced; thus, fewer products are produced. This saves energy required for producing products and materials, the emissions for transport, and fewer raw materials are required. This also means that easy repairability should be possible.

Design Implications:

1. Never design for planned obsolesce

2. Define the reasonable lifetime for the product to be designed (Shorter for single-use bottles, longer for thermal flask)
3. Design the product to have the lifetime defined. If the product lifetime is longer than reasonable, resources may be wasted. (e.g. a single-use bottles out of stainless steel are wasteful, while stainless steel is a suitable material for thermal flasks)
4. Product aesthetic needs to suit the defined lifetime (e.g., a long product lifespan calls for a trend-independent aesthetic)
5. Design product to allow easy repairability (e.g., allow for the replacement of thermos flask lid in case it breaks)

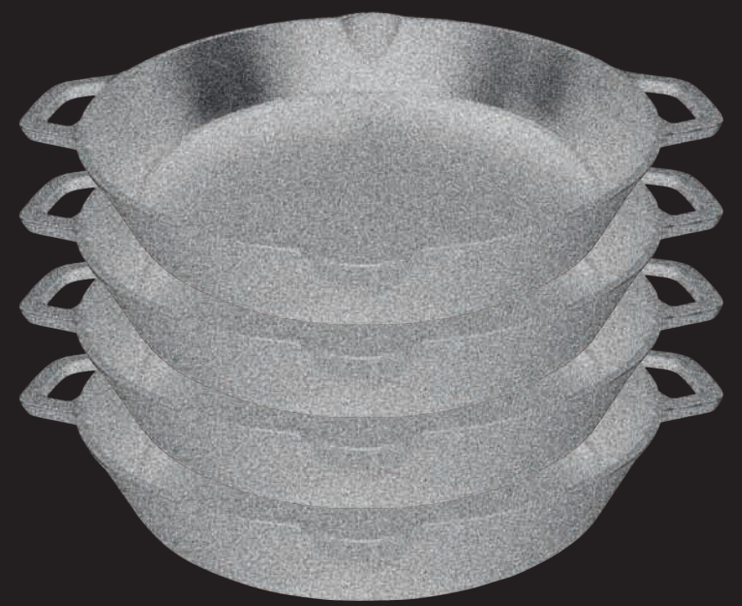


Fig.41 Cast iron pans

4.1.2 PLAN FOR DISASSEMBLY

When a product comes to its end of life and enters the waste stream, in order to have good recycling properties, disassembly must be possible and easy - this also is important for good repairability. That easy disassembly is possible; it must already be considered in the design phase of a product.

Design Implications:

1. Allow for easy disassembly of building parts

2. Allow for easy separation of materials

3. Consider the impact of connections in a product on the following aspects: Longevity, recyclability, repairability of product, and the disassembly of the product (e.g., bolts allow disassembly and reassembly and thus reparability but have a more negative impact on recyclability than, for example, adhesive bonds, which, however, do not allow reparability).
4. Minimize the quantity of building parts and materials used

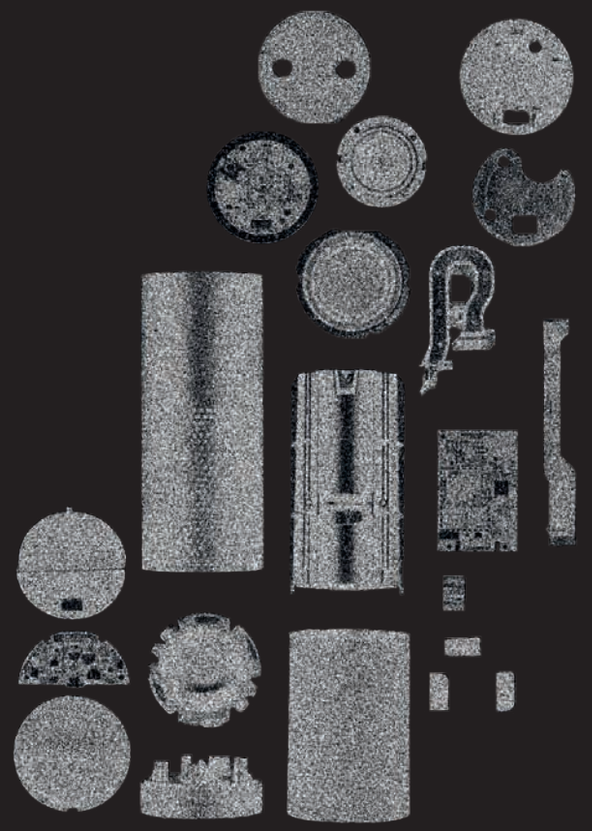


Fig.42 Loudspeaker parts

4.1.3 SELECT MATERIALS

Since ABS, PS, and PP make up about 55% of the plastic in WEEE, their recycling is the most lucrative and, therefore, most efficient (Sliz, 2019). In contrast, other materials such as PC or PMMA are only present in small quantities (1-2%); thus, their recycling is economically uninteresting. Therefore, materials that are as common as possible should be chosen (Sliz, 2019).

When considering materials in the design of a product, the following points should be considered when deciding which materials to use: Suitability, recyclability, scarcity, the energy required for production and transport, durability, and other applications which require these materials.

Design Implications:

1. Chose materials with good recycling properties and high recycling rates
2. Chose materials suitable for the use case
3. Chose common materials (e.g., ABS, PS, PP)
4. Replace critical materials with noncritical substitutes if available
5. Replace fossil-based materials with renewable materials

Fig.43 Recycled granulate

4.1.4 USE RECYCLED MATERIALS

The properties of recycled materials may vary in comparison to their virgin counterparts. Products should be designed in a way so that recycled materials can be used.

It must additionally be considered that WEEE plastics are sorted for recycling with near-infrared detection (NIR). This technology only reliably detects light-colored plastics. Dark ones are detected unreliably or not at all but make up 60-80% of WEEE plastics (Sliz, 2019).

Design Implications:

1. Choose recycled materials (e.g., rABS instead of ABS)

2. Check variation in properties of recycled materials versus their virgin counterparts (e.g., higher stiffness of rABS in comparison to virgin ABS)
3. Design products to fit the properties of recycled materials (e.g., rABS might need thicker walls than ABS due to it being slightly stiffer)
4. Consider the impact of color on recycling (e.g., lighter-colored plastics can be reliably detected in the sorting process while darker plastics cannot)

Fig.44 Plastic waste

4.1.5 OPTIMIZE MATERIAL USE

The quantity of material should be used as optimized as possible. Regarding quantity, products should contain the least amount of material possible to meet the properties and requirements. This not only improves the impact of the product regarding resource scarcity but is also the best way economic-wise.

Design Implications:

1. Rethink if the product is necessary

2. Consider if products need to be physical or if they can be a service

3. Consider a sharing system instead of product ownership

4. Reconsider which parts are necessary

5. Design products with the minimal resource use

6. Collaborate with other companies and institutions to build networks toward introducing circular products.

Fig.45 Car frame

4.1.6 OPTIMIZE MATERIAL QUALITY

A big issue when recycling is the pureness of materials. The use of composites and other multi-materials is therefore problematic concerning the recyclability of a product. Mono-materials should be used in as many building parts as possible.
Additionally, coatings and paints are often problematic since they are hard to remove and impair material purity.

Design Implications:

1. Choose mono materials instead of blends (e.g., PC or ABS instead of PC/ABS blends)
2. If mono materials are not an option, consider the impact of blends on the recyclability of the product (e.g., using blends in small quantities might make the complex recycling of them unfeasible, or if pure ABS is combined with an ABS/PC blend, both materials might be recycled as a blend, thus reducing material purity)
3. Design for the use of mono materials (e.g., grip surfaces can be textured instead of rubberized)
4. Choose non-hazardous and safe materials (not only the hazardous level of the materials (e. g. the green screen score) but also the hazardous level of additives need to be considered here)
5. Avoid coatings and varnishes to keep materials pure

Fig.46 Gold bar

4.2 BEHAVIOR AND AWARENESS

Products and consumer behavior are interrelated. Products influence our consumption patterns and other behaviors, influencing the design and demand for products. Thus behavior patterns play an essential role when targeting our resource use. This section focuses on aspects a designer can consider when targeting consumer behavior concerning the sustainability of consumer electronics.

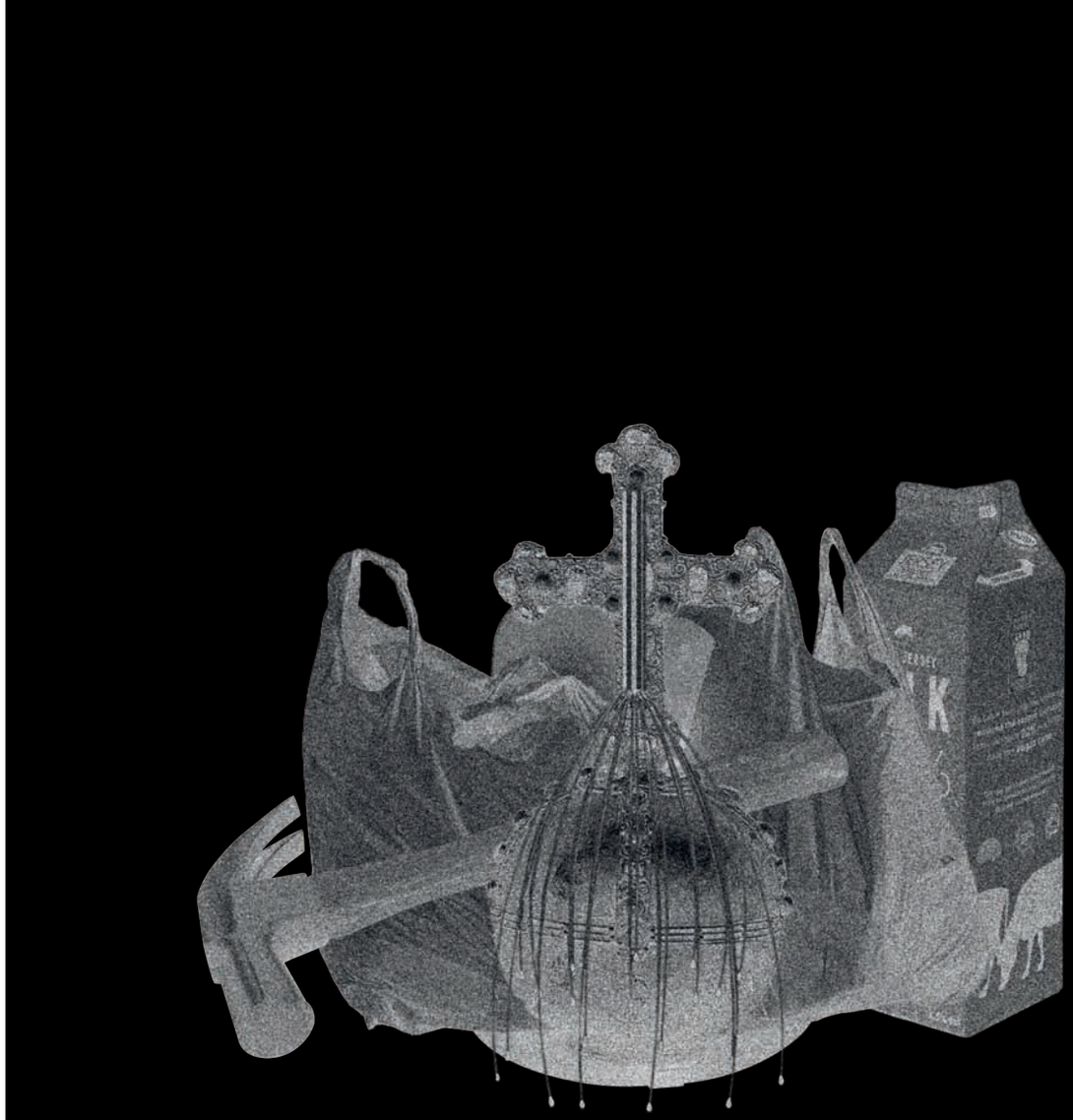


Abb.47 Collage II

4.2.1 CREATE SATISFACTION THROUGH USE

Since experiences fade quickly in everyday life, it cannot be generally argued. ‚Experiences are better than objects‘. This is because the pleasure of the purchase can last longer, depending on the product, and thus have a disproportionately greater value (Oberhuber, 2016). Those who buy a nice bicycle and ride it on nice tours have long and often deep satisfaction.

Design Implications:

1. Design for stronger emotional bonds of users to products

2. Design for good experiences during purchase and use

3. Combine product with satisfying activities to create sustained satisfaction with each use

Fig.48 Scalp massage

4.2.2 STRENGTHEN VALUES AND PERSPECTIVES

Beyond showcase consumption, products are means of communication that help a social group maintain exchange and thus defend its values externally.
If we assume a group that already consumes responsibly, products and the exchange about them help defend themselves against the influences of society‘s mass consumption. If these products can be the focus of a group meeting, this improves the effect.

Design Implications:

1. Create a product that supports trends with positive impacts, supporting the values and perspectives both internally and externally
2. Target consumer groups that already support values relevant to tackle resource scarcity and are open to change

Fig.49 Orb

4.2.3 MAKE IDEALS AND VALUES VISIBLE

After communicating internally, products can also have communicative aspects externally. If products are seen to be different through their form, materiality, use, or branding (e.g., Veja shoes), they become the medium of the new ideals. Even more, using these objects can have an educative effect on others, stimulate thinking and thus influence other social groups.

Design Implications:

1. Analyse the values of interest present in the consumers of designed product
2. Design for target values, make them visible and present (e.g., a product that targets repairability not only needs to be repairable but also needs to communicate its repairability)
3. Create products that stand out to increase their communicative effect.

4. Create products with an honest design

Fig.50 Siren

4.2.4 STRIVE FOR COMPLETENESS IN PRODUCTS

These products can exist somewhat detached from innovations. Many new products are constantly replaced to keep up with the pace. Traditional objects are generally more consistent, they often no longer have an „actual “ function, but they still carry a strong symbolism. The completeness characteristic stands in strong contrast to a rapid change of life and helps to come to rest and decelerate life.

Design Implications:

1. Dispense with components that frequently require updates or brake

2. If components that require frequent updates are necessary, allow easy upgradability for them by designing them modular. This also allows improved repairability if a part breaks.
3. Analyse wether innovations bring actual benefits to use and function or if they serve primarily as an incentive to buy the product.
4. Only innovate when there is a real benefit for the user, the manufacturer, the function and the environment.

Fig.51 Hammer

4.2.5 CONSIDER FREQUENCY OF USE

We only build a bond with products we need and use, which brings an appreciation for their effort to use and maintain them. The Norwegian industrial designer Roar Høyland already addressed this in 1938. He gave the example that improving the milk carton was more important than improving another expensive chair.

Design Implications:

1. Analyse whether a product with low impact, but high frequency of use or a product with high impact and low frequency of use is better at achieving the impact desired

Fig.52 Milk carton

4.2.6 CHANGE CONSUMPTION

If consumption does not make us happy, we should rethink how we consume. Owning fewer products means taking responsibility for fewer products that take time to use (if we use them) and maintain.

Design Implications:

1. Rethink if the problem the product is supposed to solve is actually a real problem
2. Analyse if other options than products can solve this problem in a better way (e.g., a service)
3. Analyse whether it is beneficial if one product can solve multiple problems

Fig.53 Shopping bags

4.3 COMMUNICATION AND MARKET POSITIONING

Creating ‚good-example-products' helps influence policymakers, product trends, and manufacturers. These good examples need to enter the market for maximal impact efficiently.
This section offers various aspects that help bring good examples to life. The guidelines offer ways to influence and convince key actors of the importance of this topic, find points of entry into the market and establish good examples.

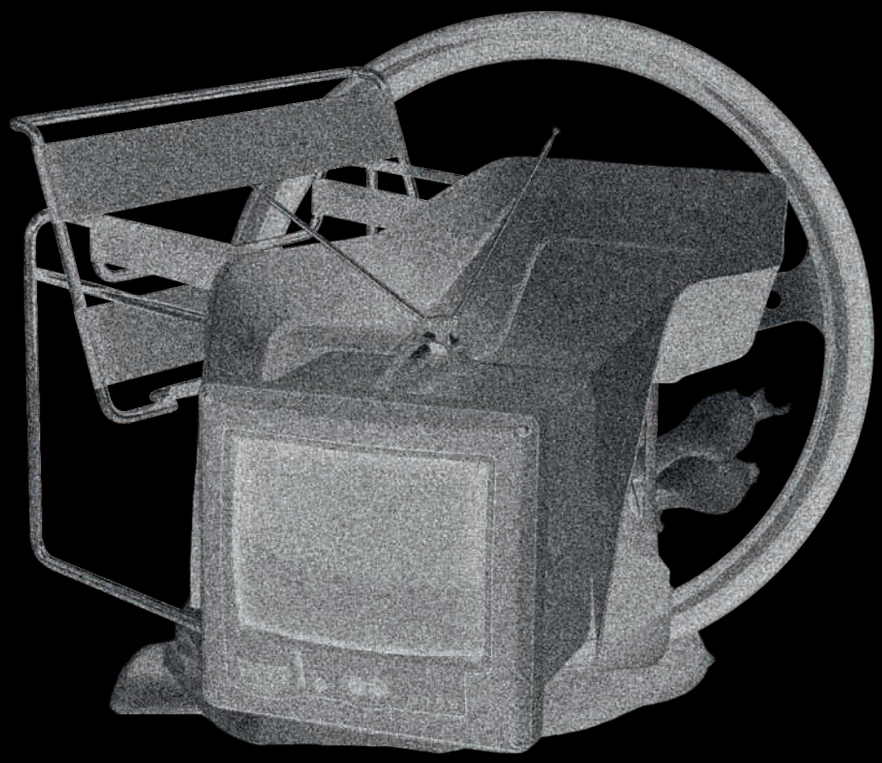


Fig.54 Collage III

4.3.1 OFFER COUNTER-DESIGNS FOR NEGATIVE PRODUCT TRENDS

Creating designs outside of existing trends with negative impacts or steering the existing trends with product design into directions with improved impact helps shift the wide-spread understanding of „good design“ toward improved environmental impact.

Design Implications:

1. Question existing product trends

2. Counter design for negative product trends - create good examples

Fig.55 Jim Nature Portable Television (Philippe Starck)

4.3.2 KNOW THE TARGET GROUP

A movement brought to public attention as early as 2000 by the study of sociologist Paul H. Ray and psychologist Ruth Anderson is LOHAS - Lifestyle of Health and Sustainability. The ‚Trend Report Target Group LOHAS - How the Green Lifestyle is Conquering the Markets‘ (titles translated by the author) published in 2007 assigns 30% of the German population (similar to the USA) to this group (Glöckner et al., 2010). The central aspect of their actions is strategic consumption, which aims to change and influence the environment through new values such as authenticity, information, honesty, and sustainability - influencing the purchase of new products.
The great opportunity is that these values reach the broad, middle-class. With their purchasing power, they are in a position to change the economy. Changing their purchasing criteria can encourage the economy to bring complementary products onto the market.

Design Implications:

1. Target groups open to changes and more strategic consumption decisions (e. g. the LOHAS group)
2. Analyse complementary trends and developments present in such groups and integrate them, if possible, to maximize the effect on sustainable transitions and establishing products

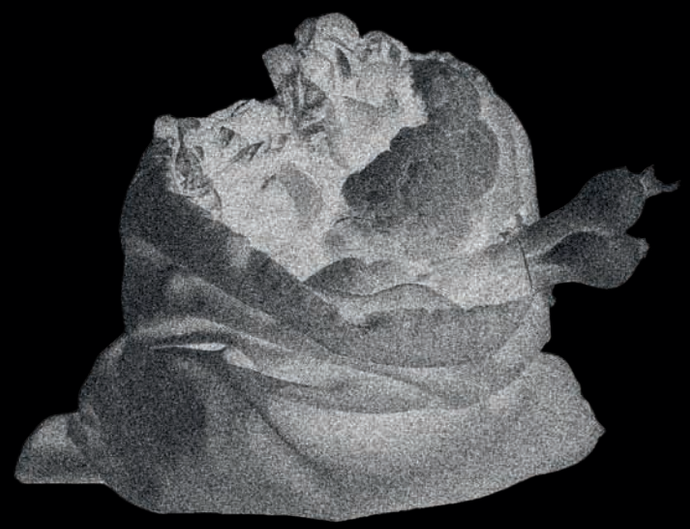


Fig.56 Conscious purchase

4.3.3 CONVINCE CUSTOMERS

Resource-oriented product design might conflict with short-term economic or operational goals but is essential for the long-term performance of companies. It also has the potential to conflict with established practices, customer expectancies, and supplier networks.

Therefore establishing resource-oriented product design practices must be well argued.

Implications:

1. Policies regulating resource use will come and get stricter. Companies that act early stay ahead of policies and will have market advantages when policies are introduced over non-acting companies
2. Customer expectancies are already changing towards more sustainable and aware behavior. Their product expectancies will likely continue shifting within the near future. Acting companies can fulfill these expectancies while non-acing companies cannot. This helps keep existing and aware customers and likely win new ones
3. The aware consumer target groups appreciate honest and value-oriented production of products. Thus good practices will have beneficial effects on customer loyalty.
4. With resource scarcity getting increasingly severe, their availability, especially critical raw materials, will be at risk while their prices will experience severe increases. Resource-oriented product design buffers these effects and secured the position in the market

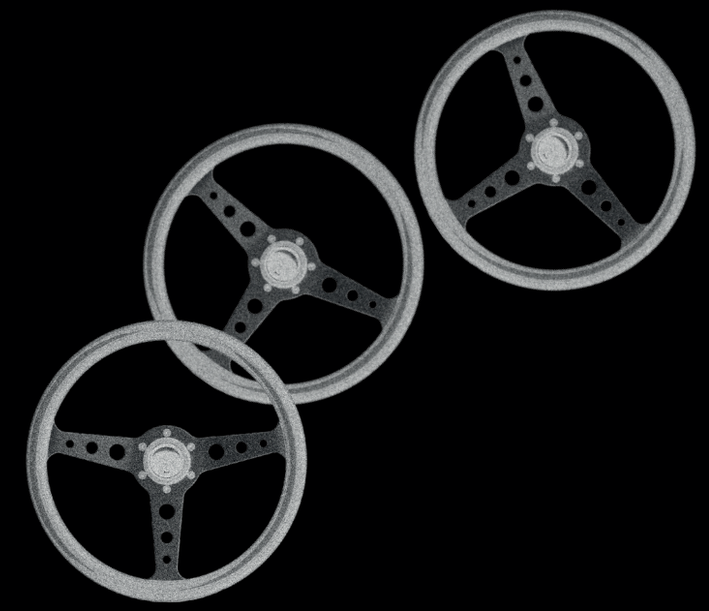


Fig.57 Steering wheel

4.3.4 USE CONTEMPORARY LUXURY CONSUMPTION PATTERNS

The contemporary consumption of luxury is, in contrast to traditional luxury, strongly linked to competencies. Such competencies are aesthetic taste, sensitivity to symbolism, and expertise. Consumers of these products want to satisfy their desires linked to these competencies and communicate them to their peers and surrounding.
This creates a market for products supporting more aware consumption with positive impacts and thus provides possibilities for economic success when introducing resource-oriented products into the market.

Design Implications:

1. Design products that openly show values, properties, and symbols

2. Design products with a striking and well-made aesthetic

3. Create a good use experience of the designed product - the functions may be simplified, but the functionality of the designed product needs to be optimized

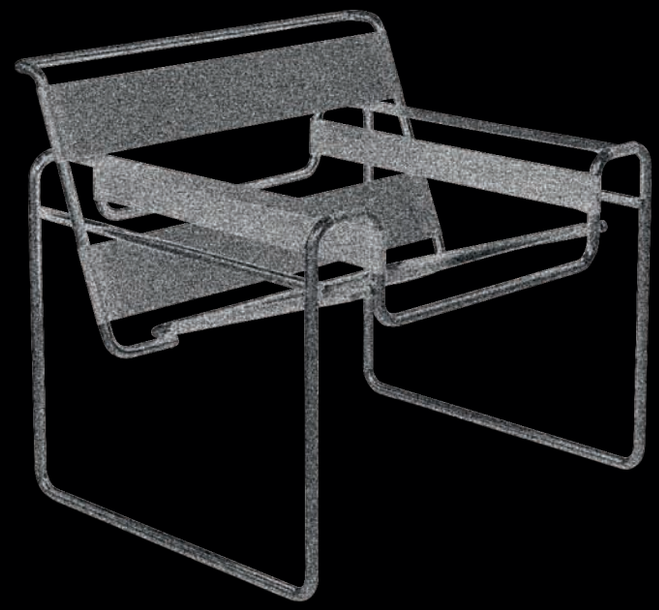


Fig.58 Wassily Chair (Marcel Breuer)

4.3.5 MARKET ‚AESTHETICS OF SUSTAINABILITY'

The guidelines focusing on the physical properties will also affect and limit the aesthetics of the designed product. Existing trends and established product aesthetics will likely conflict with the new aesthetics. This conflict has a critical communicative role. This conflict allows the new product to stand out in the near future, thus offering marketing opportunities and helping establish good practices and trends in the long term.

Design Implications:

1. Embrace the newly created aesthetic - do not hide it

2. When this aesthetic of sustainability is not established, use it as a selling point for early adopters
3. When this aesthetic of sustainability is starting to be established, it becomes the new normal and can then be further intensified/advanced.

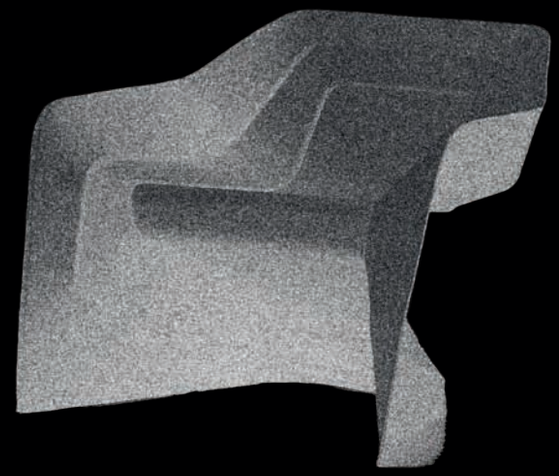


Fig.59 Hemp Chair (Werner Aisslinger)

5. USING THE GUIDELINES

In order to verify the guidelines resulting from the research, they will be applied to redesign three electronic consumer products.
The products selected are a docking station for the workplace, a timer, and a hard drive case that can be equipped. Each of these products represents one of the three main points of the research and is intended to illustrate the values or methods identified under this point. Despite the increased focus on one field, the other fields should not be neglected; the different weighting merely makes it possible to comprehensibly demonstrate the versatile aspects and possibilities of how resource efficiency can be designed.

5.1 COOPERATION AND ORIENTATION

In order to verify our guidelines in a first application example, we cooperated for this project with Punkt, a Swiss company that produces electronic consumer goods with high-quality standards, aiming to influence the everyday life of the users positively.

The company focuses on the effects of increasing digitalization, its impact on our lives, and how this affects the human psyche.
The company offers, for example, mobile phones that are reduced to the basic functions: Making phone calls and writing text messages. This reduction makes the phone a much smaller distraction in everyday life. Whether it is at work, in order not to be distracted from focusing by the constantly illuminated screen, or the tunnel vision on the smartphone in everyday life due to the unrestricted access to social media. At the same time, the mobile phone symbolizes a new lifestyle of conscious renunciation due to its understated design and high quality. In addition, the company values timeless aesthetics and functionality in all its products.
Therefore, the dialogue about the selected products focused strongly on the future relevance of the products, which developments are expected, and how the products can be designed most appropriately.

This aspect included, among other things, questions about how to deal with technological innovations, which materials are future-proof, and which aesthetic ways this change must bring.

The company's strong ideals and belief that the right products can influence consumer behavior made it the ideal partner for this project. We held in-depth discussions with experts from various fields at all stages of the project to maintain a realistic approach at all times.

Punkt.

5.2 SELECTION OF THE EXEMPLARY PRODUCTS

The selected products were chosen to represent the theme of materiality, communication, awareness, and behavioral change. The aspects of necessity, usefulness, and frequency of use in the field of awareness played an essential role from the beginning of the search process.

Since the selection of products is not only subject to the preceding requirements but also many other factors and limitations, the selection and the reasons for designing these products will be explained in the following.

5.2.1 DOCKINGSTATION / MATERIALS AND PHYSICAL PROPERTIES

Due to the pandemic, many people were forced to move their workplace from the office to their homes within a very short time. What was unfamiliar for many at the beginning became welcome normality. With this change in working life, which affects almost all areas, our work devices are also changing.

A laptop replaces the desktop computer or the network to which the computer is connected is accessed from a laptop. Ergonomic work is only possible to a limited extent on laptops, despite all their practicality, which is why the laptop is usually connected to a screen, mouse, and keyboard when working for long periods. To make it easier to carry the laptop to work, so that only one cable has to be pulled, a docking station is a perfect solution to make it easier to set up and connect the laptop at the workplace and keep the workplace tidy.

In addition, many new laptops only have a USB-C port with which all additional devices can theoretically be connected. In reality, however, we still have many products with an "old" USB-A port or occasionally need to access an SD card, connect the screen with an HDMI cable or use a LAN cable for faster internet access. Therefore, it makes sense to have a docking station at the workplace that offers all these possibilities.

The high relevance of this product in everyday life should therefore also be reflected in its design.

As a product that should represent the material aspects of the design guidelines, the focus is on the choice of materials, and the design of the form for better reparability, upgradeability as well as recyclability at the end of life. In this way, sustainable alternatives to fossil raw materials are to be demonstrated, individual connections can be replaced if they become defective, or connections can be exchanged/replaced with another if necessary.

5.2.2 HARD DISK CASE / COMMUNICATION AND MARKET POSITIONING

Data backup, data transport, and data transfer are an integral part of our increasingly digital lives. Clouds allow us to access data from anywhere in the world, waste less space on our devices backing it up, share it quickly with people and work on projects with others simultaneously.
These are just a few arguments favoring clouds instead of the "old" hard drives. However, clouds also require much energy, and data transport requires much energy, as does the cooling of the necessary hardware. The cooling of this, like the operation of the computers with which crypto mining is carried out, has a negative impact on our climate (Süddeutsche Zeitung, 2019). Apart from the ecological aspects, the security of one's data is also an issue that concerns many people: Where is our data stored? What happens if an incident occurs there and we can no longer access our data? Moreover, without raising any alarm bells, who can access our data? Access our data? We disconnect an external hard drive from the computer or tablet, making it inaccessible.

In the selection process, the previous arguments played only a subordinate role; the essential point related to this project is the preservation of functioning, complex, technical products and all the side effects that this preservation entails. This is because hard disk production and recycling require plenty of resources and energy.
This is why preserving hard disks is more sustainable per se than disposing of them. Another aspect is that the consumer can become part of the recycling process, and at the same time, an understanding of the complexity of electronic products is created by removing the hard disk from a laptop or PC. The decision was made in favor of a mobile hard drive case that is as robust as possible since, as already mentioned, data backup is an everyday topic and is often carried along. The product can become a strong communicator by using recycled materials, which are otherwise rarely or never used in this form. The already strong symbolic power of the materiality can also be reinforced by visual signs indicating that the hard drive (only the case) can be dismantled.

5.2.3 TIMER / BEHAVIOR AND AWARENESS

Many products we own but rarely use are permanently connected to the power supply. In standby mode, however, these products require much energy. Although electronic household appliances have only been allowed to draw one watt from the power grid in standby mode since 2014, according to an EU regulation, all appliances in a household together still consume up to 360 kilowatt-hours (kWh) per year. (NDR, 2022) The use of timers, therefore, already makes sense for cost reasons. In this project, however, the focus is on the consciousness-raising level.
A timer switches on the electricity; with the product that is to be designed here, the electricity is to be consciously taken away, switched off, and turned off. Consciously means that the user should take a closer look at the devices he uses: How they use them, whether their consumption is beneficial or harmful, and whether limiting them would change their lives for the better? The application can not only be related to devices that need a permanent power supply.
Smartphone batteries, which in most cases are incorrectly charged, are often left plugged in for too long instead of being disconnected when fully charged as they should be, which is detrimental to the life of the battery. However, this is only one of many applications where the watch can be used and influence the user's behavior.

5.3 DOCKING STATION

The three products have been created to provide an example for using the design guide developed. While utilizing a broad range of guidelines, the docking station focuses on the category ‚Materials and physical properties of the design guide. The physical nature of the docking station thus presents the most critical aspect of our design.

The goal was to showcase a viable and aesthetic product with all the limitations a consequent use of the design guide presents. These limitations occur in the choice of materials, the material characteristics, the components' nature, and the components' arrangement and connection in the final product.

The design of a functional, appealing, and viable product centered around the design guide provides an example of how consumer electronics could be produced, assembled, looked at, used, maintained, reused, and disposed of with an improved impact on the present and future resource scarcities.

5.3.1 PROCESS

The first step that was taken in the design of the docking station was analyzing problematic elements on current models. This was done both by theoretical research, but also by disassembling current models. The main flaws discovered were the selection, and quality of materials, the assembly and disassembly process, the nature of the components and the structure.

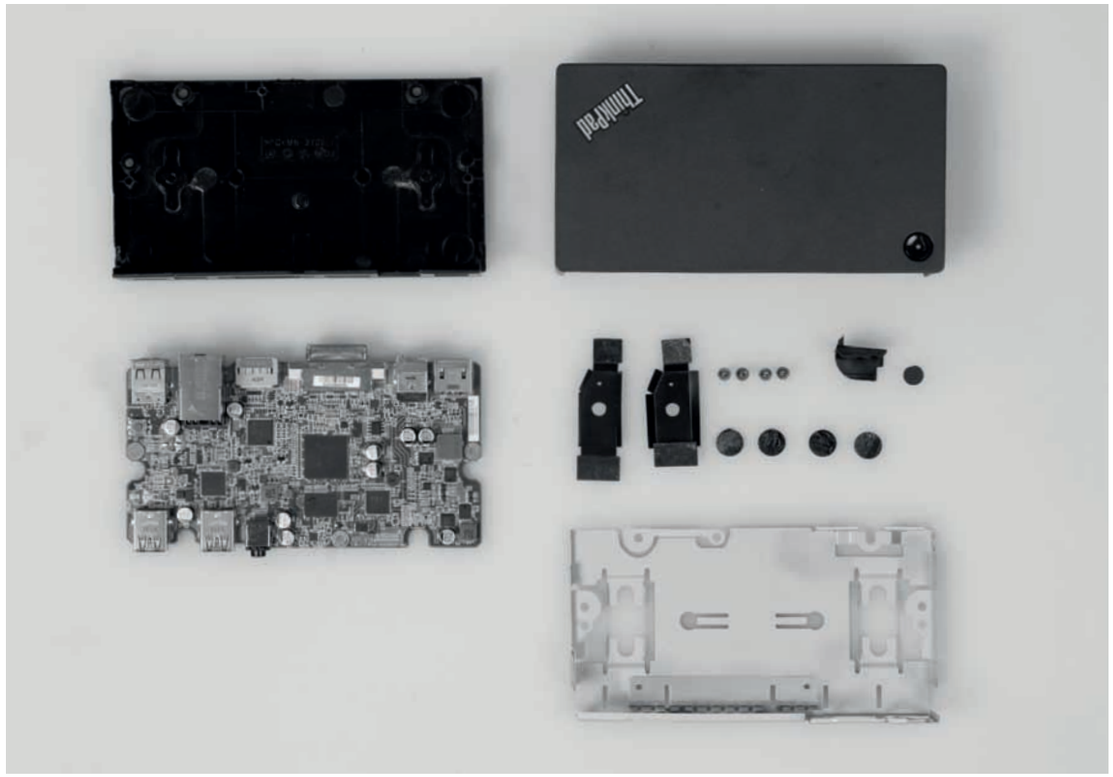


Fig.60 'disassembled' Lenovo docking station

The first step in the docking station's design was analyzing current models' problematic elements. This was done both by theoretical research but also by disassembling current models. The main flaws discovered were the selection and quality of materials, the assembly and disassembly process, the nature of the components, and the structure.

In order to create a suitable selection of materials for the docking station, the different functions the materials fulfill in this product were analyzed.

The electrical components in a docking station are limited to a printed circuit board (PCB) with the desired docks and a connection cable. These components contain the most critical elements; thus, they should be accessible in case of repair, replacement, or recycling. Otherwise, the docking station should provide a secure stand and prevent both the docking station and the laptop from slipping. Additionally, the PCB should be protected from ›

damages (e.g., shocks) and should be enclosed to prevent physical contact by users, which would present a hazard due to potential electrical shocks. The PCB further be stored securely in a suitable position.

Fig.61 ABS recycling

Based on these factors, it was decided that two primary materials were needed. One rigid and precise material provides a solid structure, fixation points for the PCB and docks for the different connectors, and elastic material with anti-slip capabilities and shock resistance.
After analyzing potential materials to fulfill this purpose, it was concluded that mono-material Acrylonitrile butadiene styrene (ABS) was suitable. Besides the technical suitability, the main factor was the ABS's high recycling rate. ABS is commonly found in a high amount of consumer electronics, as mentioned early; thus, its recycling is very efficient (e.g., other potential materials like polycarbonate are used in smaller quantities, thus offering lower recycling rates).
Due to guideline 4.1.4 ‚use recycled materials' and the excellent availability of recycled ABS (rABS) the components using that material should be composed of rABS.
With slightly varying properties compared to virgin ABS (e.g., rABS being slightly more brittle than virgin ABS), the structure of these components needs to fit these properties.
The first decision for the second material was cork. With cork being a drastically more sustainable alternative to virgin rubber, offering shock protection and having decent anti-slip properties, it was decided in the first ideations of the design to use it as a base for an ABS enclosure. Since docking stations are often carried around (e.g., to work and back) the cork parts proved to be problematic.
Brittleness proved to be prone to damage. Additionally, cork presents a vital and aesthetic factor, mainly perceived as warm and linked to home appliances; it proved confusing in the context of ‚workday electronics'. Resulting in these flaws, a different material was searched to fulfill the mentioned functions.

Fig.62 Kuwait tyre graveyard

Originally intended only for the rugged drive enclosure, the new material of choice was recycled rubber from disposed car tires. This granulate is widely available because it is impossible to make new car tires from it.
The most common area used for these molten and molded back rubber granules is the use in gymnasium floors and sports mats.
Currently, the most common way to produce parts with this rubber is by adding polyurethane binder; nonetheless, a direct molding process offers the possibility to mold these rubber granules without binders or other additives (Quadrini et al., 2018). For a 20mm tile using a polyurethane binder at a ratio of 8% of the rubber weight, the mold needs to be heated to 80°C at a pressure of one bar with a molding time of 6 min.
Direct molding processes for the same tile require a heat of 200°C and a pressure of 30 bar for 10 min (Quadrini et al., 2018). With the high costs of PU compared to rubber granules, Quadrini et al. (2018) calculated the costs of producing a 1 m^2 tile using the PU binder at 5,10€ while producing a 1 m^2 tile without any additives costs 2,52€. Even though the cost evaluations of Quadrini et al. (2018) show a price reduction of around 50% in direct molding compared to the conventional process, the high cycle times and the lack of highly developed presses makes this process difficult. ›

Nonetheless, it was decided that this type of rubber provides all the desired characteristics and comes with a high potential impact on recycling rates, whereby these challenges were accepted to keep a higher quality mono-material.

Additionally, the materials used for the PCB and cable remain the industry standard due to the high requirements in functionality and a lack of substitutes.

For easy assembly and disassembly and high stability, two stainless steel screws proved essential.

The structure of the docking station followed a variety of factors. Due to the decision to use the docking station as a laptop stand for improved usability and the need to still be compact due to it being carried around by users, prototypes were used to develop the optimal size and angle of the sides.

In the first iterations, the use of cork resulted in the docking station being composed of two main parts. A cork tray was meant to stay at the desk and provided a solid stand and a defined place for the electronics and an ABS enclosure containing the electronics. Due to the friction of the cork not being big enough to secure the laptop just by offering a wedge to place the laptop on, the scale of the cork tray was big enough to support the entire laptop. The volume and the cork's properties proved to be unsuitable during the further development; thus, as mentioned above, recycled rubber replaced it. This offered the opportunity to downsize the tray to save both volumes and optimize the material used.
The guideline 4.1.6 ‚optimize material quality 'dictated the use of mono materials; this resulted in the decision to make as many components as possible from just one material. Therefore small rubber feet or stickers in many common consumer electronics were not an option.

Instead, it was decided to make the entire bottom enclosure out of rubber. Both the decision to use recycled ABS and to create an entire half of the enclosure just out of rubber resulted in the requirement to adapt the shape of these components to suit said materials.

The parts using rABS, therefore, have high wall thicknesses, with the outer walls being around 2.5mm thick. These high wall thicknesses are also present in inner components such as locking pins for the PCB.
Since the rubber granules are unsuitable for highly precise shapes, high wall thicknesses and bigger radii are used in the rubber parts. This contrast served as a stylistic element in the further design process.
Another reason for the above-average wall thicknesses was the plan to

design a sturdy and seemingly unbreakable product. All components are held together by two screws. This allows for the waiver of adhesive connections, thus making the materials pure and disassembly possible. Due to the absence of multi-materials and adhesive connections, it is essential to make the assembly of the product as simple as possible to keep the production costs low and create a feasible product.

Easy disassembly is required by guidelines 4.1.1 ‚create longevity‘ and 4.1.2 ‚plan for disassembly‘. Easy disassembly allows for improved recycling capabilities, repair, and replacement.

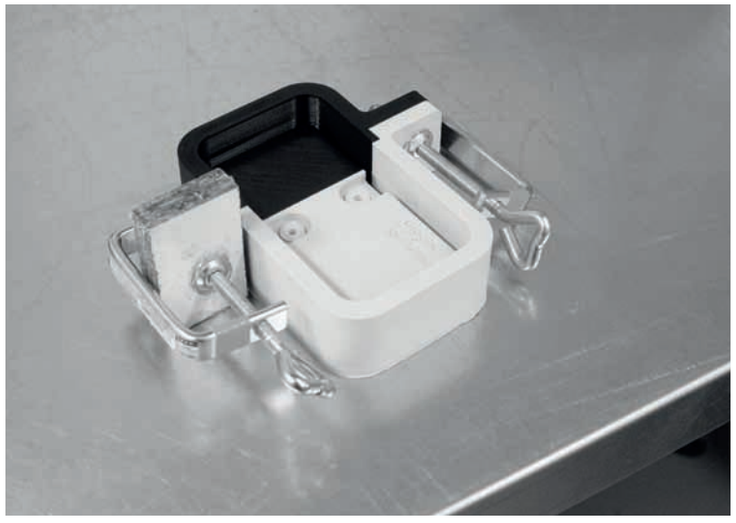


Fig.63 Mould for waste tyre granulate

While taking existing docking stations and other comparable products apart, it was found that disassembly is often tricky or not possible at all without destroying the products. Reasons for that were the use of screws turning in just one direction, adhesive connections, a high number of small screws, and the screws being hidden behind rubber feet or complicated electrical components.
This showed that a low quantity of easily visible screws and no adhesive connections were necessary for the docking station. The user or repairer should be able to spot the connections quickly and open them without rare, specific, or complex tools.
This resulted in just two M4 screws and form closures holding all parts together throughout the design process. Additionally, the high friction of the rubber proved helpful in making the form closures strong enough to create a sturdy product.

5.3.2 COMPONENTS AND FUNCTIONS

With the design of the docking station, the foundation for the other products was laid in terms of the components, as well as the construction, which materials were used and how.

Fig.64 Docking Station front

Fig.65 Docking Station back side

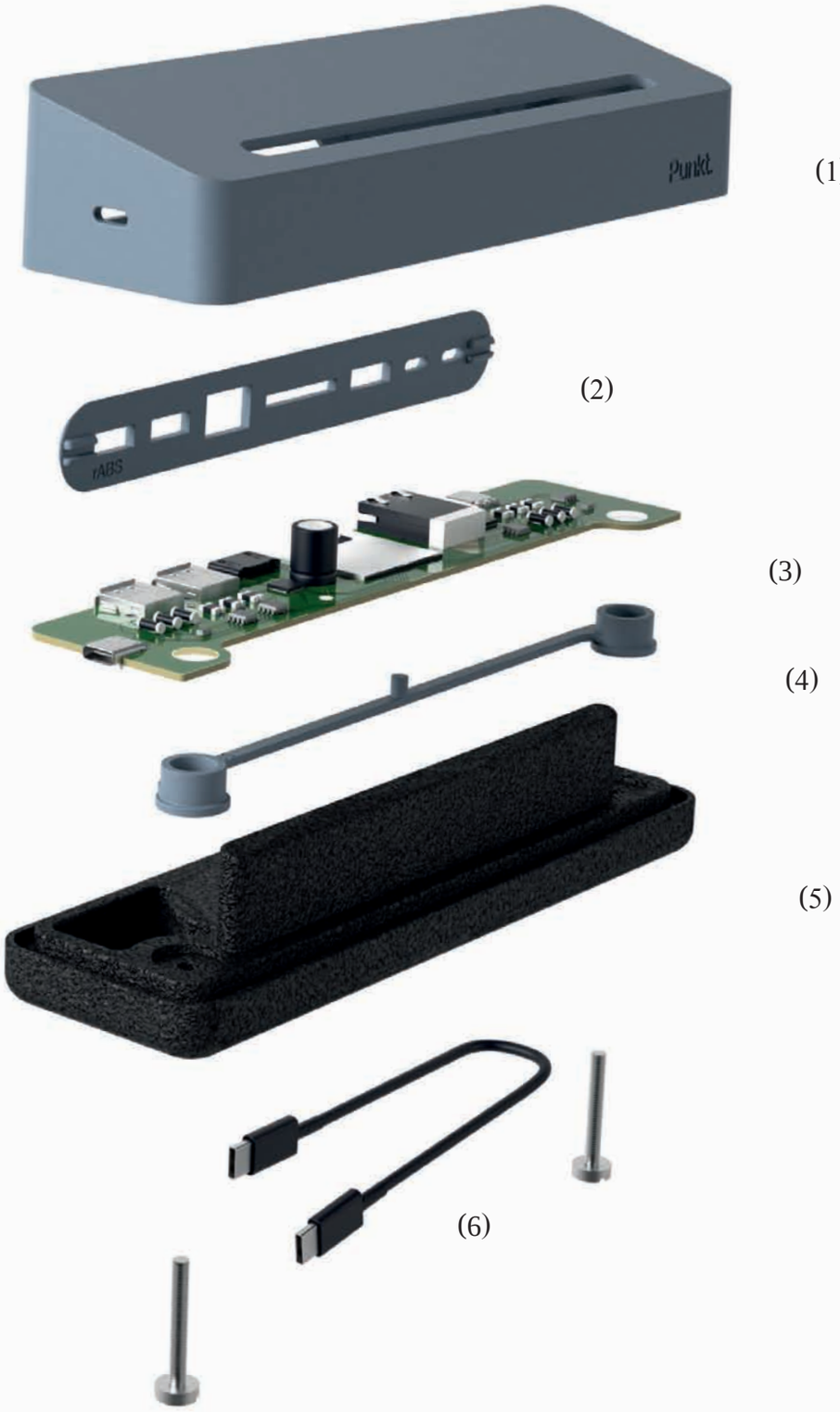


Fig. 66 Explosion Docking Station I

Top shell (1) Made of thick-walled, recycled ABS protects the electronic components and serves as a mounting platform for the other components.

Connector plate (2) The connectors of the circuit board are plugged into this plate and thus secured in position.

Circuit board (3) The number and type of connections were deliberately chosen to ensure the longest possible up-to-dateness.

Spring (4) This ensures that the board sits firmly in the docking station without the need for additional additional screws.

Rubber shell (5) Closes the docking station, the bar that penetrates the hard disk ensures that the laptop does not slip on the storage surface.

Screws (6) By tightening the two screws, all components are clamped between the top shell and the rubber shell.

DOCKING STATION

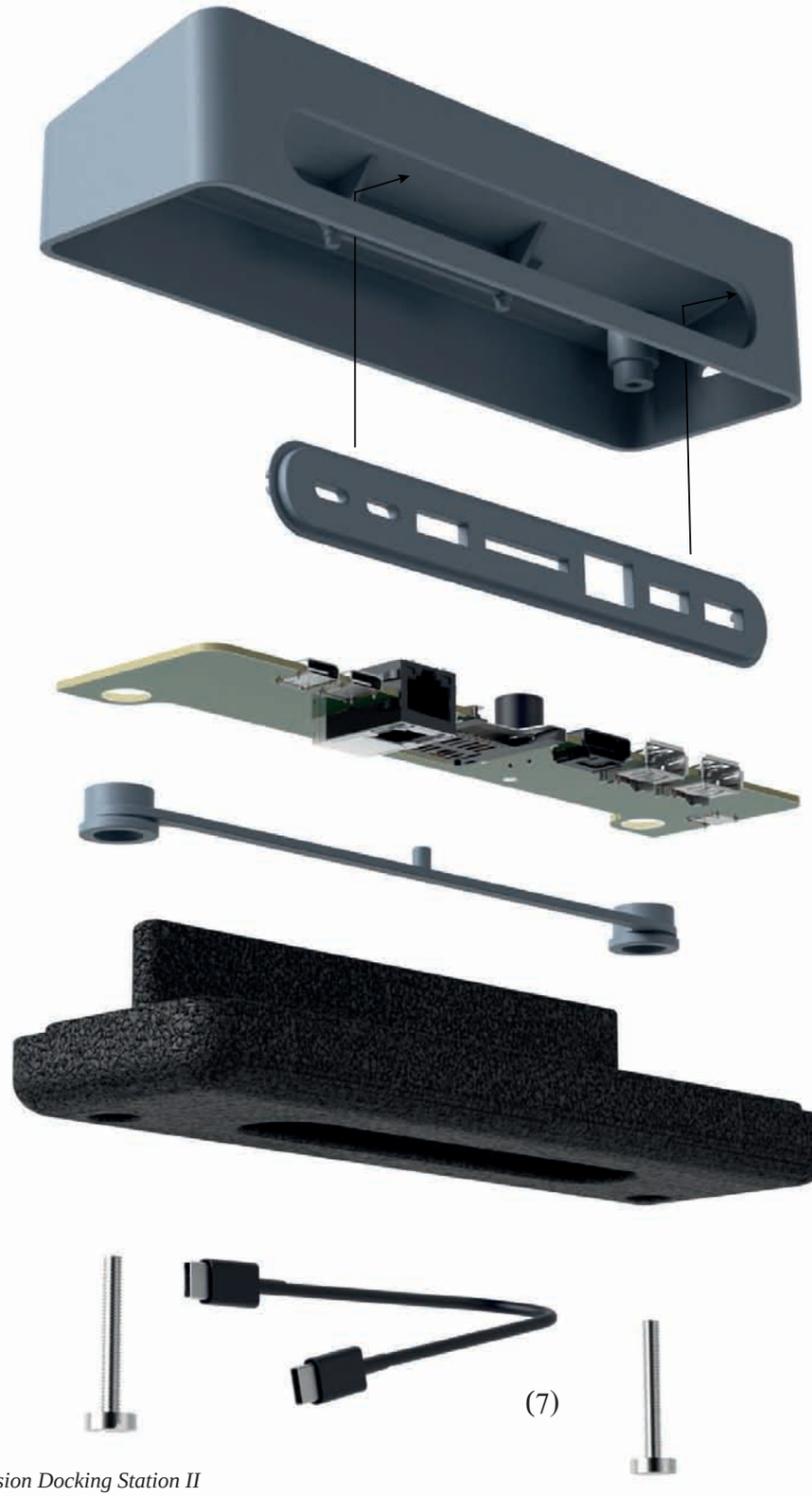


Fig.67 Explosion Docking Station II

Connection plate (2) Interchangeable to keep up with changing technologies.
This means that, on the one hand, the entire form does not have to be changed if the connections change and, on the other hand, it enables subsequent upgradeability.

Cable (7) This can be stored in the opening on the underside during transport.
on the underside.

5.3.2 RESULT

The result reached proved to fulfill the design requirements imposed by the design guideline category ‚materials and physical properties‘ while still being a viable product, shaped by the identity of our collaboration-partner Punkt.
The following pages list how the design guidelines can be translated into product features. For better understanding, exploded views are printed on the preceding pages.

Create Longevity (4.1.1) While the work environment and related consumer electronics constantly change, the product docking station is a mere junction between all the different in- and output devices. Since induction will not become faster than cable transmission in the foreseeable future, docking stations will keep playing a consistent and vital role while all the connected products and cables change. The product can therefore be designed for a longer product lifetime than the average consumer electronic. What might change over time are the connections.
While currently, a wide variety of connections is required, e.g., USB-A, USB-C, HDMI, and ethernet, future developments might result in different connection
requirements. This resulted in introducing a separate part containing the docks, detached from the top enclosure. This new part allows for the upgradability of connections for the user and the producer.
When assembled, the dock- plate is held in place by a form closure; when disassembled, the plate can be removed easily. In case of an upgrade, repair, or recycling, the PCB can also be removed by opening the two screws. A new PCB can be placed In the enclosure offering flexibility where flexibility is needed.
With such a long lifespan planned, the product's aesthetic needs to be trend independent and as timeless as possible. Due to this, calm and puristic shapes were chosen to create a docking station with an unobtrusive and clean presence.
The most substantial aesthetic factors are

Fig.68 Punkt. MP02

played by the aesthetics of the materials and the formal language given by the materials. In order to create friction on the bottom - between the docking station and floor - and the top - between the docking station and laptop - the rubber-made bottom enclosure penetrates the rABS top enclosure.
The contrasts between precise and rough, smooth and bumpy, sharp and round, and the interconnecting parts form the aesthetic narrative.
This narrative is closely linked to the concrete product and materials itself and detached from the present product trends. By removing unnecessary features that change over time and focussing on the core function of a docking station, the relevance can remain stable while comparable products ‚grow old‘ and get out of fashion.

Plan For Disassembly (4.1.2) Easy assembly, disassembly, and reassembly is ensured in the final product by utilizing two M4 coin-slotted screws to hold all components together.
The screw heads have a diameter of 10 mm and are accessible from the bottom. Since disassembly is not a part of the immediate use process (in contrast to the hard drive case), the position on the bottom was chosen to hide the screws in a regular use context. Nonetheless, when looked for, they are visible and can be accessed easily. In order to ease the repair process, the use of slotted heads was decided. This offers the possibility for everyone to open the screws simply using a coin or coin-shaped items.
When the screws are removed, to the rubber-made bottom enclosure can be levered out and removed.
A locking plate holds the PCB in place. This plate is tightened in the assembled product by the screws. After the screws and the rubber enclosure are removed, this part can be pulled out, allowing for the removal of the PCB. Subsequently, the docking plate can be pushed out of the rABS-made top enclosure.
This process allows all building parts to be disassembled. The assembly and reassembly process works the same way in reverse. All these processes can be done without damaging parts.

Select Materials (4.1.1) The materials required for the electronic components were strongly dictated by the functions required and the lack of alternatives. Such ‚forced‘ material choices are present in the design of nearly all consumer electronics.
All other components offered a choice in materials. The final design comprises three other materials: recycled tire rubber, rABS, and stainless steel.
As already stated, the choice of recycled tire rubber was based on various factors, from the physical capabilities of the product to its environmental impact. Currently rarely used in products due to its coarse structure and rough appearance, recycled tire rubber is not only cheap but available in large quantities.
Due to the rubber being vulcanized in the production of tires to achieve different stiffnesses for different use cases of tires, the recycled granules contain a mix of several stiffnesses, deeming the recycled granulate unsuitable for the production of new tires.
This granulate is 100% recyclable, thus offering a drastically more sustainable alternative to virgin rubber (natural rubber being part of the critical raw materials discussed in the problem analysis). Tire rubber can withstand temperatures up to 145°C (Reporteur, 2021).
The second primary material used in the docking station is recycled acrylonitrile butadiene styrene (rABS). ABS is 100% recyclable and has remarkable strength, toughness, and durability while allowing for smooth finishes. ABS can withstand temperatures of up to 100°C (Bouriaud, 2022).
The heat generated in some aspects of the PCB during use was considered problematic during the design process. Due to that, all highly heating parts are distant from other endangered components. This puffer should be enough to dissipate the heat

Fig.69 Prototyping the rubber shells

and not pose any threats to the product. In case further developments show that the seat proposes a problem, the space around the PCB is enough to install a heat sink like aluminum encasing to cool down the PCB and lower the impact of the heat on the rABS and rubber components.
The third material is stainless steel used in the two screws. This material was selected since it is industry standard and offers precisely the suitable properties for the screws required. The screws hold the entire product together. With de- and reassembling processes in mind and their essential role in the product, they need to be precise and tough; thus stainless steel screws were chosen.

Use Recycled Materials (4.1.2) As stated above, it was decided to choose recycled rubber granulate and recycled ABS to fulfill this guideline in all products. The recycled rubber granulate is relatively coarse with a granule size of 0,5 mm to 2 mm; this resulted in the parts composed out of this rubber having high wall thicknesses (> 5mm) and suitable radii. A compression molding procedure makes molding of this material. Thus all shapes were adapted to allow production by compression molding.

For the ABS components, recycled ABS was planned to be used. As a commonly used material, its recycling is lucrative and efficient; therefore, ABS offers reasonable recycling rates. This polymer is available in several ratios of virgin ABS to recycled ABS.
In order to to use the highest ratio of recycled ABS possible, all parts using this material were designed to be suitable for that with outer wall thicknesses of 2,5 mm.
The rubber granules originate from car tires and thus come in black. In this case, it was decided to keep the original color in the rubber components to form a closer connection to their origin. The rABS parts will be colored and optimized for later detection in the infrared selection process in the recycling stream and the number of colors acceptable for its recycled ABS ration in production.

Fig.70 Rubber granulate and pressed rubber shell

Optimize Material Use (4.1.5) With post-covid work environments becoming more and more flexible and mobile, the the function of connection, disconnection, and reconnection play a major role on several levels.
For the ‚work- day electronics ', this function is performed

by docking stations. They allow the transformation of a mobile laptop into a desktop setup, the connection of storage media, and offer high-speed connections, e.g., to the internet with ethernet connectors.
This role will likely remain relevant in the future and present a necessity for an optimal modern work environment. Docking stations perform active physical functions and thus require to be a physical product. With Punkt being a small company with diverse products, implementing sharing systems instead of product ownership or circular systems is currently unrealistic.
Additionally, docking stations are used by many on a day-to-day basis ruling a sharing system not reasonable.
Both the use of recycled materials and the requirement to be sturdy and seemingly ‚unbreakable 'came with the necessity to use higher quantities of rubber and rABS concerning the part size. Viewed over time, the extended product lifespan anticipated fewer products used and thus reduced material quantities.
Due to that, higher material quantities per component are acceptable. The overall quantity of components is reduced to the absolute minimum required to create a viable and functional product by removing unnecessary features and focusing on the core function a docking station needs to fulfill. Leaving away unnecessary additionally has the effect that the product renounces the ever-new 'false' and pointless innovations that often only serve marketing purposes and do not offer any real improvement for the use of the product.
Optimize Material Quality (4.1.6) Following this design guide with all its design implications; it was clear to maximize the use of mono materials, renounce additives, coatings, and varnishes and produce as many components as possible of just one material.
Besides the electronic components, all parts of the final design fulfill these requirements.This resulted in a number of challenges and limitations.
Many plastic enclosures in consumer electronics contain additives like plasticizers and fire retardants. The functions they fulfill need to be compensated in the ›

docking station by the shape of the components alone. This was another reason for the higher wall thicknesses and the space between the PCB and the enclosure.
Using only mono materials meant that the rubber granules could not be processed in the most common way, in which polyurethane binder is added, but need to be processed by direct molding discussed above.
Avoiding coatings presented no challenge since the original color and surface of the rubber was kept and the high surface quality that can be reached with ABS.

5.3.3 OUTLOOK

As no engineers were involved in designing the docking station,
further development and tests are required to transform the station into a market-ready product. The product can still be considered feasible with all components and the structure discussed with experts.

The biggest threat in the design of the docking station is the heat development in the PCB when connected to a high number of output devices over a long time.
Even though measures were taken to prevent heat development from threatening parts, the usability and safety of the product, the design allows for the implementation of heat sink like aluminum parts.
If future development shows that heat generation is problematic, this can be a viable solution.

5.4 TIME SWITCH

While utilizing a broad range of the guidelines, the time switch focuses on the category ‚Behavior and awareness‘ of the design guide. The user's behavior patterns influenced by this product are the main target in the design process of the time switch. As in all three products, other guidelines from ‚Materials and physical properties‘ and ‚Communication and marketing‘ were also present in the design, but they will not be explained further as otherwise there would be redundancy.

We separated the behavior patterns into two groups. The first one is the behaviors directly linked to the active use of the product; the second one is behavior the product influences which is present when not directly using the product.

The goal was to create a product that changes the user's behavior towards more considerate, aware, and efficient resource use.

Out of this goal, the idea of a time switch emerged, enabling users to take control over their electronics, energy consumption, and product use.

5.4.1 PROCESS

During the development of this project, it was discovered that even though the mega trend of resource scarcities has a significant impact on the everyday life and presents a major threat to the development of humanities living conditions and the planet, there was nearly no significant awareness of the topic found.
This showed that a logical first step towards the implementation of behavior change is the creation of awareness. Not only the consumption of critical raw materials but humanity's general consumption of resources.

The basic idea behind the first iterations was a water tap. A water tap is connected to the pipes through which the water flows. It blocks the water flow when it is not required and opens it when needed. This omnipresent product is so established in the everyday life was considered a good and

Fig.71 Draft: Water tap

fitting analogy for designing a time switch and performing a similar task with electric power.
The time switch was mounted directly to the power outlet in the first iterations. With most outlets located on the wall, this supported the analogy of a tap and would visualize the electric flow through the cables in the wall, passing the switch into the product where it is used.
In a set time frame, the switch would supply the connected products with power.
If that frame passed, the time switch would turn off the power, switching the connected products off.
Such a time frame could be, for example, the time one's favorite TV show is running or the duration the washing machine takes.

Over the development, the design transitioned from the more visual analogy of a water tap to a more present physical interaction with the product. ‚Taking back the control 'was the resulting narrative for the project. The core aspect for the following iterations was creating the sensation of exercising power over products and consumption. Instead of a delicate time setting, in which the start and the end of the desired power use could be set, a more straightforward timer mechanism was placed.
In connection with a ‚buzzer-like 'on- and off-button for immediate control over the on- and off-status, a timer, set by twisting the button, allows for setting the desired duration in which power is supplied. The changed setup allows users to switch the power on and off at any time; the timer provides a simpler way of entering the desired use duration. Additionally, the timer forces the users to contemplate the intensity of how and which products are used each time they make use of the connected product. ›

Fig.72 Interaction with setting wheel on prototype

This incentivized new behavior creates awareness of how much the users consume the connected product and power and likely how users consume products and resources.

Another reason for deciding against the tap analogy in the course of development was the realization that, on the one hand, a time switch that hangs directly on the socket is unstable and, on the other hand, there is often insufficient space due to furniture.

The result was a separate time switch module placed on a table or kitchen counter connected to the wall outlet by a cable. The central elements of the time switch turned out to be the outlet for the end devices to be plugged into and the highly prominent retractable push-button, which could be twisted to set the desired amount of time.

Clear communication and direct impact were the key factors in the design process.

The time switch should communicate its mode of action and, most importantly, the ideals and values behind the design.

The time switch should communicate its mode of action and, most importantly, the ideals and values behind the design. Concerning its mode of operation, the process is simple.

First, the time switch connects to the power grid by plugging it into an existing power outlet. The product to be regulated is then plugged into the outlet on the main body of the time switch.

An on and off switch regulates if the connected products receive current, and a time setting regulates the duration for which said product receives the current. Furthermore, it should be communicated when the time switch is active and how much time is left.

As the central objective behind the design of the time switch is the creation of awareness on resource consumption and the change of related behaviors and less the direct ‚regulating the time during which the power supply is activated‘ function of comparable products.

Thus these values need to be communicated. While in the first iterations, the time switch was mounted directly on the power outlets, it was decided that the communicative aspect played an essential role in creating awareness and changing behaviors that the product needed a more prominent place.

One of the main reasons the time switch was chosen as a suitable product for the category of ‚behavior and awareness‘ was its direct impact on the use of resources. With rising costs for energy and many unused products pulling current in standby mode or by being unnecessarily switched on, the time switch solves a direct resource-linked problem and offers incentives for more considerate behavior in concern to resource use. This nudges users into questioning the consumption and use and potentially their overall consumption patterns.

5.4.2 COMPONENTS AND FUNCTIONS

The timer is in terms of the components used the most complex product of the series, but nevertheless strict attention was paid to easy dismantling. It was also ensured that only the most necessary and longest-lasting components were used.

Turning and retracting button (1) This is used to set the time and to activate and deactivate the timer. Sinking the knob automatically switches off the power, regardless of the position of the knob.

(1)

Fig.73 Time Switch

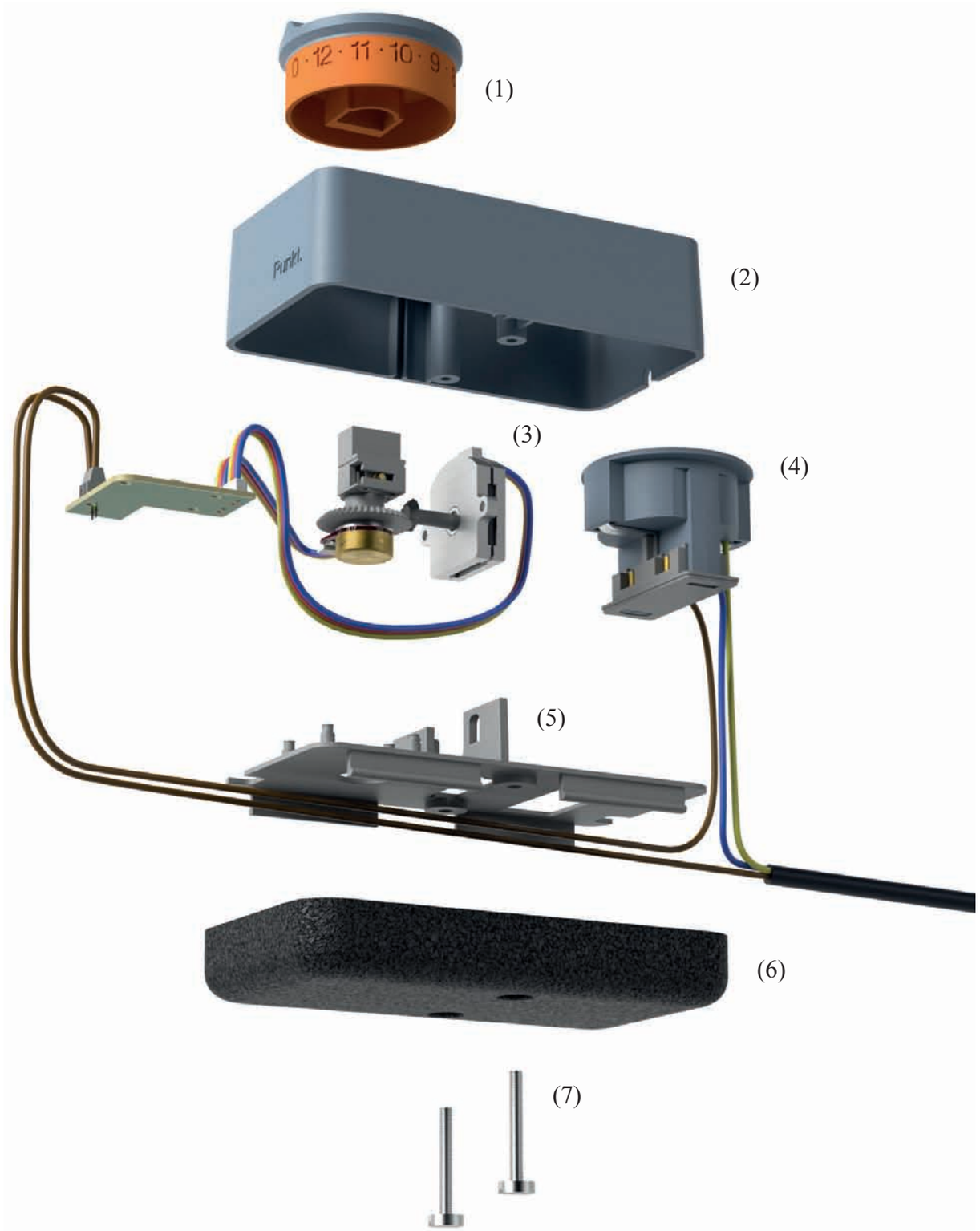


Fig.74 Explosion Time Switch

The rotary button (1) consists of the scalar ring, which contains the mechanism and the cap which indicates the remaining time from a the remaining time from a distance.

Top shell (2) Closes the timer from above and clamps or stabilises the internal components.

Drive and retractable mechanism (3) A potentiometer records the set time, a stepper motor ensures that the rotary knob turns back like an egg timer.

Connector socket (4) The unit can be replaced as a whole.

Holder (5) All components can be placed on this holder and the cables can be arranged.

Rubber shell (6) Ensures that the timer stands firmly and prevents it from slipping when setting the time.

Screws (7) Two screws clamp the individual components between the rubber shell and the top shell.

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TIME SWITCH

5.4.2 RESULT

The result proved to fulfill the design requirements imposed by the design guideline category ‚behavior and awareness' while still being a viable product, shaped by the identity of our collaboration-partner Punkt. Since this product might be considered limiting or ‚extra work', the target group already needs to be interested in a certain amount in less wasteful behavior and product use.

Create satisfaction through use (4.2.1) Even though the factor that using the time switch can save both money and resources can bring satisfaction, the direct use must satisfy directly. This means creating an easy-to-use product that gives the user the feeling of being in control.
The decision to shut the device on or off is a clear decision that a direct and easy command should follow. For that, a big push button was considered early on, a command for which little subtlety is needed.
Deciding on the duration of use takes more thought.
The user needs to consider the amount of time before each use; thus, a more delicate way of interacting with the product was suitable. It was decided that this command is made using a rotary knob, presenting a more delicate and precise way to interact with the product.
Additionally, the high frequency of use due to its high number of possible use scenarios combined with a contenting use experience while saving money and resources increases the product attachment in users and their satisfaction.
Strengthen values and perspectives (4.2.2) and Make ideals and values visible (4.2.3) Since the product is designed for a target group that is open to change, adapting more sustainable behaviors and learning more on the topic of sustainability and more specific sustainable resource use. The Punkt. customers already question existing trends and behaviors to improve their lives and surroundings.
The product should draw attention to existing behavior and misbehavior, offer possibilities for improvement, provide the user with control over their behavior and their products, improve the user's sustainability impact, create awareness and communicate the existing awareness and values the user already has to others.
When active, an orange element on the extended button shows that electricity and thus resources are being consumed during this time. If the time switch is turned off, this colored element disappears in the housing.
When switched off, the Time switch has a mild and puristic basic form and aesthetics; when switched on, it attracts attention. Because the Time Switch stands out from existing products with a similar function due to their positioning, shape, and material stand out, encourage exchange, and arouse curiosity.In the design, care was taken to avoid unnecessary secondary functions and pay attention only to the core function. From the volume and materiality to the positioning of the screws and components, the entire physical nature of the product is characterized by the clear functions of the individual elements. All these elements were considered to design a product that communicates and strengthens values and perspectives internally in the user group and externally to outsiders getting in contact with the designed time switch.
Strive for completeness in products (4.2.4) The most critical element in the time switch is the socket and plug due to high national standards. In order to save resources and costs in production, the time switch is designed in a way that these critical elements are separated from the ‚universal' rest. This allows for a more cost and resource-efficient production. The parts defining the type of plug and socket are installed during the time switch assembly process.
All other components are universal; the required components and shapes were considered.
No unnecessary element was included in the final design. Function-wise only the core function the time switch needs to fulfill was included in the design. ›

Fig.75 Plug unit

A simple timer for up to 12 hours, an on- and off switch, and a socket with a plug are all elements with which the user interacts.
Additional side features like a daily repetition have been left out in order to create a simple, long-lasting product that does not get quickly challenged with the ever new innovations appearing on the market.

Consider the frequency of use (4.2.5) Since the connected products and their use are already known to the user, the integration of the Time Switch in the usage of the existing product only alters the process and does not create an entirely new one. This allows for easy integration into everyday life.
The time switch is highly universal because it is not a standalone product; it allows for many different use cases. It can be combined with nearly every consumer electronic, allowing for a high frequency of use.Both these factors combined can introduce an appreciation for the effort of saving resources and using the time switch.

Change consumption (4.2.6) It could be argued that the time switch itself could be even more resource-efficient by connecting the device to e.g., a phone and controlling the settings digitally. This would remove resource-intensive components like the stepper motor or the potentiometer and replace them with a minor component for connecting the time switch to the input device.
Since the core function of the time switch is the creation of awareness on resource consumption and the change of related behaviors and less the direct ‚regulating the time during which the power supply is activated‘ function of comparable products, it was decided that a strong physical presence and interaction is more important than the direct resource use in the production.
Thus, the physical product is essential and cannot be directly replaced by a service or digital appliance. The problem of unreflected consumption significantly affects resource scarcity and resource use; thus, the problem is accurate, and a solution is required. Nearly no one would leave a tap running when not actively washing hands or using it otherwise, yet it is still widespread to leave electronics connected to the power on standby. The time switch targets this new way of thinking and consuming.

5.4.3 OUTLOOK

As no engineers were involved in designing the time switch, further development and tests are required to transform the station into a market-ready product. With all components and the structure discussed with experts, the product can still
be considered feasible.
The biggest threat to the product's physical nature is that the currently planned components might have a higher power consumption during the use phases of the time switch than connected products might have in a standby mode. This is unlikely as the use times are often a lot shorter than when products are not used, but further development and a power consumption analysis would be helpful to rule this
possibility out. The product currently has a high presence due to its size and appearance. This is intended and required in the current stage to attract attention. When such products become established in society, they can also become reserved and quiet again.

5.5 HARD DRIVE CASE

The Hard Drive Case was designed with the goal of showcasing the third category of the design guide ‚communication and market positioning‘. This category focuses on possible ways to enter and establish resource-oriented products in the market. Even though this category is highly relevant on the organizational level, it also results in concrete design implications for the physical product. As in all three products, other guidelines from ‚Materials and physical properties‘ and ‚Behavior and awareness ‘ were also present in the design, but they will not be explained further as otherwise there would be redundant.

The central message of the design guides in the category discussed here is to embrace the differences in the product designed with the guidelines and the conventional product aesthetics and trends.

Due to this, it was decided to find a product category that is countering existing trends already by itself. The aim was to create a product different from current standards but still able to theoretically be established in the market while strictly following the guidelines towards an improved impact on resource scarcity.

5.5.1 PROCESS

It was discovered that many trends present in today's products have a negative environmental impact. Examples are phones getting thinner and their screens getting larger. Larger screens require more energy and critical materials, while the thinner phones result in fewer and fewer separable components, thus hindering effective recycling.

Not only trends in products but also many trends in our consumption behavior are problematic.

Satisfaction consumption provides results in demand for cheaper and cheaper products in order to enable users to consume more and more frequently. This results in lower quality products, more energy and resources used in production, more energy required for the use phase, and more material to be reused, disposed or recycled.

The influence of these trends, present in products and consumption patterns, is strengthened by the fact that a large population living in poverty can now afford more and more consumer goods. The resulting impacts show that solutions need to be found.

With the design of the hard drive case, the goal was to create a product that breaks with these trends, is less resource-intensive, has a high product life span, and is designed for a target group that allows for a market entry.

The main structure for the hard drive case was already developed at the beginning of its design process. The following iterations mainly focused on aesthetic and functional details. The recycled rubber parts were initially developed for that hard drive case to protect the sensitive components of the hard drive and were later used for all three products designed.

5.5.2 COMPONENTS AND FUNCTIONS

The hard drive case consists of three essential parts: the cover, the rubber shell and the electronics unit. In addition, there are elements necessary for the closure and the and security of the hard drive.

Cover (1) On the inside of the cover there are recesses for the spring, which holds the hard drive in position when the cover is put on.
Spring (2) The spring, which is also made of pressed granulate, is necessary to hold the 7-15 mm thick SATA hard drives in place during vibrations.

Fig.76 Hard Drive Case open

Fig.77 Hard Drive Case closed

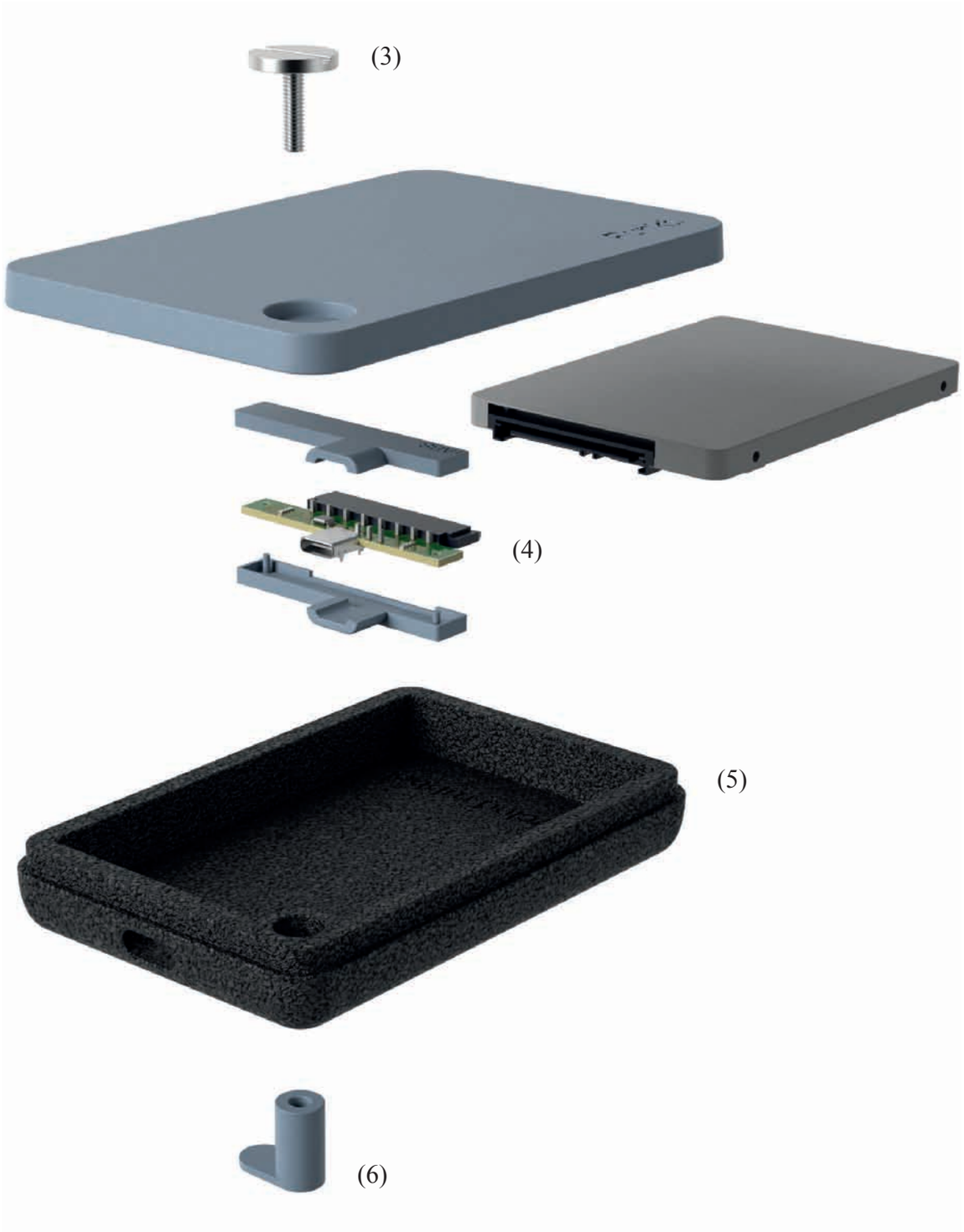

Fig.78 Explosion Hard Drive Case I

Screw (3) Once the cover with the 'nose' is in place, the case is closed with the coin screw.

SATA connection (4) The circuit board is enclosed in two halves of the case, which are clamped together and held in place by inserting them into the recess in the rubber shell.

Rubber shell (5) The extra thick turn protects the hard disk from shocks.

Screw dome (6) This is inserted into the rubber shell from below, the foot prevents it from turning and the screw can be tightened without any problems.

HARD DRIVE CASE

5.5.2 RESULT

The result reached proved to fulfill the design requirements imposed by the design guideline category ,communication and market positioning 'while still being a viable product, shaped by the identity of our collaboration-partner Punkt.
Hard drive cases in which internal hard drives, both SSD and HDD, can be inserted to create an external hard drive already exist. These products are currently found in niches with specific user groups.

The target user of these products is tech-interested, wanting both to save money and resources by using already owned hard drives and to have the capabilities of internal hard drives at a lower cost than comparable external ones. The result aims at entering a more mainstream market by using a company like Punkt. for entering the market. With aesthetics strongly being influenced by material choices made for improving the impact on resource use, the hard drive communicates its differences to both existing external hard drives and other hard drive cases.
The following section describes how these design guidelines translate into product features.

Offer Counter-designs to negative product trends (4.3.1) Using the hard drive case means questioning which internal hard drives are already owned and which broken laptops might still contain the now usable drive.
This thought process targets the widespread behavior of just replacing a broken product with a new one, as products got so cheap that this option is feasible, while the old product is discarded, and the often still usable components and resources are wasted.
Once an existing hard drive is located, the user must dismantle that hard drive's old home to take it out. This process creates an awareness of what is contained in the products used daily and might create an interest in what else is still usable and how other products are structured. Additionally, it creates the skill of dismantling and installing components, which can result in repairing other products, replacing broken components, or recycling products correctly. As many existing products are either hard to dismantle due to a high number of small and specific screws and connections, or even impossible without damaging the product due to adhesive connections and new replacement products are cheap and advertised as often better or innovative, this skillset is lost.

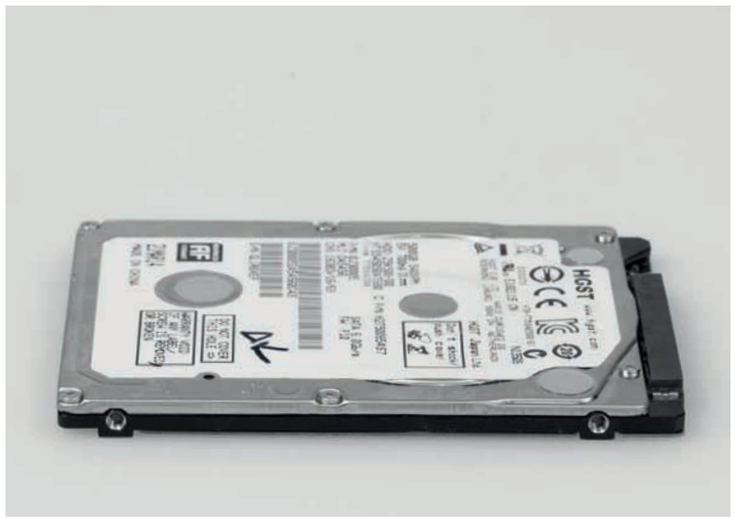

Fig.79 SATA hard disk

reating incentives to learn these skills again is important for saving resources directly and creating awareness of resources and components.
The hard drive is suitable for 2.5-inch SATA SSD and HDD hard drives with a maximum height of 12mm; this allows for various-sized hard drives. Additional to these 12 mm, using rASB and recycled rubber requires high wall thicknesses (5mm for rubber and 2mm for rABS). This results in an increased height compared to most existing external hard drives. The choice of materials forms another contrast.
While most existing hard drives are made from black polymer, the Hard drive case here uses coarse and rough rubber and a grey and rougher rABS enclosure.
Additionally, the hard drive ›

can be taken apart into every single part by simply opening one coin with a screw-slotted head.

Existing hard drives are mainly glued together, presenting difficulties in disassembling them. These contrasts show that the hard drive enclosure designed stands out from existing products.

When this more sustainable nature of products in the form of function, use, and aesthetics is not yet established, this contrast allows them to attract attention to enter the market. In case such nature gets established at some point, in forms a new normal, thus smoothing out the contrasts.

Know your target group (4.3.2) The customer base of Punkt. can already be largely assigned to the LOHAS. Due to this situation and the LOHAS as a suitable target group for implementing products such as the hard disk case in the market, it was decided to choose LOHAS as the target group. Their strategic consumption already aims at changing and influencing their environment by following values like authenticity, honesty, and sustainability.

Complementary trends that can help establish the hard drive are the desire to understand where products come from and how they are made. An example is the trend of baking and cooking from scratch again while consuming less and less ready meals.

Convince customers (4.3.3) As a designer, the final user, the client, or the company one might work for need to understand the importance of transitioning towards more sustainable practices, including implementing products with sustainable resource use. As this pathway often presents short-term economic disadvantages, and increased development effort and uncertainties products designed to aim for that goal should be accompanied by strong arguments.

With uncertain times laying ahead, clear and decisive trategies are necessary to navigate through these times and dangers. The resulting pressure provides a strong basis for argumentation. The design guide lists four main argument categories. The Policies, customer expectations, customer loyalty, and the creation of buffers. Specifically for the hard drive case, arguments for each category can be the following.

Policies: On 11 January 2022, the European Commission launched a consultation on establishing a consumer right to repair in cases not covered by the current warranty period (Webster et al., 2022).

These proposals will have a significant impact on manufacturer's business models, which will need to change in order to facilitate this repair. With them, entire supply chains must adapt to meet the resulting demand in spare parts and repair facilities. In the case of the designed hard drive case, such proposals and future comparable policies will have a significantly lower impact than in the manufacture of established hard drives, as the repair effort is minimal, the components few, and the entire product sturdy and designed for a long lifespan. Thus, producing and distributing the hard drive case protects and buffers future policies that put traditional producers at risk.

Customer expectations: With customers getting more aware of sustainability issues, they demand responsible practices by companies. Companies that engage in the development, production, and distribution of electronics with a sustainable resource use can satisfy this new and rising demand, while traditional production practices of consumer electronic producing companies fall behind. This applies to the hard drive case and its impact on resource scarcities like for all other consumer electronics.

Customer loyalty: Honest and value-oriented production practices are appreciated by the aware customers targeted, which is beneficial for customer loyalty. The hard drive case is a highly transparent product due to consisting of few parts; besides the electronic components, only two mono materials and the easy disassembling process.

Additionally, it is designed for a wide variety of hard drives, easy repair, and upgradability, thus offering ›

many use scenarios and a long lifespan. This allows for a strong product-to-user relationship and, thus, an appreciation of the product and its manufacturer. These factors have a highly positive impact on customer loyalty.

Creating buffers: With the production of components containing critical materials being unstable, producing companies will be at risk of reduced production capabilities and, thus, at risk of major economic losses and bankruptcy.

Hard drives contain a selection of critical raw materials, some, for example, contain the rare earth elements praseodymium, neodymium, and dysprosium (Thuy Nguyen et al., 2017). Using existing hard drives and just making the enclosure minimizes the risk and creates a buffer in case delivery issues arise with one or more critical materials.

Use contemporary luxury consumption patterns (4.3.4) As targeting contemporary luxury consumption patterns offer a possibility for the financial success of products with sustainable resource use offers the possibility to make such products feasible.

The hard drive case was created to satisfy the luxury competencies by providing a striking aesthetic, openly communicating its values (e.g., by having each component labeled with the material it consists of), and focusing on the user experience (the disassembly, the installation, the assembly, the use, the upgrade, and the update).

As this type of luxury consumption is present among others in the group of LOHAS, this goes hand in hand with the fulfillment of guideline 4.3.2 ‚know your target group'.

Market ‚aesthetics of sustainability'(4.3.5) The aesthetic of the hard drive case is strongly dictated by choice of materials. The rubber heavily contrasts with all the materials normally present in comparable products. Additionally to its aesthetic, its unusual haptic increases this contrast. In order to give this strong expression room and generate attention, the hard drive was designed to give the rubber case enough room and volume to give it a strong presence. The upper case is made from rABS, which contrasts with sharp edges and

precise lines while sturdy and having a rough surface.
The central screw holding all components in the hard drive is visible on the top cover.
While the screws are hidden on the bottom in the other exemplary products, disassembly of the hard drive case is an inevitable part of the use. Therefore it was decided to make the screw very prominent. The positioning does not only create this prominence; also, the size of the screw head to a diameter of 16mm.
Since disassembly is part of every use process, it was important not to require any specific tools; a slotted screw head was chosen that can be opened with a coin. Since screws are usually hidden and kept as small as possible, this is a strong visual aspect of the hard drive case. As already mentioned, the increased volume of the hard drive case is due to universality in concern to the acceptable hard drives and wall-thicknesses required forms together with the screw head and the materials visual appearance, a new and contrasting aesthetic. This can be seen as a point of sale, and it needs to be communicated in that way.

5.5.3 OUTLOOK

With hard drives experiencing fast developments, the results are, for example, changing connections and volumes. Currently, the SATA connectors are widely established, but changes will occur. In order to fit future developments, the adapter inside the hard drive case will need to be replaced over time with new connectors. Since the hard drive can be disassembled easily into every single part, only the actual adapter and the casing will need to be changed, while all other parts can remain the same.

It can be argued that hard drives will be replaced with cloud storage in the future. With data security and privacy presenting increasing problems and a growing appreciation for the physical product, especially from the group targeted, it can be concluded that it is highly likely that physical storage in the form of hard drives will continue to play a vital role in data storage which preserves the applicability and usefulness of the hard drive case.

CONCLUSION

The topic of this Bachelor thesis was chosen since we, as prospective product designers, are aware of the negative impact on sustainability issues product design had in the past, has in the present, and likely will have in the future.
With this burden, much responsibility nowadays lies in the hands of designers.
Since the beginning of our studies, we were taught that product designers are problem solvers. Yet the major problems and threats humanity faces in the twenty-first century are of high complexity, interlinked, and might seem impossible to solve. With this project, we aimed at understanding and tackling a focused part of the highly complex sustainability issues: Resource scarcity in the production of consumer electronics. Even though this is just a fragment of the overall problem, we faced high complexity.
A wide variety of origins for this mega trend (e.g., political interests, behavior patterns, or limitations in sourcing processes), possible small solutions that tackle fragments, and various hurdles and opportunities.
The project showed us the importance of designing for sustainability transitions, not only when directly designing solutions for sustainability-related problems but when designing for solving all the smaller and bigger problems we face nowadays. The work of designers, the agency of companies, the adoption of policies, and everyone's consumption behavior need to change in order to tackle these issues.
Over the course of the project, we had the opportunity to generate insights into the perspective of a producing company, thanks to our collaboration partner Punkt., into existing design practices, perspectives on the topic, and ambitions of the new generations, thanks to our professors, fellow students, interview partners, and interlocutors.
The final results of this project were created during four months of work with limited resources. More resources would be required for further development and the creation of a more extensive design guide. We hope that this work has not only made us think and act but also makes others aware of the urgency and the often simple possibilities for improvement.

ANHANG / APPENDIX

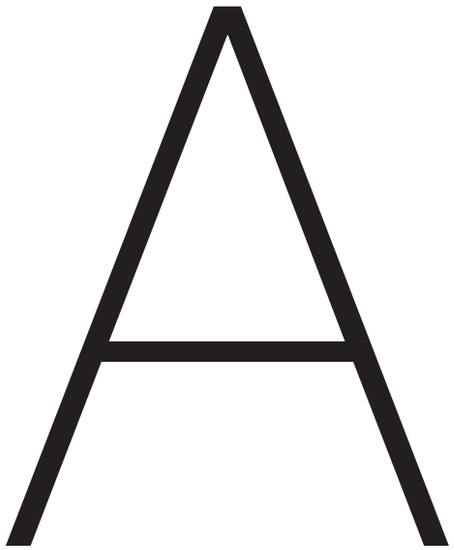

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Abb./Fig.43 Recyceltes Granulat / Recycled granulate: Eigene Darstellung, basierend auf: [Recycled granules]. (n.d.). Shooting Equipment. https://www.shootingequipment.de/out/pictures/master/ product/1/100458_Sauer_Kunststoffgranulat_fuer_Kniendrollen_1.jpg

Abb./Fig.44 Kunststoffabfälle / Plastic waste: Eigene Darstellung, basierend auf: [Plastic Waste]. (n.d.). Israel21. https://www.israel21c.org/the-company-solving-the-dirty-secret-of-recycled-plastic/

Abb./Fig.45 Auto-Rahmen / Car frame: Eigene Darstellung, basierend auf: [Car frame]. (n.d.). Leichtbau BW. https://www.leichtbau-bw.de/fileadmin/user_upload/hm_web.jpg

Abb./Fig.46 Goldbarren / Gold bar: Eigene Darstellung, basierend auf: [Gold Bar]. (n.d.). Moroder Scheideanstalt. https://www.moroder-scheideanstalt.de/goldbarren-ankauf/

Abb./Fig.47 Kollage II / Collage II: Eigene Darstellung

Abb./Fig.48 Kopfmassage / Scalp massage: Eigene Darstellung, basierend auf: [Scalp massage]. (n.d.). Kaufland. https://media.cdn.kaufland.de/product-images/1024x1024/dfc87c70832892db4330dd38844b3c00.jpg

Abb./Fig.49 Reichsapfel: Eigene Darstellung, basierend auf: Arnoldius. (2019, October 12). Der Reichsapfel des Heiligen Römischen Reiches [Photograph]. Wikipedia. https://de.wikipedia.org/ wiki/Reichsapfel#/media/Datei:Imperial_Orb_of_the_HRE.jpg

Abb./Fig.50 Blaulicht / Blue light: Eigene Darstellung, basierend auf: [Siren]. (n.d.). Techgalerie. http:// www.techgalerie.com/images/3209/3209_super_zoom.zom

Abb./Fig.51 Hammer: Eigene Darstellung, basierend auf: [Claw hammer]. (n.d.). ShopGrayTools. https://shopgraytools.com/products/claw-hammer#gallery

Abb./FIg.52 Milchkarton / Milk carton: Eigene Darstellung, basierend auf: [Milk carton]. (n.d.). Freedom Media. https://freedom.media/cartons-with-a-conscience/

Abb./Fig.53 Einkauftüten / Shopping bags: Eigene Darstellung, basierend auf: Bramwell, A., Moment, & Getty Images. (n.d.). [Grocery bags on counter]. Green Living. https:// greenliving.lovetoknow.com/image/225740~grocerybags.jpg

Abb./Fig.54 Kollage III / Collage III: Eigene Darstellung

Abb./Fig.55 Jim Nature Portable Television (Philippe Starck): Eigene Darstellung, basierend auf: [“Jim Nature” TV-set, 1994]. (n.d.). Auction.Fr. https://www.auction.fr/_en/lot/jim-nature-tv-set-1994- philippe-starck-jim-nature-tv-set-1994-h-37-5-x-40-11370605

Abb./Fig.56 bewusster Einkauf / Conscious purchase: Eigene Darstellung, basierend auf: [Birkenstock]. (n.d.). Birkenstock Hahndorf. https://birkenstock-hahndorf.com.au/products/ birkenstock-classic-madrid-regular-fit-birko-flor-nubuck-mocha#2189505724470-2

Abb./Fig.57 Lenkrad / Steering wheel: Eigene Darstellung, basierend auf: [Steering Wheel]. (n.d.). Momo. https://momo.com/en-gb/product/heritage-eu/steering-wheels-heritage-eu/heritage-indy/

Abb./Fig.58 Wassily Chair (Marcel Breuer): Eigene Darstellung, basierend auf: [Wassily Chair]. (n.d.). AmbienteDirect. https://www.ambientedirect.com/knoll-international/limited-edition-wassily- sessel_pid_1314717.html?nodds=1

Abb./Fig.59 Hemp Chair (Werner Aisslinger): Eigene Darstellung, basierend auf: [Hemp Chair]. (n.d.). Moio Hemp. http://www.moiohemp.com/product/moio-hemp-plastic-chair/

Abb./Fig.60 'demontierte' Lenovo Dockingstation/ 'disassembled' Lenovo docking station: Eigene Darstellung

Abb./Fig. 61 ABS Recycling/ABS recycling: WLK 20 SJ. (2016, December 28). [Photograph]. Weimar. https://weima.com/de/zerkleinern/kunststoff/

Abb./Fig. 62 Kuwait Reifen Friedhof/Kuwait tyre graveyard: Tires. (2021, September 7). [Photograph]. New York Post. https://nypost.com/wp-content/uploads/sites/2/2021/09/tires-41.jpg?quality=75&strip=all&w=1535

Abb./Fig.63 Pressform für Altreifengranulat/Mould for waste tyre granulate: Eigene Darstellung

Abb./Fig.64 Dockingstation Front/Docking Station front: Eigene Darstellung

Abb./Fig.65 Dockingstation Rückseite/Docking Station back side: Eigene Darstellung

Abb./Fig.66 Explosion Dockingstation I/Explosion Docking Station I: Eigene Darstellung

Abb./Fig.67 Explosion Dockingstation II/Explosion Docking Station II: Eigene Darstellung

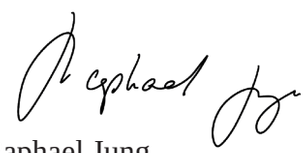
EIDESSTATTLICHE VERSICHERUNG

nach § 19 Absatz 1 der Studien- und Prüfungsordnung

Hiermit versichere ich, dass ich die vorliegende Arbeit selbst- ständig verfasst und keine anderen als die angegebenen Quellen und Hilfsmittel verwendet habe. Alle Ausführungen, die wörtlich oder sinngemäß übernommen wurden, sind als solche gekennzeichnet.

Schwäbisch Gmünd, 27.06.2022

Jan Sagasser



Raphael Jung