WE NEED TO TALK

Ethical and sustainable design of consumer electronics

Paul de Medeiros

Lund University

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by Paul Topf Aguiar de Medeiros

Degree Project for Master of Fine Arts in Design, Main Field of Study Industrial Design, from Lund University, School of Industrial Design

Department of Design Sciences

Examiner: Claus-Christian Eckhardt
Supervisor: Per Liljeqvist

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Abstract

This Master's thesis explores ethics and sustainability in the design of consumer electronics. It begins with a theoretical review of sustainable design methods and ethical principles relevant to globalised value chains. Through an explorative design process, it culminates in proposed strategies for the design of sustainable electronics. Designers' evolving roles, sustainability-oriented innovation, and the need for open discourse in the industry are highlighted.


PENALTY FOR
PUSH TO
STOP
IMPROPER USE

Foreword

Addressing sustainability and ethics is one of the biggest and most complex challenges our generation of designers face. Our profession is based on a mode of industrial production and an accelerated form of globalised consumerism, the likes of which the world has never seen before. This system has raised the global quality of life and lifted hundreds of millions of people out of dire poverty. Meanwhile, we must come to grips with increased levels of global inequality and complex structures of exploitation, post-colonialism, modern slavery and oppression, and take responsibility for the part we play in perpetuating this status quo.

I am not inventing these ideas, nor am I claiming that my contribution is unprecedented. Rather, this thesis reflects and documents my personal journey to dive into the subjects of sustainability and ethics in relation to industrial design. I have found no solutions, only more questions.

This project was started in 2018, and most of the work was completed that same year. Since then, I have continued to feed my research by reading, questioning and working with sustainability and ethics in a professional capacity. All this has culminated in this text, which encapsulates some of my learnings and represents most of the work performed in 2018. Regretfully, a case study which was instrumental to my process had to be left out, as the company changed management before permission was given to publish the case study. Many conversations with industry professionals, which helped me relate my theoretical work to commercial realities, were also left out as they were outside the scope of this text.

Above all I would like to thank Per Liljeqvist for his guidance, his unique and critical perspectives and his never ending support. Thank you to Rebecca, Phil, Claus, Tim, Jeff, Malte, Pola, Emma, Zoë, Qian Jiang, Tomo, Lisa, Sjoerd for being there when I needed to talk.

All design is ideological. So let’s not shy away from the political.

Introduction

Our current system of production and consumption of consumer goods is built on the exploitation and violation of countless people. Mines, plantations, drilling wells, smelters, factories, cargo companies and recyclers all over the world are violating human rights to provide goods at the lowest price, often with no thought given to the impact on the individual, on communities and on the natural environment.

Not only are we not doing enough to solve the issues we face, our capacity and responsibility to solve them are frequently questioned. It is still acceptable for designers to build their careers on the backs of the workers who make their products, with little to no regard for the lasting impact their 'creative innovation' has on the planet we live on.

The topics I discuss in this thesis are not rocket science. Despite the complexity of the details, on a fundamental level there can be no debate of the underlying morality of the issues we are dealing with. We are on this planet together, and just because we happened to be born in a certain place and time, does not absolve us of the responsibility to be critical of the consequences of our actions. And just because our job title says 'designer', that does not mean that we shouldn't take our responsibility to work towards having our products manufactured and disposed of in responsible ways.

When I started this project, I started with the simple question "is there anything a designer can do to impact the sustainable and ethical aspects of their work?". The answer to this is a resounding yes. However, this does not mean that there is a simple solution. The way forward is often unclear, the correct solutions can be unintuitive, and we occasionally do not even know the right questions we should be asking. The goal of this thesis is decidedly not to create the 'perfect' sustainable and ethical speaker. Rather, it is a documentation of the exploratory process to better understand the various perspectives within responsible design and start to outline possible approaches to move forward.

This project has been successful in allowing me to learn a great deal about the responsibilities of a designer. It has also shown me the large amount of work that has already been done and is being done by incredibly inspiring and ambitious people. To me it has become clear that after the conclusion of my studies, a design career which does not allow for the development of responsible products is not an option for me.

Although a lot of this document deals with depressing and negative issues, my hope is that the reader will see that by addressing these issues of ethics and sustainability, we are not only owning up to our responsibilities as designers, but also embarking on an undertaking fuelled by ambition, true innovation and a bit of idealism. By changing our thinking to include immovable principles of responsibility, we approach design challenges from a new and exciting angle and the positive impact we can have on everyone who touches our products has the potential to grow exponentially.

Although sustainability and ethics can often be seen as a burden, and the tone of this thesis might at times seem negative, I strongly believe that working on these issues is our generation's challenge. I think we can find motivation and even some form of excitement in the fact that, as previous generations have changed the field of industrial design to suit the challenges of their time, we now have an opportunity to do the same and be part of a movement towards more responsible design and more sustainable commerce.

Research Questions

The idea for this thesis originated while designing an electronic product during a summer job, and I realised that my theoretical knowledge on sustainability did not translate into any practical knowledge that I could apply in the field. I didn't know how to communicate these issues properly, and I didn't know how to integrate my theoretical knowledge into my design process, which was focused more on making a cheap and usable product.

My goal for this thesis is to investigate how Industrial Designers can influence the sustainable impact of their work. To me, ethical questions and questions of ecological sustainability are interlinked. Especially with the design of electronic products, it is important to be aware of the impact your products have on humans and societies, not just on the environment. So I also wanted to learn about the choices a designer can make to work towards creating ethical products. These two interests led to the following research question:

> *How can designers influence the impact their products have on the environment and on people, throughout the product's life cycle?*

Furthermore I was interested in establishing the link between this type of theoretical 'academic' thinking, and the practice of commercial product design. I strongly believe that the connection to the industry - and as an extension to the consumer market - is an integral part of Industrial Design. And so I saw the evaluation of the potential for any theoretical ideas about ethics and sustainability in design to be implemented by companies as a key part of this project. This led me to the following research question:

> *How can an established hardware company make the shift towards becoming a responsibly operating organization?*

These two questions already indicate that there might be some tensions between different parts of this thesis. On the one hand I am interested in empirical concepts of sustainability and ethics, that could theoretically be applied to a broad spectrum of design projects. On the other hand I am interested in a single case study, in which my work would become so specifically targeted to this one case that the conclusions might no longer be relevant to other projects.

I believe this reflects a general dichotomy in the field of sustainable and ethical design. On a highly abstracted level it is easy to define clear parameters that everyone can agree on to be absolutely true. However once one starts applying these basic principles to real-world cases, one finds a level of complexity that makes it difficult to say anything with absolute certainty.

This complexity sometimes seems to inhibit people from working on these issues: if there is no guarantee that there will be a satisfying or easily comprehensible conclusion at the end of a work-intense process, it is easy not to see the importance of working on it at all. If there is to be any hope of our industry radically improving its impact - as is necessary - then we must change this perception. We cannot find solutions to these complex problems by trying to tell others how right we are. Instead, we must have an open and critical discussion of the work we do, the high-level principles that guide us and the way we implement them. In other words, I believe our focus must shift from being ‘right’ or ‘good’, towards being ‘better’.

There are professions more harmful than design, but only a few.

- Victor Papanek

Literature study

The evolution of Industrial Design

When I started my studies in Industrial Design Engineering in 2013, I had been curious about the origin and evolution of the field for some years. My parents always strongly valued good design and taught me from a young age to appreciate and value objects that were crafted intentionally, combining both aesthetics and functionality. Around the time I decided to study industrial design, I started to learn more about the history of the field.

During this time, I learned about the early emergence of industrial design in 19th century England during the industrial revolution. Engineers and artists reacted to emerging needs and technological advancements and created a new discipline, one that combined the hard and soft requirements related to objects made for people. After early turbulence that defined the general direction of western design in the 19th century, the early 20th century showed the establishment of large-scale and immensely impactful schools of thought such as the Bauhaus in Germany. The principles about modern living laid out in these years are still instrumental to our understanding of design today.

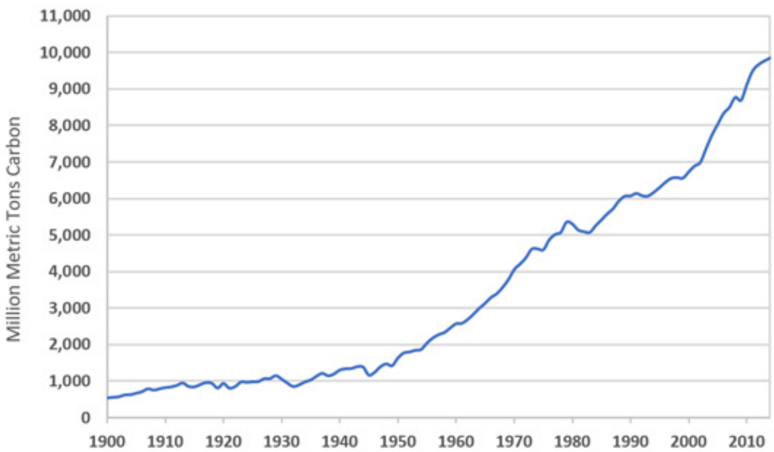
After the world wars, a few impactful movements such as De Stijl in the Netherlands and radical design in Italy maintained some influence, but gradually the emphasis shifted towards individual designers and corporations. In the 60s the post-war US-led marketing industry gained a hold and heavily influenced the world of industrial design. Commercialization, fashion and aesthetics became leading factors in design and the automotive industry gained a special status amongst many industrial designers as an example of the epitome of the discipline, combining technological innovation, fashionable aesthetics and the utilization of design as a commercial tool – an extension of the marketing and branding efforts of a company.

While social responsibility was a leading topic in the design industry in the first half of the 20th century, this took a back seat as star designers used their personal brands to increase the commercial value of their work – similarly to what fashion designers had been doing for centuries. The first discussions about extended responsibility of designers and how they might respond to changing impacts due to globalization emerged in the late 60s and 70s. Coinciding with the emerging scientific field surrounding climate change, people started to see that globalised industrialization, mass consumption and environmental stresses were linked. Some industrial designers realized at this time that since they worked at the intersection of engineering, mass production and marketing, they played a key role in this.

The identity crisis of Industrial Design that emerged in the following decades was not limited to the seeming dichotomy between sustainable and commercial interests. With computers and digital systems taking an ever more present place in people's everyday lives, industrial designers found themselves branching out into new disciplines such as User Experience design, interaction design and service design. With lines between disciplines blurred, in the 21st century there can no longer be a single definition of 'The' industrial designer.

During my time as a student, I have seen sustainable design go from a fringe topic, relegated to part-time elective courses, to a mainstream focus which is mentioned in most design projects at school. I think it is fantastic that concepts such as Circular Design, Cradle to Cradle, biomimicry and design for disassembly are being taught and discussed as part of the core education of design students today. However, for me personally I am keen to place these methods and concepts into a wider context. I am curious to know where they come from, what fundamental work are they based on, what are the things we are still figuring out and where do these methods fall short?

Because one thing is clear; we have not 'fixed' the issue yet. We are currently still stuck in a system that uses up finite resources, damages ecosystems and pollutes at such a rate that our current way of life cannot possibly be maintained for more than a generation. This gap between academic interest and systemic change in the industry is described in 'Towards true product sustainability' as 'the big disconnect'(Dyllick & Rost, 2017). Until we bridge this gap, I believe we need to continue to learn and question and understand how we can do better.



Global carbon emissions from fossil fuels, 1900-2014, source: EPA

The ethics of sustainable design

In his book about ethics in software design, the author and designer Mike Monteiro repeatedly calls upon the moral responsibility of designers. He describes the designer's role as that of a gatekeeper, continuously questioning ideas and innovations and saying 'no' when necessary. In these investigations, he says designers have the responsibility to defend and represent the stakeholders that do not have a seat at the table. He also calls on us to "value the consequences of our actions more than the cleverness of our ideas"(Monteiro & Castillo, 2019) .

Reading Monteiro's book 'Ruined by Design' made me curious to look more into ethics and morality in general. I was curious to better understand the foundations of sustainability and the environmental movement. I hoped this would help me understand more fundamentally where the moral call to take responsibility comes from.

The topics that I have touched on in this text so far are far too large in scope individually – let alone combined – to cover exhaustively in a master thesis. I am aware that learning about these topics is an ongoing process for me, and I have only managed to scratch the surface during this project. I still strongly believe in the merit of investigating fundamental ethics and learning to understand the theoretical foundations of sustainability and responsible design.

In my attempt to dip into literature from the ethics domain, I looked at two main topics: environmental ethics and ethics of globalization.

Environmental ethics

I found a great introduction to the first topic in the book 'Environmental Ethics, a very short introduction' by Robin Atfield (2018). In it, he describes that in order to take responsibility for something, one must first acknowledge and be aware of one's influence.

Once one has accepted that humans can influence and damage the natural environment, one creates a divide between the human and the natural. This image: Joanna Penn

raises the fundamental question as to what motivation one should have beyond the altruistic, to care for that which is not human?

The very short introduction to environmental ethics explains that there are three distinct perspectives one can adopt: anthropocentric, biocentric and ecocentric. The first focuses only on human interests and acknowledges only the instrumental value of natural things. The biocentric view accepts some form of intrinsic value to things that are alive. The ecocentric view goes a step further and attributes a moral standing to abstract concepts such as ecosystems and species. A fourth group called ecanthrocentrism has been suggested to reflect people that exist between ecocentrism and anthropocentrism; navigating complex contradictions between values and actions (Rülke et al., 2020).

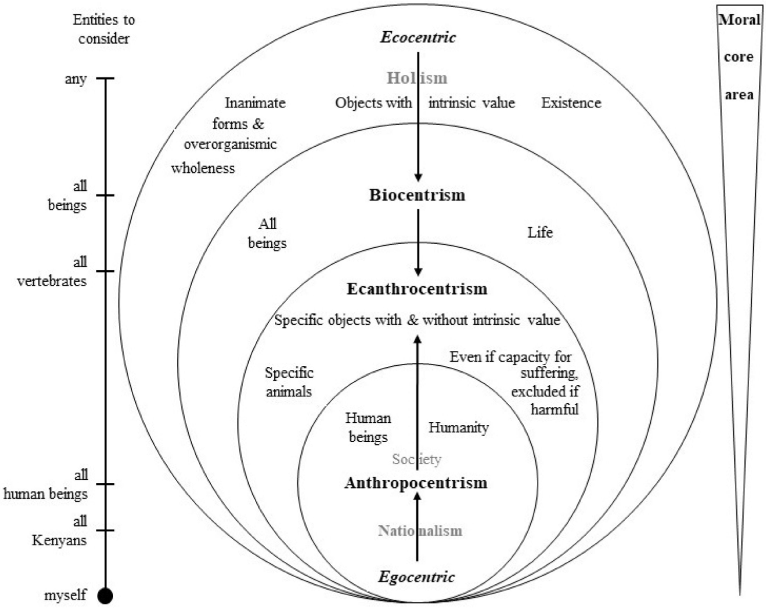
Although it is interesting to read about very well thought-through arguments about the specific scope and nature of our responsibility to the environment, the very short introduction falls short of providing insight to address what I perceive as one of the most pressing questions in regard to environmentalism.

Why should we care, and how much should we care?

The book seems to suggest that it is an individual choice to be moral or immoral, and then provides excellent insights to those that have chosen to be moral. However, in reality we can see people that consider themselves to be moral make choices that are harmful to the environment all the time.

To look at it from a personal perspective: I have read this book and others on the topic of ethics. I consider myself to be a moral person, or at least I would like to be one. Yet I am still likely to continue to eat meat, fly in planes and consume products that contain single use plastic. It could be easy to adopt a cynical approach and state that all humans are immoral and telling ourselves otherwise does nothing to change this. Yet I choose to believe that it must be possible to live a moral life, even in a system built on immoral principles.

A widely used argument to support acting in a way that harms the environment as a designer, is that this is necessary to ensure the survival of the company. How should one weigh two such moral responsibilities, when their impacts



Entities to consider
any
all beings
all vertebrates
all human beings
all Kenyans
myself
Ecocentric
Holism
Inanimate forms & overorganismic wholeness
Objects with intrinsic value
Existence
Biocentrism
All beings
Life
Ecanthrocentrism
Specific objects with & without intrinsic value
Specific animals
Even if capacity for suffering, excluded if harmful
Human beings
Humanity
Society
Anthropocentrism
Nationalism
Egocentric
Moral core area

Rülke, 2020

are so vastly different and unquantifiable? It is one thing to accept a theoretical moral responsibility to future generations, it is another to risk the livelihoods of yourself and your colleagues to protect the assumed interests of a future ecosystem against harm.

In his introduction, Attfield mentions a broad interpretation of consequentialism which might shed light on this. Consequentialism is an approach to rightness based on a comparison of the impacts or consequences of actions on their potential positive and negative contributions to a defined value matrix. Instead of solely measuring happiness as a value, such as in utilitarianism, Attfield's broader consequentialism would take the intrinsic value of living organisms , ecosystems and species both of today's and future generations into account.

Ideally this broader consequentialism would allow us to weigh the positive and negative impacts on the well-being or survival of living organisms, and thereby create clear guidelines as to how to act ethically. However, I find shortcomings in this approach due to the disparate values and the unquantifiability and unpredictability of impacts.

Firstly, the values are so varied that it becomes impossible to compare them or prioritize amongst them. Often, incremental sustainable improvements are not about eliminating harm but rather about reducing and/or shifting harm. For example, take the choice of shipping method when bringing goods from Asia to Europe. For most companies the two viable options are airfreight and sea freight. The first is undesirable because of the high emissions associated with flight, whilst the latter is undesirable because of the indecent working conditions often associated with large long-haul cargo ships. How can we possibly make a judgement based on the comparative negative impact of increased emissions versus potential labour right violations? How many tons of CO2 might the exploitation of a worker be worth?

Secondly, these impacts can often not be quantified. Taking the same example as above, a comparative question might ask how many tons of CO2e emissions the exploitation of a worker is worth. Only one of these two impacts is linked to a quantifiable unit. In addition to that, the question remains how reliable the expected impact is. It is unlikely one will find a freight forwarder who freely admits to labour rights violations on their ships. Although theoretically possible, it is not practical or realistic for most companies to organize independent and unannounced audits to verify the veracity of a forwarder's claims regarding working conditions. Thus, we must often base our evaluation on the perceived risk of harm, which inevitably ways less strongly than harm which can be measured or observed and quantified.

This means that in practice, the broad consequentialist approach is skewed by factors which do not represent the actual impacts or consequences of actions. There is a need for either an approach which can compensate for this, or we might conclude that consequentialism is not the appropriate tool to ensure rightness in commercial decision-making.

Although I have taken this line of thought to its end for now, I would like to illustrate my view that it is important for designers to continue to investigate these fundamental questions of ethics, and to reflect on what ethical tools and frameworks can help us better guide the impacts of our work intentionally.

Mike Monteiro suggests that designers should 'represent those that do not have a seat at the table'. I like this, because it is in line with the traditional perspective on designers as the 'glue' in a team of interdisciplinary experts. Doing market research, understanding the needs and preferences of users, representing commercial interests of the client and using expert input to optimize the design's functionality and manufacturability are essential parts of an Industrial Designer's job.

Ethics of globalization

In his book 'One World Now' Peter Singer illustrates the major shift the field of ethics has had to make in order to adjust to a globalised world. One example he gives is that of contract theory. This ethical tool challenges one to apply the principle of post-determination when designing a system. The thought is that if you do not know what role you will end up playing in a system when you design it, you will make it so that the system is just for all that are a part of it. Peter Singer applies this to our globalised world and challenges the reader to imagine themselves having equally as much of a

What principles would you choose if you were ignorant of the position you yourself would occupy?

- Peter Singer

chance of ending up in a factory on the other side of the world, as they do of ending up in an office down the street.

Similarly, Mike Monteiro applies contract theory to the design profession. Not only should designers represent all stakeholders, they should then also imagine that they do not know what role they would end up in after the design is implemented.

It is precisely in this role as connector, representing various stakeholders and in controlling whose voices are heard in the design process, that designers have an opportunity and a responsibility to be aware of and make use of the most appropriate ethical tools and frameworks. The design process can be a messy and sometimes confusing one, and there are constant pressures to deliver based on traditional indicators such as profitability and brand identity. So, it is only with an equally strong approach to integrating ethics into this equation, that we can build robust sustainable and just systems.

An overarching theme in this thesis is that ethics and environmental sustainability are two sides of the same coin. However, it makes sense to keep them separate – similarly to social responsibility and environmental sustainability – in order to bring some order to these already complex topics. This being said, I do want to make a brief note here of the fact that the designer's position as a connector within an interdisciplinary team also gives them a critical role to play in moving towards more environmentally sustainable business practices.

This process, dubbed 'sustainability-oriented innovation' (SOI) by Klewitz and Hansen (Klewitz & Hansen, 2014), consists of three different areas. Process innovations (cleaner production, waste-handling, eco- efficiency, logistics), organizational innovations (environmental management systems, supply chain management, local sourcing and production, health and safety, redesign of the company's innovation process) and product innovations (eco-design, design for sustainability, life-cycle analysis, (eco) labelling, fair-trade and organic products). As interdisciplinary as this list is, Klewitz and Hansen found interactions between all three areas. Industrial Designers happen to also move between these three areas, and thus can provide important support to sustainable efforts which cross the silos within an organization.

This section of the thesis has been by far the most challenging to write. I find that I lack the knowledge of ethical frameworks and tools to place myself as a designer in a wider ethical context. In the above paragraphs I have tried to put together thoughts which illustrate the fact that designers have a crucial role to plays as connectors, and representatives of those who are otherwise under-represented in the creation of systems of production which move vast quantities of materials around the globe, altering and shaping them in the process and leaving financial ripples and waves in their wake.

Although outside of the scope of what I can discuss in this thesis, I think there is a much more pertinent discussion to be had. Once one accepts that the ethical and moral responsibility of designers goes beyond the value provided to the end-user, there is a rich world of thought stemming from semiotics, social theory and the analysis of postmodern consumerism to dive into. This is not a new idea. Ellen Key is an excellent example of a 19th century author who understood that design was more than just making beautiful objects: it shapes the way we live and has the power to move an entire society in a new direction (Åhrén et al., 2008). So if products have meaning and value beyond their functional purpose, as discussed in the field of product semiotics, then designers have the responsibility to not only shape ethically right products in terms of their function and their means of production, but also in terms of the intangible values they represent.

Jean Baudrilliard delivers acclaimed critiques of consumerism, methodically picking apart the why and how of today's globalised system of production and consumption. I strongly believe this system was made by people and can be changed by people. If we can create an inherently contradictory system which convinces consumers that they are expressing their individualism through mass-produced items (Baudrillard & Poster, 1988) – then surely it must be possible for us to create a system in which people seek to express individuality through the care they give to their possessions, in which competition is channelled into owning the oldest and most well-maintained lawnmower instead of the newest handbag. Where businesses develop competences centred around the extraction of value from existing products, rather than the extraction of finite resources from the most vulnerable corners of the globe. I have only begun to explore these topics and publications, so I will leave further ruminations on the topic to my next thesis and for now continue to another subject of this one: sustainable design.

Sustainable design in theory

As designers we tend to focus on the shape and function of the products we create. But most decisions we make in the design phase of a product also end up determining the impacts of this product both up-and downstream from the consumer. This has been dubbed the 'Product Life cycle Perspective'. By looking at the entire cycle from extraction of resources, to the ultimate disposal of a product, we can gain a picture of the entire impact a product has. We can zoom in on certain aspects, for example performing a 'Life Cycle Analysis' (Boeijen et al., 2014) in order to map the emissions stemming from various stages of the product's life. Being aware of the entire product life cycle, and the impacts related to choices of materials and construction, designers can design a product that causes as few unnecessary negative impacts as possible.

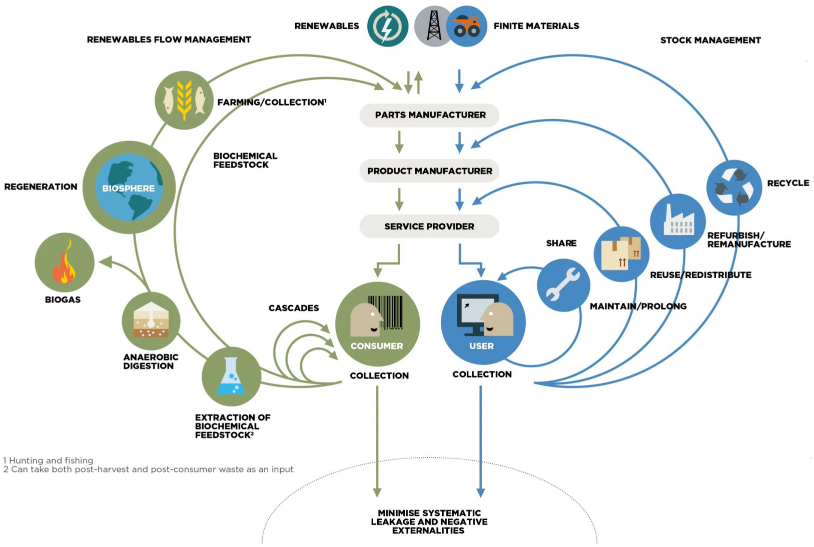
When adopting a life cycle-based approach, it is important to remind ourselves that we cannot lose sight of the social impacts. By its nature the life cycle approach does not include the people who are related to the production of the product, those who use it and those who deal with it at the end of its life. A social life cycle assessment can help address this (Petti et al., 2018), although the methodology is complex and requires a high level of expertise. For now, we will accept that it can be in the interest of clarity to separate the issues of environmental sustainability and social responsibility and proceed to look closer at the former.

Biomimetics is a field of study that encourages us to apply lessons from nature into our designs. Advanced innovative products can be developed based on principles found in animals and plants(Benyus, 2009). This is not just limited to the design and function of products. When biomimetics is applied to processes, we can potentially develop complex systems which provide multiple benefits and in which no negative externalities exist.

This concept is the fundamental thought behind the Cradle to Cradle approach (McDonough & Braungart, 2002). Cradle to Cradle stems from the observation that natural systems do not create 'waste'. Every output from one process forms an input for another process. The idea is that we should set ourselves this goal from the very beginning of a product development process. We should design the construction of products and choose materials in such a way that the entire product can become something else that is useful at the end of the original product's useful lifespan. The three core principles of Cradle to Cradle are to eliminate the concept of waste, exclusively make use of renewable energy and to celebrate diversity (Cradle to Cradle Certified Product Standard Version 3.0, 2013).

A wide range of work in the field of 'eco-design' aims to describe various approaches to designing products which are less harmful to the natural environment. The goals of eco-design are durability, material efficiency, energy efficiency, the restriction of problematic materials, efficiency in use, recyclability, or reparability (Diehl & Crul, 2009). A limitation of eco-design approaches is that they tend to focus on the limitation of negative impacts within our current system of production and consumption. This means the approach rarely leads to disruptive innovations or developments focused on positive impacts or paradigm shifts.

Building on principles from Cradle to Cradle, biomimetics and some early eco-design methodologies, the Ellen MacArthur Foundation played a key role in popularizing the concept of a Circular Economy (CE), part of which is an approach called Circular Design. The origins of CE lie in discussions from the 60s, 70s and 80s (Murray et al., 2017) and like Cradle to Cradle, the goal of this approach is to build systems around material streams that create no waste (and thus are 'circular'). A unique and valuable contribution from this approach is the 'Butterfly diagram' which effectively illustrates the basic principle of circular economy which is that systems of production can only be sustainable in the long term if they consist of closed geobiochemical and technical loops. This is to say, it divides our global material streams into two



Butterfly diagram, Ellen Macarthur Foundation main categories: organic materials and technical materials such as plastics and metal.

Within these two main material streams, the butterfly diagram shows the 'circular strategies' that can be employed to keep the materials in the loop. The goal, as described in 'Products that Last' (Bakker et al., 2019), an introduction to circular design, is to keep materials in as small a loop as possible for as long as possible. For products made of technical materials this means maintenance and repair are the preferred strategy, while recycling the base materials is the least desirable strategy.

The design project presented later in this report is based mostly on this approach to Circular Design. In preparation of and during the execution of the concept design part of my thesis, I read about sustainable design and various strategies that have been explored by others. In doing so, I identified the following focus areas which I thought to be relevant to the design of consumer electronics. Each of these topics will be expanded on further in following paragraphs.

› Be critical and transparent
› Work with responsible partners
› Use good materials
› Design for longevity and repair
› Design for recycling
› Promote evolving user values

Be Critical and transparent

Adopting a critical and transparent approach is without doubt the most important point on the list. Sustainability and ethics are incredibly complex issues and navigating these topics can only be done with any success if one maintains a critical attitude towards one's data inputs, assumptions, models, theories, methods and conclusions. Gaining trust and inviting criticism through transparency can democratize the process and, at least to some extent, mitigate one's own blind spots.

Although one might wish that sustainability could be a box one checks off or a test one can pass, the reality is that there currently is no such thing as sustainable consumer electronics. If we also reject the option of completely giving up on electronics altogether, we must then conclude that our methods for manufacturing and the designs we create must become iteratively 'more sustainable'. Sustainability is not a question of either or. Rather it is a journey, a process of becoming more sustainable (Mohrman & Worley, 2010).

Since we cannot go from unsustainable to sustainable in one step, it is important that we adopt a critical and transparent approach. The critical approach means that we continue to question our assumptions as we gain new data and insights. Transparency ensures accountability and can as a bonus build trust with customers. Take for example the Dutch company Fairphone which is trailblazing the electronics industry by making smartphones while having a brand which is built around social issues and sustainability. They regularly publish reports providing insight into their finances and performance on key indicators. Additionally, they have a blog on which they write about their experiences and progress towards various goals. On this blog, they write just as openly about failures as they do about successes. This builds credibility and allows the company to gain the trust of customers – to an extent that most marketing departments can only aspire to (Fairphone, n.d.).

Work with responsible partners

Similarly to the first point, this one applies both to the companies you work with and the company you work for. As an individual designer, one must first make sure that the company you work for is one in which responsible work can be done. When working for a company which does not allow a critical approach, is inherently opaque and which has a business model that is incompatible with sustainable design and manufacturing principles, one's intentions can be ever so good but the possibility for significant and meaningful impact will be limited. As Monteiro puts it, “You simply cannot correct a problem that management does not see as a problem.” (Monteiro & Castillo, 2019).

I believe that this point is too significant to move past casually. Knowing whether the company you are working in is the right place for you to focus your efforts for change is incredibly hard. Companies might seem amenable to sustainable change, but not be willing to make the commitments and investments that are necessary. Or one might have an impactful position within a company, that turns out to be so large and complex that even the smallest changes require the full efforts of you and your team. On the other hand, working in a lean startup might allow for ambitious and far-going approaches, but the reach and impact of the company will usually stay limited for a considerable time – and there are no guarantees that the company will not adopt more ‘business as usual’ strategies in order to enable growth and appease investors. However, it is outside the scope of this thesis to dive further into this topic. Instead, I will look closer at what it means to work with responsible partners as a company.

When selecting companies to work with in one’s supply chain, the traditional approach looks at financial factors and occasionally at risk management and relative or aggregate negotiating power. An alternative approach is to look at the triple bottom line: profit, people and planet. This concept represents the ambition to report not only financial performance, but also social and environmental performance on an equal level (Rimmel, 2021)how it is used now and where it is heading. Daily, we read and hear in various media about concepts such as corporate social responsibility (CSR.

The classic approach to sustainability and social responsibility in supply chains relies on exerting buyer power in order to set in place requirements which suppliers must fulfil. Patagonia for example, a clothing brand which is commonly cited as a successful example of a large-scale business built on responsible principles, requires dealers and suppliers to commit to the same goals that they have set, comply with audits and sign formal compliance contracts (Patagonia, 2010). A significant body of work exists documenting

Patagonia and Fairphone supply chains, source: Patagonia and Fairphone strategies and methods for the so-called 'governance' of supply chains with codes of conduct, binding standards, audits and more.

Ideally companies should go a step further than governance and set up collaborations with their suppliers. This would mean shared learning, defining key indicators together, sharing investments and setting up incentive programs that reward suppliers for delivering more value than required to name a few examples (Cisco et al., 2015).

Fairphone is an example of a company that focuses more on collaboration and multi-stakeholder partnerships. Fairphone provides insight into their experiences on a blog, for example with their main supplier who assembles their phones. Here they highlight the challenges they faced during a failed attempt to implement a worker welfare fund with their first assembly partner. This experience illustrates the importance of working with a company that has shared values, but also the importance of driving the collaboration from a stable purchasing position (reliable order frequency and size) and the challenges of working within existing local frameworks for human rights and worker representation (Kouwenhoven, 2018; "Worker Welfare Fund: Electing Worker Representatives," 2014). In the end, it seems that Fairphone's attempts to set in place complex and long-lasting systems for worker welfare were not quite successful. Instead, they ended up adopting an approach centered on worker representation and paying living wages (Kouwenhoven, 2019).

However, in other areas Fairphone remains active in multi-stakeholder partnerships, for example in the mining industry in Africa, where Fairphone sets up collaborations with small companies, local NGOs and other companies that use the minerals from these mines in order to promote better working conditions and professionalize the industry (Building a Foundation for More Responsible Gold Mining in Uganda, 2018; Fair Materials 101: How Can Mining Be Used for Good, 2021).

In Dyllick and Rost's typology for product sustainability (2017), the most ambitious level of sustainability for companies to aim for requires a rethinking of values and priorities for businesses that produce and sell goods. Instead of

Typology for product sustainability (Dyllick & Rost, 2017) trying to reduce the negative impacts of business as usual, companies should instead develop products for the purpose of creating as much positive value as possible throughout the product's life. In essence, this means looking at one's entire sphere of influence, finding opportunities to do good and then building products around this. Operating on this level of sustainability is only possible when working closely with partners throughout the supply chain. With this level of involvement other sustainable practices such as sourcing local materials and controlling waste streams become much easier as well. As Patagonia noticed, having strong collaborations with suppliers also improves the quality of products and reduces the number of claims from customers. And so we see each instance of the triple bottom line being benefited by close supply chain collaborations.

We can conclude that ideally we should turn around the classic model of production-based companies: instead of working with people in order to create products for profit, we should create products for profit in order to work with and create value for people. This subtle yet significant change would represent a paradigm shift in values and should provide a clear prioritization when it comes to balancing financial, environmental and social factors. This sentiment is reflected in Victor Papanek's claim that "the only important thing about design is how it relates to people" (Monteiro & Castillo, 2019).

Use good materials

If sustainable value chains are built around material streams, then materials must be at the heart of one's design approach. The choice of materials is directly related to the design solutions which are considered from the beginning of the product development process. Certain materials will inherently dictate the impacts a product will have; for example, conflict minerals which will most likely be sourced from conflict areas, materials which are usually sourced from scarce and non-renewable stocks, or materials which cannot be recycled. The approach here should be based on continuous questioning of where materials come from, how they are processed and where they end up. Additionally, companies should curate lists of prohibited materials which are incompatible with their sustainable and ethical goals. Finally, companies should aim to search for opportunities to use different materials which allow them to rethink standard approaches to the design of their products.

Consumer electronics are an especially challenging product category when it comes to materials. Electronic components tend to be made of a mix of metals and polymers in the form of tiny components, coatings and composites. This means that with our current technology, recycling can only reclaim a small part of the electronics – usually the most valuable metals – while the rest is incinerated.

Only 15.5% of e-waste is recycled in the formal sector, with the rest either being recycled informally (with a high risk of revenue going into organized crime in countries across the world) or not at all (Baldé et al., 2017). Next to financial concerns, informal recycling is often done under unregulated labour conditions, exposing workers to inhumane working conditions and dangerous working environments.

Knowing that most electronics end up in informal recycling or landfill, there are two things we can do as designers. Firstly, we can design for recycling (which is a separate point further down this list) to increase the likelihood that formal businesses can make a profit from recycling electronic waste. Secondly, we can make sure that we do not include those toxic materials which are likely to harm workers when electronics are recycled in a context without safety equipment. For example, PVC plastic and Brominated Flame Retardants (BFRs) can emit carcinogenic fumes when burned. Since informal recycling often involves lighting large piles of electronic waste on fire to extract precious metals, leaving out these toxic materials is an easy and pragmatic change with a direct impact on the negative effect a product has on humans involved in its life cycle.

Green Peace's guide to greener electronics also highlights the choice of materials as one of three key points to making more sustainable electronics. Critically, they link this to the curation of transparent supply chains, where this point becomes intricately linked with the two points above it in this list. When a supply chain is transparent and one works with trustworthy suppliers, one can learn about chemicals used during production. Intuitively it might seem like designers have no business involving themselves in the chemicals a factory chooses to use to clean surfaces or complete intermediary production steps – after all, a designer is concerned only with what is in the final product. However, requirements which are defined regarding for example the cleanliness, surface quality or water resistance of a product create a need which a factory ultimately fulfils with the use of these chemicals. So, learning what chemicals are used and why, can help a designer to perhaps change some requirements which cause more harm through waste than they do benefits to the end-user.

Ultimately, these insights can be used by designers to reduce the amount of unnecessarily harmful materials and chemicals which are used in their products by creating and curating lists of prohibited materials and by understanding how their specifications and requirements cause downstream use of harmful materials and waste.

Another activity which I believe to be an essential part of the principle ‘use good materials’ is to seek out innovative or novel materials which allow breaking with existing design conventions. I see this as being strongly in line with the general role of a designer: to question why things are as they are and develop better and more optimized solutions. For example, emerging innovations in biomaterials could take some of the products which we would automatically place in technical material streams and place them in the organic materials streams instead (Bak-Andersen, 2021)economic, and cultural concerns, practitioners and educators require a clear framework for materials use in design and product manufacturing. While much has been written about sustainable design over the last two decades, outlining systems of sustainability and product criteria, to design for material circularity requires a detailed understanding of the physical matter that constitutes products. Designers must not just know of materials but know how to manipulate them and work with them creatively. This book responds to the gap by offering a way to acquire the material knowledge necessary to design physical objects for sustainability. It reinforces the key role and responsibility of designers and encourages designers to take back control over the ideation and manufacturing process. Finally, it addresses the educational practice involved and the potential implications for design education following implementation, looking at didactics, facilities and expertise. This guide is a must-read for designers, educators and researchers engaged in sustainable product design and materials (Bak-Andersen, 2021) .

Design for longevity and repair

Designing for longevity and repair are well documented strategies for circular design (Bakker et al., 2019) and might seem straightforward at first glance. However, creating products that last is more than just making products that are durable – it also involves understanding replacement behaviour, and understanding the factors which determine whether a product is likely to be maintained and repaired – in addition to the question whether it is possible to begin with.

Products are often not replaced because they no longer function. Rather, replacement behaviour is a complex phenomenon in which multiple forces are at play. In an excellent paper on the subject, van Nes distills it down to a simple, single-dimensional differential. With it she illustrates that when the gap between the actual state and the desired state of a product becomes too large, the consumer will replace it (van Nes, 2016). More specifically, if the tension between these two factors becomes stronger than the barrier to replace a product, the product is replaced.

Since increasing the barrier to the purchase of replacement products does not fit in the scope of what a designer can or should do, we are left with the task of slowing down the growth of the gap between actual and desired state of the products we design. We can do this either by stopping the actual state from declining, or by stopping the desired state from drifting away from the actual state.

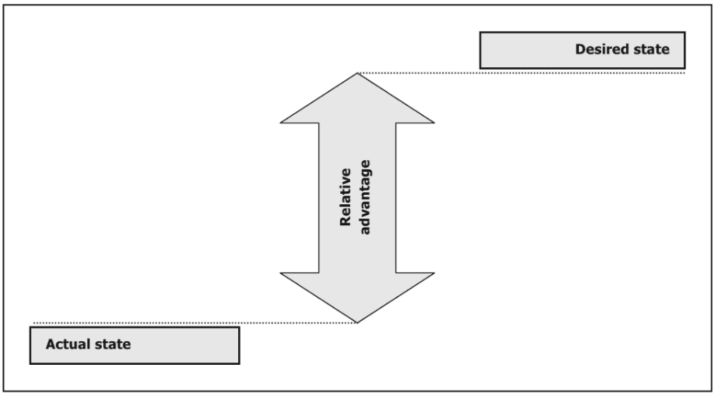
Firstly, to keep the actual state from deteriorating, we should design durable products. My suggestion is that one should develop a strategy during the concept design stage in which we identify the most likely points of failure for a product. This could be a surface area which gets scratched and banged up making the product look old, or it could be a failing component. After mapping the most likely points of failure and wear, we can design the product to either mitigate the failure modes or to lower the barriers for maintenance and repair.

Van Nes poses that one should “make repair easy and fun” (van Nes, 2016). An example of this could be the Fairphone. The fact that it takes few tools and very little time to crack the phone open and replace components such as the motherboard or the camera module is a significant reason for people to buy the phone. The communication of this feature is done through vibrant, fun and energetic marketing. However, I would question whether it is possible to make something like repair truly ‘fun’ for most consumers, or whether this strategy would always be relegated to a small niche of the market. Although I believe that the motivation for repair is more complex, and should not be simplified for most products, for the sake of this project I have proceeded with the assumption that if difficulty of repair is kept low, more people are likely to do so.

According to Van Nes’ model, in addition to keeping the actual state as high in value as possible, one can keep the desired state from drifting away from the actual state. This will be discussed in more detail in the ‘design for evolving user values’ section.

Design for recycling

Design for recycling is another well-documented principle for circular products. It is especially relevant for consumer electronics but regretfully remains somewhat of a white whale. In order to really make circular electronics a reality, the way we create electronic components would have to change radically. Even if it is possible, such a change would surely take a long time. Meanwhile, industrial designers can do their part to make electronic products as recyclable as possible given current industry standards (A New Circular Vision for Electronics Time for a Global Reboot, 2019)with many benefits. This has led to an increase in the use of electronic devices and equipment. The unintended consequence of this is a ballooning of electronic and electrical waste: e-waste. It is difficult to gauge how many electrical goods are produced annually, but just taking account of devices connected to the internet, they now number many more than humans. By 2020, this is



Replacement decision as a deterioration of the actual and desired state (van Nes, 2016).

projected to be between 25- 50 billion, reflecting plummeting costs and rising demand. E-waste is now the fastest-growing waste stream in the world. Some forms of it have been growing exponentially. The UN has called it a tsunami of e-waste. It is estimated this waste stream reached 50 million tonnes in 2018 and this figure is expected to double if nothing changes. Globally, society only deals with 20% of e-waste appropriately and there is little data on what happens to the rest, which for the most part ends up in landfill, or is disposed of by informal workers in poor conditions.

As elusive as it might be, I am a strong proponent of a data-driven and factual approach to design for recycling. Certain basic principles are true, and some product categories could already be improved by following the principles better; do not combine different materials, avoid the use of glue and epoxy and avoid the use of thermosets. Beyond these principles lie infinite levels of complexity related to infinite combinations of materials and production methods. Working hands-on with recycling companies and with environmental data such as pollution levels is the only way to identify challenges.

There are a myriad of polymers one can use for injection molded products, and that is not to mention the fillers and additives used to tweak the material's properties. Ideally, one should work with one or multiple recycling companies in order to understand the challenges they face in retrieving value from waste. Otherwise one might, for example, spend a lot of resources to change from one material to another because it is theoretically 'more easy to recycle' only to find out that due to the mechanical design of the enclosure, the recycling company will still just throw the entire thing in the incinerator.

Knowing where to spend our limited resources and efforts is one of the biggest challenges when it comes to sustainable design. In design for recycling, my approach would include developing a list of prohibited materials and construction methods as well as a strategy to enable easier recycling based on the challenges involved in the recycling of existing, similar products.

For example, prohibited materials for consumer electronics might include epoxy resin which cannot be recycled and PVC which releases toxic fumes when burned (Greenpeace, 2017; Joseph, 2007). A strategy for easier recycling, when looking at products with batteries, should consider that batteries must be removed from products before incineration. This offers an opportunity to reduce cost of recycling by clearly marking the location of the battery and making it easy to remove – preferably without tools. Additionally, if one understands how recycling companies are most likely to take apart the product and what infrastructure they have for further separation of waste streams, one could design it so that the removal of the battery also causes other components to separate, thereby making it easy to separate waste streams. For example, taking out the battery could cause the PCB and display to slide out of the product's housing as well, allowing them to be recycled separately from the plastic body.

However, unless one works directly with the recycling industry to understand the realities of today's and near future recycling infrastructure, any resources placed into these design changes will remain purely speculative.

Design for evolving user values

Under 'design for longevity and repair' I already introduced the model for replacement behaviour described by van Nes (van Nes, 2016). Durable product design and a good repair strategy can help to slow down the decline of the 'actual state' value. Designing for evolving user values on the other hand, is one way to keep the 'desired state' value from moving away from the 'actual state' value.

Although the model as it is presented makes it seem like a purely linear state, the paper also discusses the fact that there are situational influences and consumer characteristics which influence the difference between actual and desired state. Therefore, I believe we shouldn't necessarily see the two values on a linear axis, with the actual state 'moving down' while the desired state 'moves up'. Such a linear scale could suggest that it is all about quality; and that older products inherently degrade in quality while users always search for something better than what they have (Chapman, 2009).

Although these are two ways in which the states can move away from each other, it usually tends to be more complex than that (Chapman, 2009).

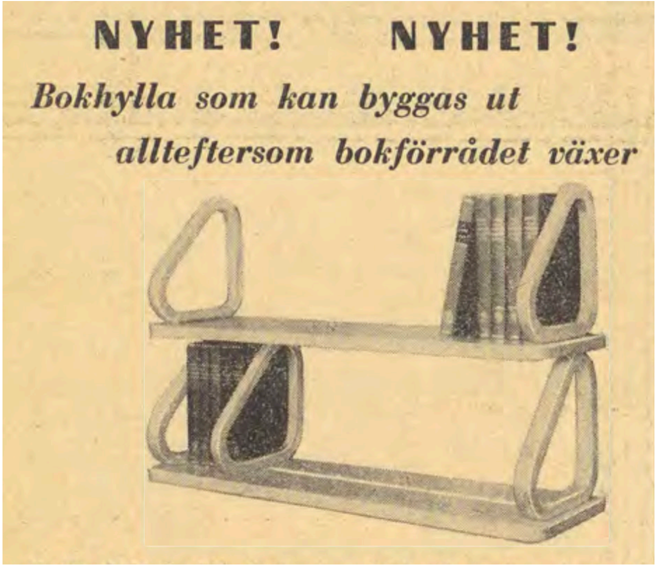
Look for example at a digital speaker. A person might buy a portable and waterproof speaker they can take with them to parties when they are young, only to see their needs change as their lifestyle changes over time. In this case the speakers might end up neglected in a closet (Forti et al., 2020), making way for a product that is more suitable for their new lifestyle.

Similar to how sustainable design should take into account future life cycle phases such as disposal, a new product development should also consider how a product can be adapted to evolve with changing user needs, thereby mitigating one contributor to premature product obsolescence.

This concept has previously been described in the form of 'modular' products such as Phone Bloks (Phonebloks, a Global Campaign to Bring to Life a Modular Phone to Reduce e-Waste at Scale., n.d.), although the focus is more often placed on repairability. Modular and expandable systems are commonplace in storage furniture, for example this shelving design which can 'grow together with your collection of books' in one of IKEA's first catalogues from 1950 (Nettoprislista våren och sommaren 1950 från Ikéa, Agunnaryd, 1950). However, it seems that the consumer electronics industry has been moving away from this concept, towards integrated products that cannot be altered, while updates to connectivity standards make older products obsolete within a decade.

An example of this trend can be seen in the comparison of HiFi systems. In the 1980s and 90s, audio systems were highly modular 'towers' with separate amplifiers, receivers and speakers. One of the most popular HiFi systems today is manufactured by Sonos, which already does not support their own products from before 2015, showing a very different attitude towards what a product is and how it should age ("Set up Separate S1 and S2 Sonos Systems," n.d.).

This is not to say that I think we should completely revert to how we used to design electronics in the 70s and 80s. Instead, I think some older products can serve as an example that it is possible to design electronics in a different way than we do today.



News! A shelf which can be expanded as your book collection grows. Source: IKEA catalogue 1950

Phonebloks design concept, source: Dave Hakkens

Looking forward, we should design products which evolve in their functionality to suit evolving lifestyles, and which can offer durable emotional attachment. Instead of designing and marketing products on short-lived values such as their novelty or technical superiority, a shift is required to designing and selling products for the various types of value and engagement they can offer (Greenpeace, 2017).

Griesshammer et al. (2007) defined three types of value (or utility) that products can offer: practical utility, symbolic utility, and societal utility. Practical utility represents the functionality of the product. Symbolic utility is responsible for feelings like prestige and sense of identity or belonging to a group. Societal utility is the value a product can offer to a public good, such as a product which does not just minimize its negative impact on the environment but has a positive impact, such as filtering carbon dioxide out of the air.

Dyllick and Rost (2017) would call this ‘public value’ instead of ‘social utility’. They put a particular emphasis on public, because they claim that the traditional approach assumes a trade-off between public and private value is necessary. Therefore they expect that we need a fundamental shift in our thinking about products, to enable us to see opportunities to make products that are both more valuable to the individual and to the public. An example they use are the Nike flyknit shoes. Due to their innovative design and manufacturing technique, the shoes are more comfortable and less heavy – both forms of increasing the practical utility of the shoe. Besides this, the amount of waste created during production and the manual labour which is required to make the shoes have been dramatically decreased, which is classified as ‘public value’.

Current strategies to ensure ever-growing sales despite saturated markets employ the first two types of product utility to cause premature obsolescence (Greenpeace, 2017): either by employing planned obsolescence and making a product fail functionally, by releasing new products with novel functionalities, or by using marketing strategies to convince consumers that their ‘old’ products no longer represent the symbolic value which they are looking for.

11 years of iPhones. Source: James Martin / CNET

In the future, consumers will expect and demand an increasing public value from the products they buy. This is a trend which is perhaps already reflected in the sale of organic food in Danish supermarkets (Hindborg & Kaad-Hanses, 2021). Fairphone's ongoing yet slow success, can also be attributed to a growing niche in the market which cares about sustainable products.

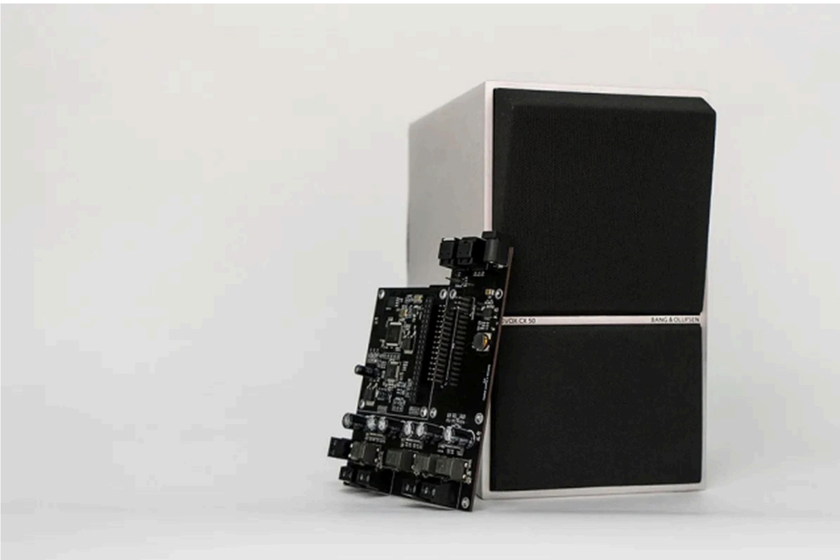
So successful sustainable products should provide some public value, ideally in a way that also benefits their practical and symbolic utility. A goal one might adopt here is one in which practical utility is enhanced by offering repairability and adaptability. Following this, symbolic utility is derived from the customization and individualization of products through shared experiences and improvements made by the consumer. This type of individual expression would surely be much more natural and less inherently contradictory than the current faux-individualism which is sold to us through the marketing of mass produced items.

To take this somewhat theoretical approach and make it more practical, here is an example of a product in which such a strategy is applied. The Bang and Olufsen 2018 Beocreate 4 is a PCB board which can be used to turn any passive speaker into an active digital speaker (Beocreate 4 Channel Amplifier Product Page, n.d.). Practical utility is offered by the functionality, including the ability to program the board, connect it to a Raspberry Pi for wireless music streaming, replace any of the soldered components, build it into the body of an existing speaker and more. Symbolic utility, although partly derived from the Bang and Olufsen brand, will most likely stem from the DIY nature of the product and the emotional attachment created during installation and customization of the product (Chapman, 2009). I would argue that to own a Beocreate 4 is as much of a signal as it is to own a top-of-the-line Bang and Olufsen speaker straight from the factory. It just happens that one of these two fits into a sustainable mode of consumption (public value), and the other does not.

Conclusion

In this literature study, we have looked at the evolving role of industrial designers and established that this field has a crucial and unique role to play

Beocreate 4. Source: Bang and Olufsen



in connecting both traditional and under-represented stakeholders in order to create value through new and sustainable product development. We explored the ethical foundation behind our shared responsibility to build sustainable and ethical systems of production and consumption. Finally, we looked at strategies for sustainable and ethical design of consumer electronics. The insights from this work can be summarized in six strategies:

- Be critical and transparent
- Work with responsible partners
- Use good materials
- Design for longevity and repair
- Design for recycling
- Promote evolving user values

However, I think it is worthwhile to point out that sustainable design and ethical design are not check boxes that can be marked, they are not strictly defined requirements which can be met, and above all they are not static and homogeneous throughout varying (geographic) contexts and time. The truth is that as it is right now, responsible design in consumer electronics does not exist.

Maybe it will never exist, and therefore it is important to me to also look into the ethical foundation of these efforts. To work in ethical and sustainable design is to work with an inherent contradiction. It might be argued that every effort to make things less unsustainable or less unethical is an insincere attempt to cover up the perpetuation of an unjust system. Therefore, it is important to me to understand and acknowledge the ethical imperative to at least do that which we can, to minimize injustice as much as possible.

The industry has changed before, and I believe it can and will change again. Take for example the car industry, which developed such a strong focus on styling and marketing in the post-war decades that a blind eye was turned to traffic accidents and mortality resulting from increased car sales across the US. Journalistic coverage, a lively debate and public opinion forced automotive companies to pay attention to their responsibility to make safe cars, and the industry changed leading to a decrease in accident mortality (Helvert, 2016).

So when it comes to the sustainable and ethical design and production of products, I believe progress can and must be made through open and critical discourse.

We need to talk.

The 4 Concepts

There is no single way to make more sustainable and ethical products. Various strategies can be applied and each offers its own particular challenges and merits. A product that follows the concept of Circular Design would use 0% virgin materials and produce 0 grams of waste, while consuming only 100% renewable energy during its entire life cycle. In most cases this ideal is unobtainable, so when looking realistically at product development one must make decisions based on what realistic measures will result in the most significant reduction of a product's impact.

An example of how different strategies are sometimes incompatible with each other, is to compare a durable product and an organic product. An organic product may be made entirely from compostable materials that can be sourced responsibly and in a way that does not deplete or harm natural resources. This product might only last a few weeks or months during use, since it would not be waterproof or might not be very strong. The durable strategy on the other hand, uses glue, plastics and other virgin materials in order to create a product which can be expected to be in use for multiple generations.

There are many more variables to be taken into account here, and possibly endless variations of strategies could be imagined - each with their own specific use-case. Therefore it is important to maintain a critical view in each design project of the actual context of use and the implications of this on the strategy that should be chosen to develop a responsible product.

While reading about sustainability, ethics and design I was curious to implement some of the things I was learning in some concept designs. Since a lot of the research I was reading about was theoretical, my idea was to use the process of designing multiple concepts to explore various approaches to sustainable design. The primary question I wanted to investigate was 'what are potential design approaches to making a more sustainable portable wireless speaker?'.

An example of what I mean by ‘various approaches to sustainable design’ is to compare two strategies for addressing the impact of single use plastic (beer) cups used at concerts and festivals. One approach could be to use bioplastic for single-use cups in an attempt to move them from the technical to the organic material streams. Another approach is to switch to multi-use cups.

In addition to the above-mentioned product redesigns, one can also design a service such as a deposit system, in which a small amount of money can be earned for cups which are brought back to a collection point to be reused and/or recycled.

This idea of various strategies for sustainable products is commonly discussed in literature, for example by the Research Institute of Sweden (RISE) which presented their view on the three dimensions of Circular Products in a webinar on 2020.10.21. In it, Dr. Robert Boyer presented three dimensions of Circular Products, each of which can be addressed to various degrees in any product that might be considered ‘Circular’. Recirculation, the degree to which a product can stay in the material loops of the butterfly diagram. Utilization: products designed to serve a valuable function. And endurance: products designed to last.

Ideally, a product would perform perfectly on all fronts: it would be made out of recycled and realistically recyclable materials, it would be designed to be as functional for as long as possible and it would be designed to be extremely durable and easy to maintain and repair.

However, I felt this was an unrealistic target to set straight away, with the complexity potentially getting in the way of progress. So, I decided to design 4 separate concepts, each with a different focus. This would allow me to test out some different approaches and see what does and doesn’t work for this specific product type. Eventually, I could take the best insights from each concept and combine them into a final concept design for a sustainable portable speaker.

To start with, I came up with and described the following ideas for ways in which a speaker could be more sustainable:

1. Modular
Separate product components have their own housing, and connect with standardised connectors to form a physical superstructure.

2. Upgradeable
The design is made to accommodate future hardware upgrades through the replacement of parts in standardised slots

3. D.I.Y.
The final assembly of the product is done by the user. This could make use of decentralised production.

4. Integrated modular
Separate product components are kept together in one housing, but follow standardised design specifications and are easily accessible for replacement, upgrades and functionality expansions.

5. Expandable design
The product is part of a product system, in which older products can be used together with, or as a part of, newer products.

6. Incrementally improved
This concept is not radically changed from a regular portable speaker, but it is marginally better on all fronts.

Through multiple rounds of sketching around these ideas, I combined, tweaked and eliminated these ideas until I arrived at four final concept directions:

› **Design for evolving lifestyles and technologies**

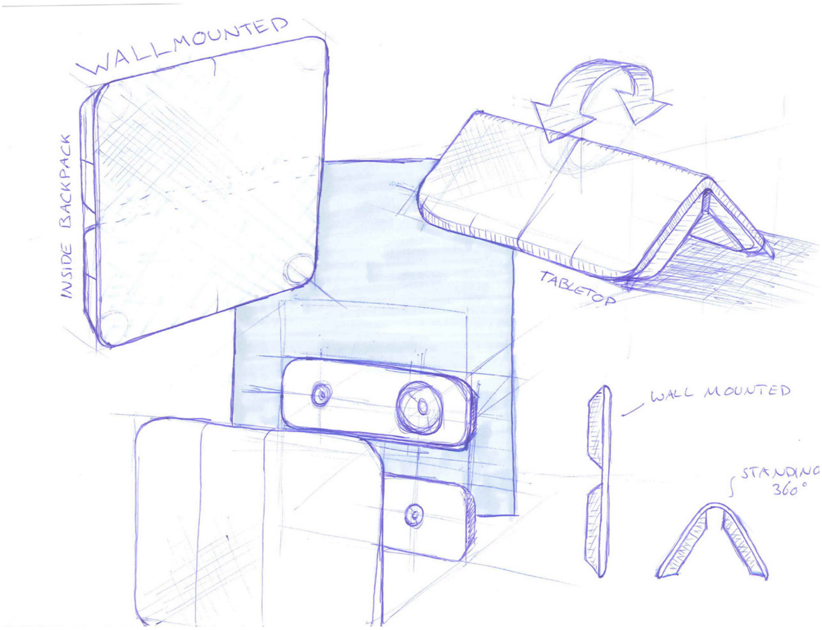
› **Design for repair**

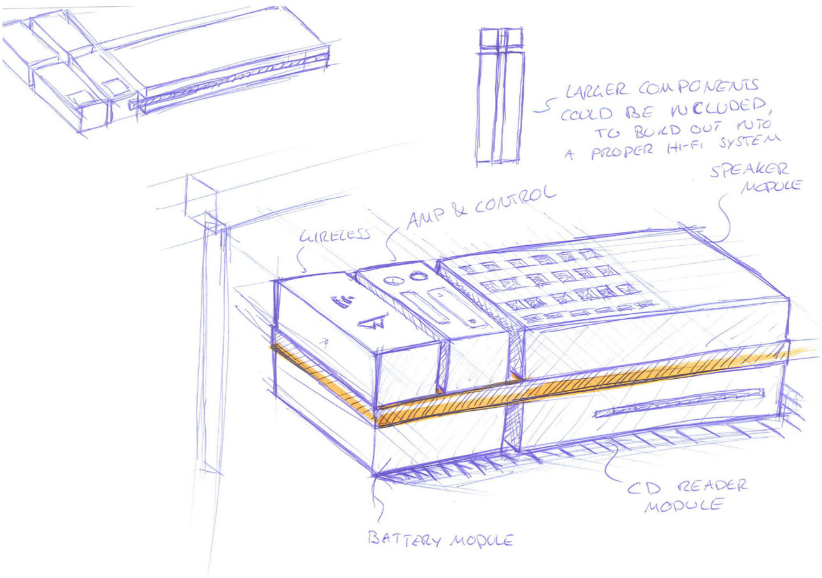
› **Design for durability**

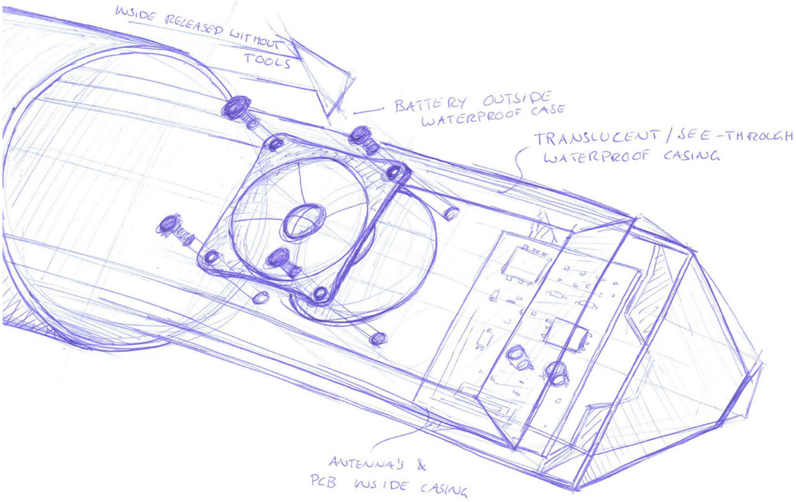
› **Design for recycling**

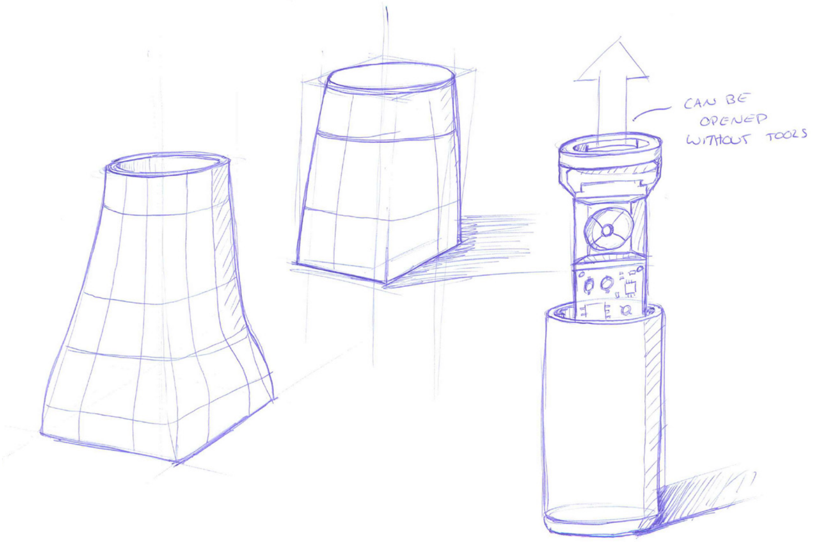
I felt that these four concepts represented four different (yet not necessarily mutually exclusive) approaches to making a more sustainable portable speaker. Then I developed each concept out into a more detailed concept design.

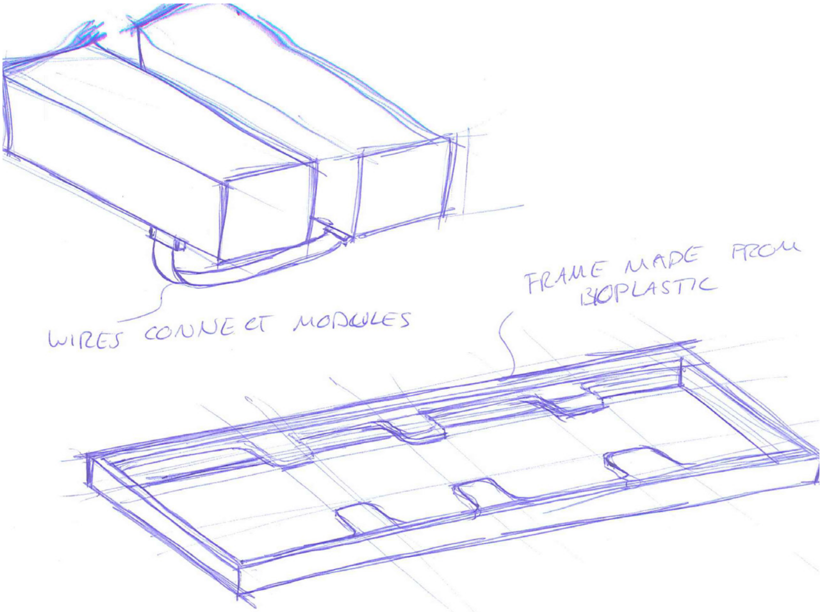
The following pages show an excerpt of design sketches made throughout the duration of this project.

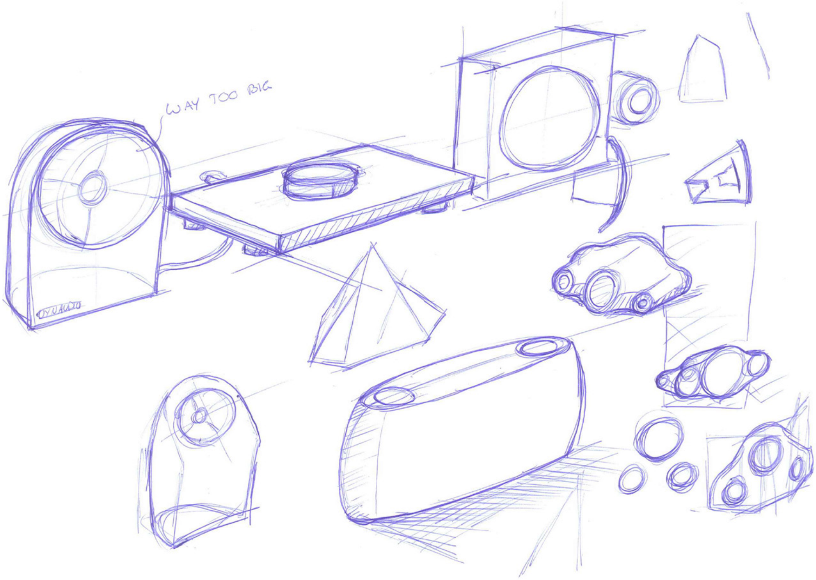

WALLMOUNTED
INSIDE BACKPACK
TABLETOP
WALL MOUNTED
STANDING 360°

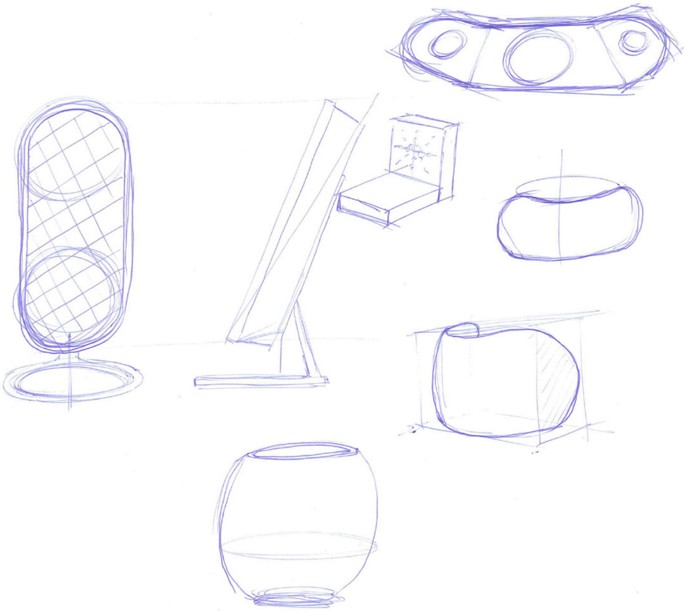

LARGER COMPONENTS COULD BE INCLUDED, TO BUILD OUT INTO A PROPER HI-FI SYSTEM
SPEAKER MODULE
AMP & CONTROL
WIRELESS
CD READER MODULE
BATTERY MODULE

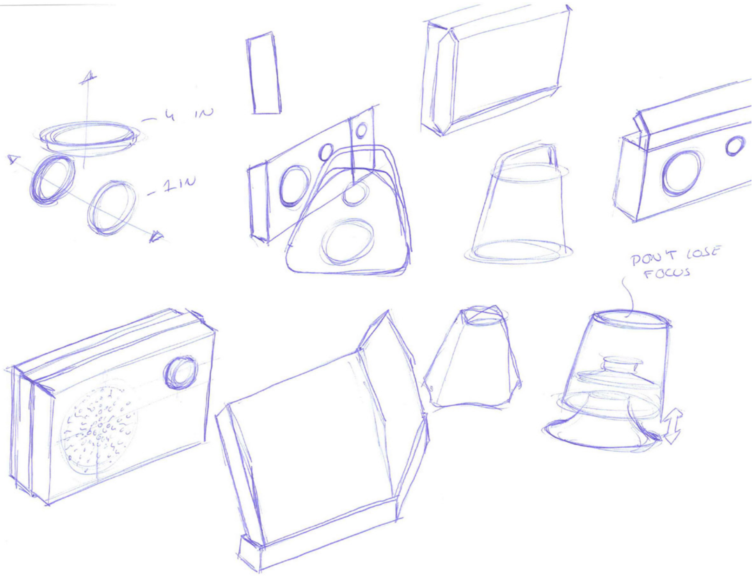

INSIDE RELEASED WITHOUT TOOLS
BATTERY OUTSIDE WATERPROOF CASE
TRANSLUCENT / SEE-THROUGH WATERPROOF CASING
ANTENNA'S & PCB INSIDE CASING


CAN BE OPENED WITHOUT TOOLS


FRAME MADE FROM BIOPLASTIC
WIRES CONNECT MODULES


WAY TOO BIG




4 IN
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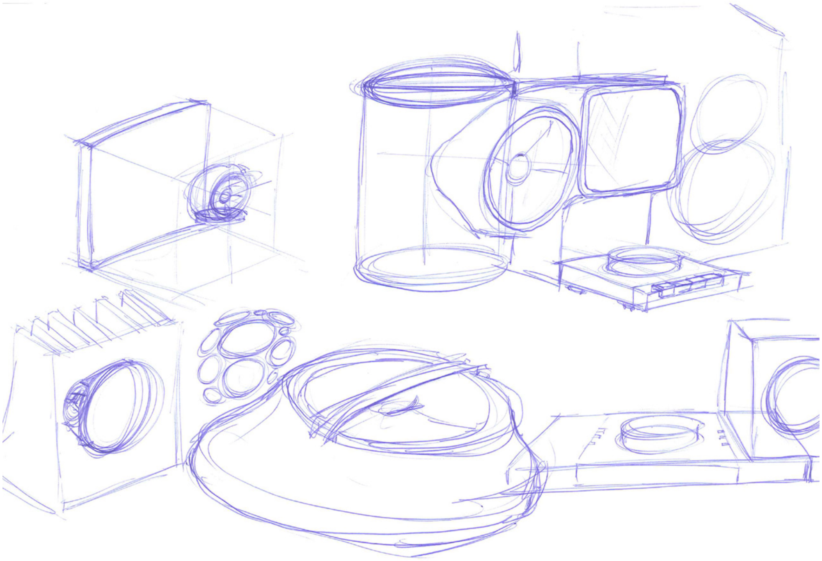
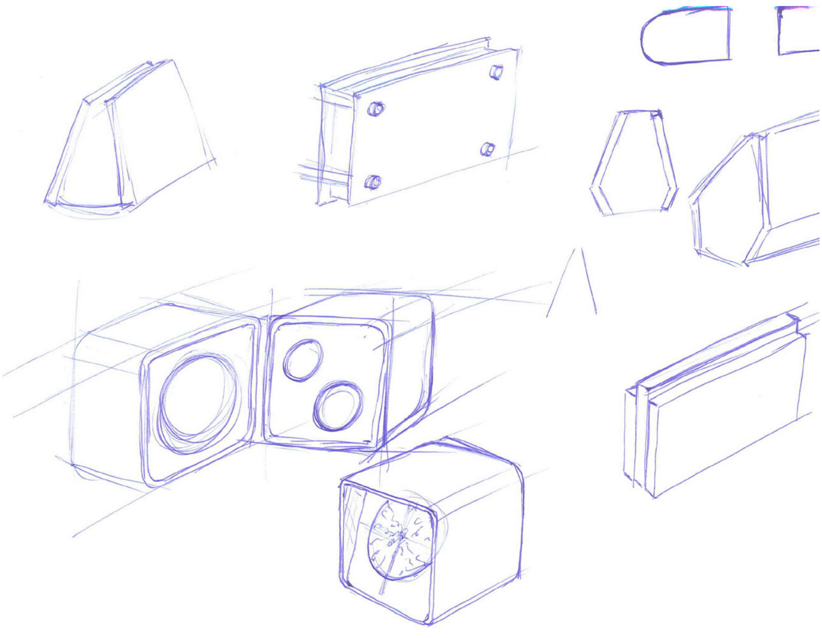
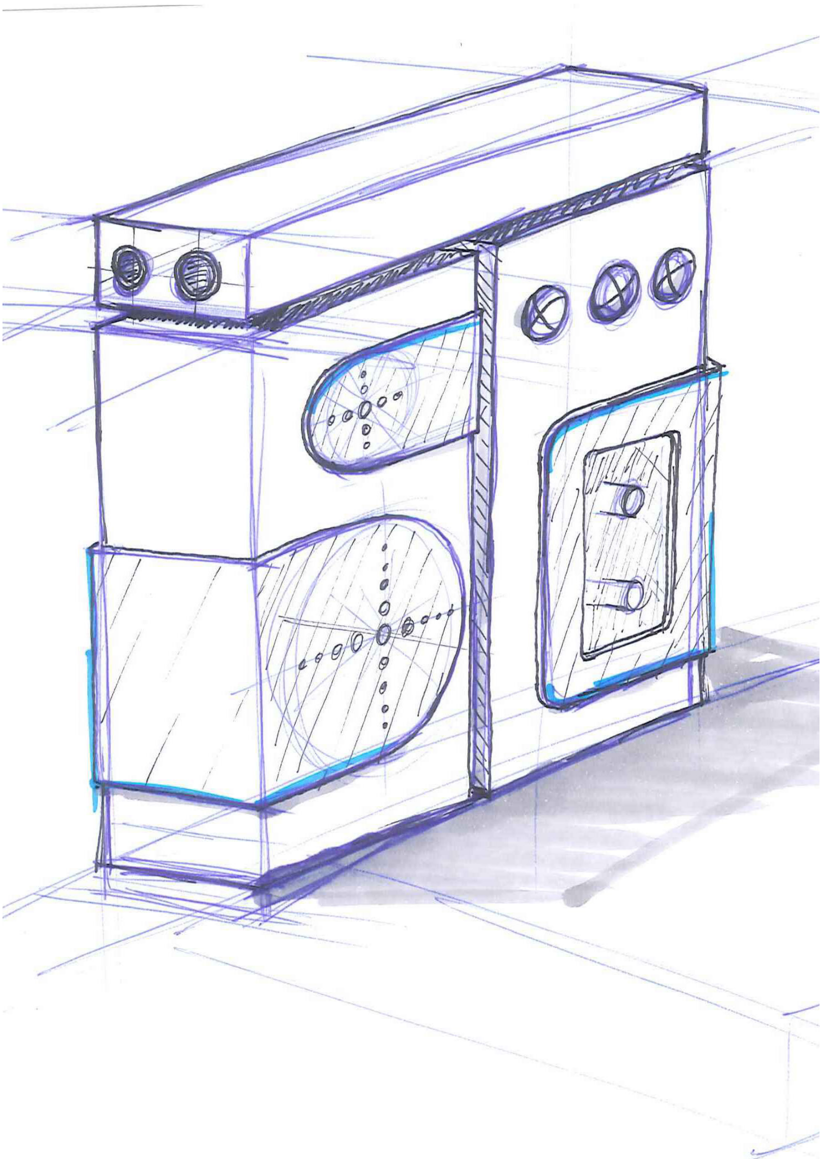
DON'T LOSE
FOCUS







Concept 1: Design for evolving lifestyles and technologies

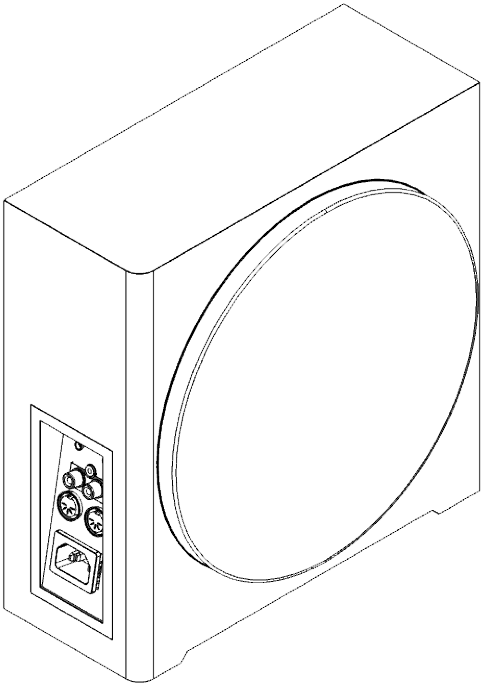
It is not so long ago that all HiFi systems were modular, backwards compatible and standardised across the industry. Amplifiers, tape decks and CD players could be stacked on top of each other and connected to various passive and active speakers. These systems could easily be opened for repairs, and the really motivated hobbyist could exchange connectors or find adapters to make them compatible with newer standards. These systems are still commonly available, and retain a good amount of value on the second hand market. Another feature is that one could purchase components of the system as one needed them: when moving to a larger living room, more speakers could be added. When a new format such as the CD was adopted, the appropriate CD player could simply be plugged into the existing system.

That being said, these HiFi systems did require a good amount of research to ensure compatibility. Amps had to be paired up with passive speakers with the correct impedance, and were limited in their number of in- and output connectors. Various record players and tape recorders might have pre-amps, and advanced functions such as remote controls also started to create more brand-specific ecosystems.

These days systems are either all-in-ones or, as is the case with the SONOS ecosystem of speakers, they use proprietary software which means an expandable system can only work with components made or approved by the same manufacturer.

The aim with this concept was to design a speaker which could be a 'hub' that would allow users to connect multiple input and output devices, without needing a lot of knowledge about connectors, impedance and passive/active speakers. One should be able to buy second hand hardware, plug it in, and listen to music.

Secondly, the concept should be one that can grow and evolve with the user. Aesthetically, the fabric in front of the drivers can be switched out to allow for new colours or patterns. In terms of performance, the drivers should use standard sizes, allowing the user to upgrade to higher quality drivers when they can afford to.



Concept 1, Hub speaker

Using a housing which is over sized, and making it easy to access the interior of the product, could also allow the more enthusiastic hobbyists to ‘hack’ the product and add in their own drivers, amps or other hardware.

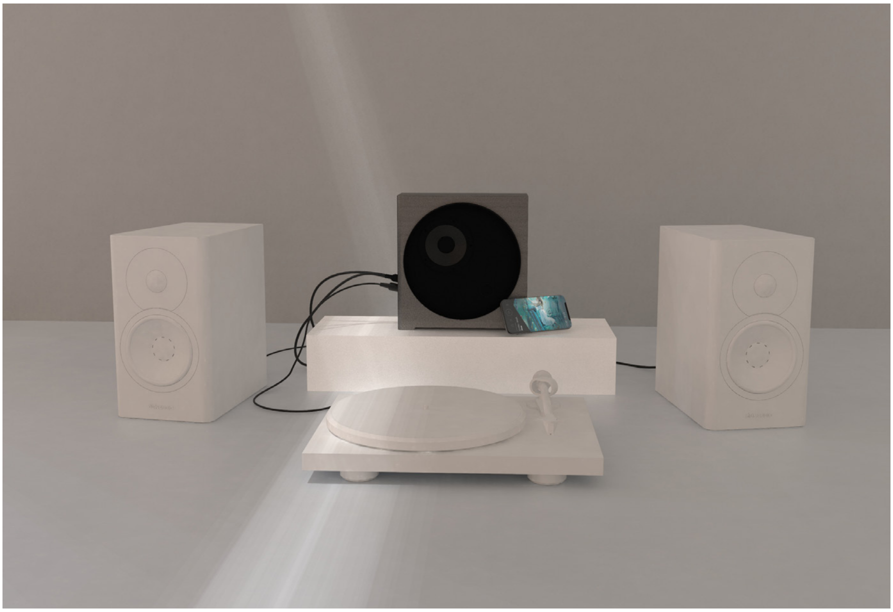
With the fabric cover, drivers and housing somewhat defined, we are left with the connectors, internal amp, software and power supply.

In the concept I drew a large panel on the side, with prominently displayed connectors. The idea here was to clearly display this part of the product, since providing a large number and variety of connectors is an important part of the concept. Additionally, I imagined that the connector panel could be relatively easy to remove and replace, enabling future upgrades to include connectors which are currently not on the market. Technically, this would require the connector panel to convert analogue signals into digital signals. Then, these digital signals could be fed into a control board which is integrated and a permanent part of the product and to which the drivers and power supply are connected. Wireless receivers such as Bluetooth and Wifi should also be integrated in this panel.

For the power supply, I would like to question the need for a battery in a portable speaker. Most places where a speaker should be used, already provide easy access to mains power. Beaches, nature and other public places far from an outlet should arguably not be disturbed by loud music anyway. For the intended use cases of this speaker, a retractable power cord should suffice.

The internal amp, control board and software should provide the ‘smart’ functionality that allows users to plug in devices and start using them, without needing to know much about their specifications. This means that the HUB speaker should be able to recognise the impedance of passive speakers connected to it, and adjust the outgoing signal accordingly. Similarly, it should be able to equalise incoming analogue and digital signals to such an extent, that sounds processed by the HUB are always roughly equally loud or quiet. Perhaps an ‘unfiltered’ toggle option could be added for those consumers that do not wish their signals to be automatically adjusted.

The physical design shown in the renders is an embodiment of how the HUB speaker might look.



Concept 1, Hub speaker

Concept 2: Design for repair

It is often discussed that electronics are increasingly designed to be difficult or impossible to repair. Portable speakers are no exception; with many speakers boasting waterproof ratings, and difficult to open exteriors. Repairability is not just about making it easy to access the internal components of a product however.

In order to make a product realistically repairable, it should be easy to access components and it should be easy to purchase replacement parts. These two things are quite straightforward, and the direct result of product and service design decisions.

Besides these two things, a product should also be designed and marketed in such a way that the consumer values it enough to want to repair it. This is a much less straightforward problem to solve. In addition to the user wanting to repair the product, it must also be clearly communicated that the product can be repaired. This can be achieved through marketing channels and product documentation and through the use of design cues that can show the repairability; such as visible fasteners and/or connectors or even text printed onto the product.

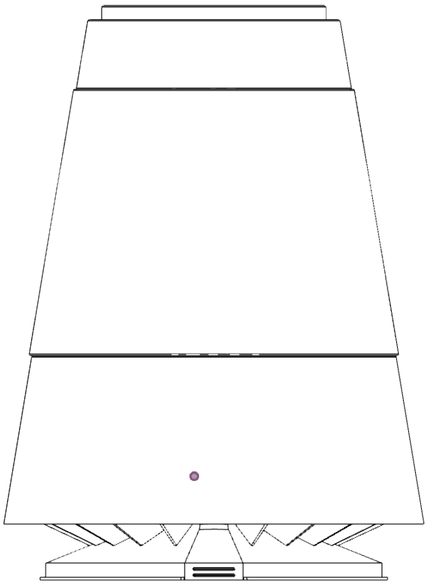
The Fairphone is a great example of all four of these elements being implemented in a product:

Easy access to components: the entire phone can be disassembled in minutes, with just a screwdriver.

Easy to purchase replacement parts: since no standard components are used, all parts can easily be bought on Fairphone's web store, which is easy to navigate and clearly states compatibility of parts.

Wanting to repair: the Fairphone is not a cheap phone, and is clearly marketed in such a way that one of the reasons people will buy it is its repairability.

Knowing it can be repaired: besides the repairability being one of the main selling points mentioned in Fairphone's marketing, the design also includes printed labels on the phone to indicate repairability. Some versions of the



Concept 2

phone have a transparent outer case, which means the internal components are always visible.

In my concept design I wanted to envision a speaker which can be opened up without the use of any tools. Then I wanted all the components to be clearly laid out, so it would be easy for the user to understand what components could be replaced and how.

I came up with a conical speaker with a translucent outer body, showing vague outlines of the components inside. Two brightly coloured latches on the bottom invite the user to press them, which releases the translucent cover and allows the interior components to slide out. A manual included inside the speaker provides details, schematics, an overview of materials in the speaker, recycling instructions and a QR code with a link to a web shop to buy components.

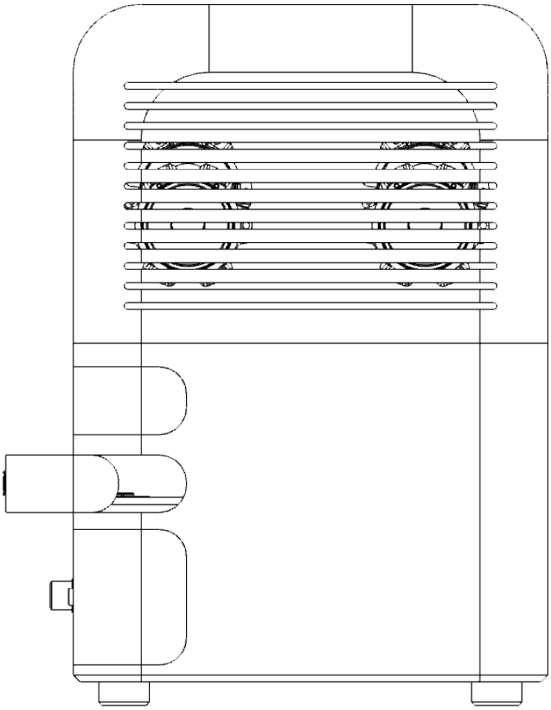
Concept 2

Concept 3: Design for recycling

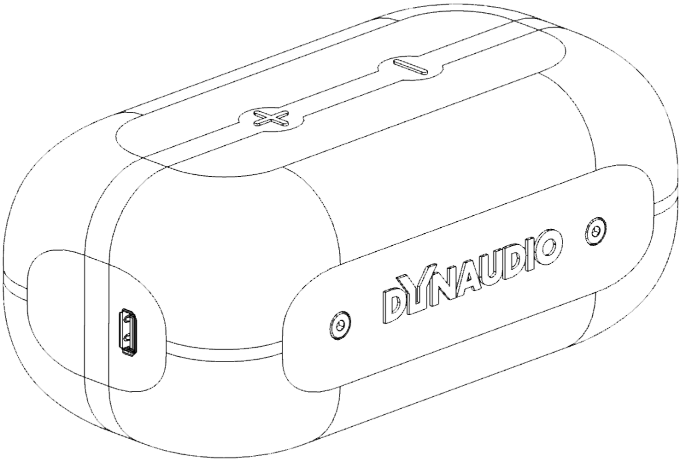
My goal for this concept, which focused on optimizing for recyclability, was to allow easy separation of waste streams at the recycling plant.

To my understanding, the main waste streams which should be divided for recycling are the battery, the electronics (PCBs), the housing and the drivers. The drivers mostly contain copper, iron and neodymium. If made of plastic, the housing should be separated. However, if made of metal, I believe the drivers can be sorted into the same fraction, since it is mostly metals that will be extracted from the drivers and housing.

For this concept design I chose to make a metal housing with integrated drivers. The battery, amplifier and connectivity/control board all have their own separate drawers. When the drawers are opened, the battery and PCBs can be taken out without the use of tools. With each drawer clearly labelled, the idea is that workers at a recycling plant should be able to separate the main waste fractions within a matter of seconds, without needing to grab any tools.



Concept 3



Concept 4

Concept 4: Design for durability

It seems a lot of portable speakers on the market today manage to be quite durable. Being waterproof is an industry standard at this point, and the designs often feature rugged housings which can stand to be dropped from a reasonable height.

A concept which is often brought up when discussing durable designs, is the ‘patina’ some products can gain, which somehow makes them look more interesting over time. This way, scuffs and general wear do not detract from the perceived value of the product, but actually add to it. In my concept design I chose to use cast aluminium with a rough surface texture, to see if this could be something that would gain a patina over time, as opposed to plastic or rubber which just tends to look dirty and old after sever usage.

Another issue with most portable speakers on the market today, is that their watertight design means the housing is impossible or difficult to open. This is problematic for repairs and recycling. For one, it is required to open electronics and remove their batteries before recycling them, so an electronics recycling company I spoke to for this thesis told me that portable speakers and other watertight electronics are sent to a specialized company for battery removal. When it is this difficult to remove the battery, this also means that the user will not be able to replace the battery when it stops holding charge. So no matter how durable the product is designed, the life of the product will still be relatively and unnecessarily short.

To address this, the concept design is made of an outer shell of aluminium which consists of two halves, with a large silicone ring wedged between them. Two large and obviously visible bolts clamp the two halves together, creating a watertight seal on the silicone ring. Now most of the body is made of aluminium with a rugged look, and the entire product can be taken apart with two standard hex bolts. Controls and ports can be integrated into the silicone ring for watertight connections.

Concepts overview

Experimenting with material design

Materials play a significant role in the sustainable design of products. By choosing materials, designers influence impacts up and down the value chain. Beyond understanding whether a material is renewable or not and if it can be recycled, materials can determine how durable a product is and how easy it is to maintain. Some materials are toxic during use, others release toxic gasses during recycling or can only be sourced or refined using toxic chemicals.

The butterfly diagram which was introduced in the literature chapter, divides our global material streams into two main categories: organic materials and technical materials such as plastics and metal. The diagram illustrates the cyclical pathways for organic materials and technical materials. The final step (which should be avoided for as long as possible) for technical materials is to be recycled. With current technologies some materials cannot be recycled without some degradation taking place; this either results in a phenomenon called 'downcycling' or requires recycled material to be mixed with virgin material to improve the quality or usability.

To avoid these complex challenges inherent to the recycling of technical materials, a potential strategy is to use organic materials instead. A perfect example of how this cycle works can be seen in organic food waste, such as apple cores or orange skins. These materials can be composted and broken down to form new fertile soil which can be used to grow new crops.

In recent years, more and more biomaterials have been developed which are compatible with this natural recycling process of composting, and which can be used instead of some technical materials. An example of this is Biotrem (Biotrem Homepage, n.d.) which creates single-use plates made from wheat bran, resulting in a product which is not only compostable but even edible.

Related to the emergence of these biomaterials, a certain stream within the design field has adopted a focus on what they call 'material design'. By experimenting with the properties and behaviour of various organic components and binders, designers develop novel materials with unique properties which form the basis for their product designs. This process allows designers to explore radical new means of production and local sourcing of waste materials to create valuable new products (Bak-Andersen, 2021) economic, and cultural concerns, practitioners and educators require a clear framework for materials use in design and product manufacturing. While much has been written about sustainable design over the last two decades, outlining systems of sustainability and product criteria, to design for material circularity requires a detailed understanding of the physical matter that constitutes products. Designers must not just know of materials but know how to manipulate them and work with them creatively. This book responds to the gap by offering a way to acquire the material knowledge necessary to design physical objects for sustainability. It reinforces the key role and responsibility of designers and encourages designers to take back control over the ideation and manufacturing process. Finally, it addresses the educational practice involved and the potential implications for design education following implementation, looking at didactics, facilities and expertise. This guide is a must-read for designers, educators and researchers engaged in sustainable product design and materials (Bak-Andersen, 2021). Aside from pushing the envelope on the possibilities to design with natural and local materials, this movement is also gradually giving rise to a new aesthetic which makes place for raw and natural textures and colours.

It is difficult to overstate the importance of this development for our societal shift towards more sustainable consumption. Making it permissible or even desirable for products to look ‘raw’, to have non-homogeneous textures and for the properties of a material to be visible in the design of a product, paves the way for an increased acceptance of ‘patchwork’ and ‘worn’ looks. Products which have been used for a long time and repaired multiple times can be as desirable as those with a sleek ‘clean’ look. An example of this shift in mainstream consumer products is the packaging design of Arla milk in Denmark and Sweden; instead of full-colour printed cardboard packaging, Arla now positions the product as being a sustainable quality product and allows the natural texture of the cardboard to be visible in the design.

To take it a step further, one can claim that ‘raw’ looking materials are also more sustainable to produce. If a metal surface can be brushed instead of polished, this greatly reduces the amount of toxic chemical used during production. Similarly, wooden products tend to have a lower footprint when the natural wooden surface is visible instead of being covered by a pigmented lacquer or a polymer laminate.

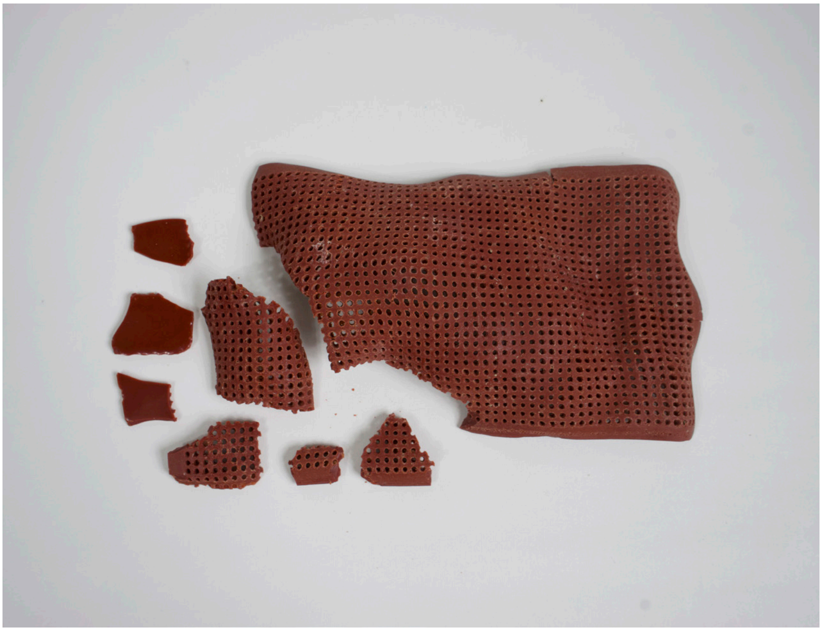
Seeing the importance of this material design movement, I was curious to experiment with materials myself. I had previously tried out some recipes from the online open access biocomposite material library materiom (Materiom Homepage, 2023). This was educational, but I was curious to get some first-hand experience making an actual product out of a novel biomaterial – to fully understand the process and the challenges we need to overcome in order to integrate biomaterials like this into our repertoire as designers of mass-produced products.

While working on the BLOK concept design, I formed a collaboration with two fellow students who were writing their Bachelor thesis at the same time. Axel Landström and Victor Isaksson Pirtti were experimenting with materials, and had developed two recipes based on local waste materials. The first, based on a resin waste product from the paper industry mixed with various waste products from the mining industry and the second, based on a glutenous material developed by material scientists at Lund University mixed with various minerals from the mining industry.

For the first material we decided to attempt to cast the button covers and the grille cover out of the thermoplastic resin. To do this, I 3D printed positives of the parts and then cast a silicone mould around them. Using a vacuum chamber, I removed any air bubbles from the mould to ensure a smooth surface.

After this, the orange-coloured resin was melted and mixed with the filler, which turned it red. Once liquid, the resin was poured into the moulds and allowed to cool and harden. After the first test, it became clear that the main challenge with the resin material was its brittle nature. Even during the de-moulding process, the material started to chip and shatter, rendering the resulting component unusable.

We tried again, this time leaving out the binder which we hoped would increase the ductility of the material. Additionally, we attempted to remove



the material from the mould while it was still somewhat warm and a bit soft. However, this resulted in the component bending and eventually – after it had cooled down further – chipping on the edges.

The second material required a completely different process. After mixing the dry ingredients with water, a type of dough was formed. The dough could then be shaped, before being placed in an oven to dry for around 12 hours. In order to achieve the intended shape for the back shell of the BLOK concept design, we created a wooden mould. The dough could then be wrapped around this mould. After drying, the mould could be mounted into a CNC mill and the outer surfaces of the shell could be milled down to their intended dimension.

Working with the dough-like material was tough. Interestingly, my experience working at a traditional bakery came in handy. We applied the same principles as when handling a sourdough bread; kneading and working the dough to develop the gluten and create a more cohesive and elastic mass. The main difference was that the material at hand was so tough, that it could not be kneaded by hand. Instead, we used a large mallet. After hammering the material into a cohesive mass, we folded it multiple times, each time hammering it out again to a workable thickness. Finally we hammered and rolled it down to the desired final thickness and draped it around the wooden mould before placing it in the drying oven.

After taking the material out of the oven, the first issue became apparent. During the drying process the material shrank, and cracks formed on the edges. Using a Dremel to cut off the edges to allow the material to be taken off the mould, the material proved to be quite hard, yet it seemed possible to shape it using conventional high speed steel tools. That being said, this material also proved to be quite brittle and it quickly became clear that it would not be suitable for a durable outer shell of a consumer product.

The second issue, which in the end prevented us from even using the material purely to illustrate the design concept in a visual model, was that the material had fused to the body of the mould. An easy fix for this would have been to apply parchment paper on the mould before applying the material. This might


bodum

also have prevented the cracking on the edges during the drying process by allowing the material to move over the surface of the mould while shrinking. That being said, there was not enough time left in the thesis project to start over. Instead, we decided to take the second mould and attempt to machine it in the CNC.

Since it had become clear that the material was not suitable for use in the design mock-up of the BLOK speaker, we decided to mill the surface of the second moulded part in order to look like the front of a speaker. Specifically, the concept was to create a contrast between the natural unprocessed bumpy surface of the material and the smooth grey milled area. The result is a striking example of the new aesthetic possibilities that are created when working with novel biomaterials, and when one challenges conventional industrial manufacturing practices for consumer products.

That being said, these materials are clearly not currently at a stage in which they can be used for mass produced products. More work needs to be done to develop the characteristics of biomaterials to allow them to meet the stringent requirements of consumer products. This is not limited to mechanical properties. The scalability of production is currently also a major limiting factor.

This development is not entirely unlike the development of oil-based polymers in the early 20th century. At the time, it was clear that a whole new category of materials was under development and that these would revolutionize industrial production; new shapes, surfaces, colours and mechanical designs would be enabled by this new material. However, early materials such as Bakelite were quite limited in their applications and whole new production methods had to be developed to make the most out of the potential of these new materials.

As designers we also must not forget that while these new polymers were being developed by material scientists, designers had to develop new form languages and change the physical shapes of their products to be suitable for the new materials, their properties and their manufacturing methods. After all, a plastic chair could not simply be made in the exact same way that a wooden chair used to be made. The development of a new modern aesthetic which included industrial materials such as plastic and sheet steel went hand in hand with other societal changes in the 20th century. It is my hope and expectation that the development of a new ‘sustainable’ aesthetic will go hand in hand with the transition of our society to a more sustainable way of life.

BLOK speaker:
a sustainable portable speaker concept.

BLOK speaker is the final concept design which I developed for this thesis project and represents the main outcome of the thesis. The concept aims to combine all the best practices identified through my research and previous concept designs. It represents a design of a portable wireless speaker which employs a variety of strategies in order to be as sustainable as possible.

In this chapter, I will first provide an overview of the final design and prototype. Subsequently I will address each sustainability strategy which was applied to the design and explain how the strategy is embodied in the speaker, and how it aims to make the product more responsible. Finally, I will critically assess the resulting design, and discuss to what extent it lives up to its ambitions.

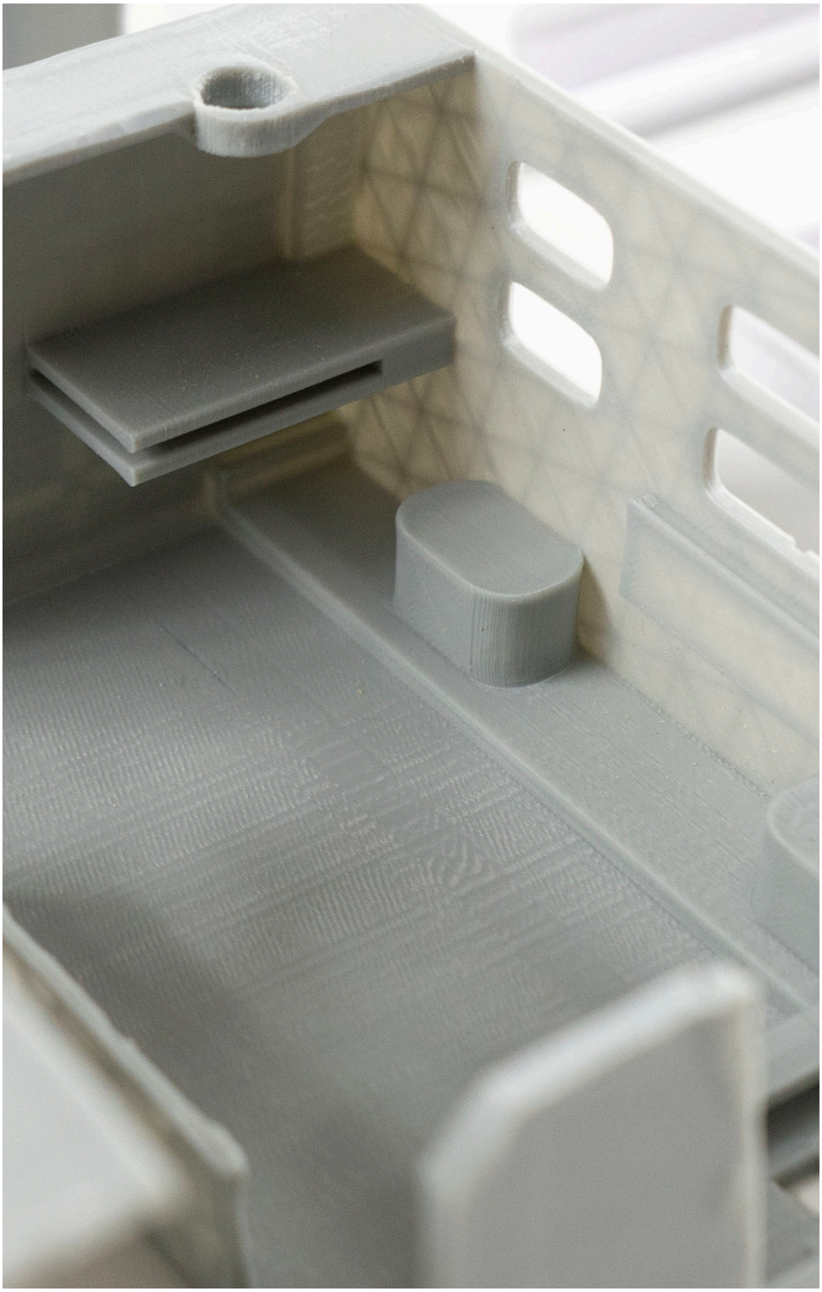
BLOK is about 30x12x8cm in size, and weighs about 1.8kg. The speaker is made up out of the components of a Dynaudio Music 1 speaker: A battery, control board, wireless connectivity board, multiple input button boards, a driver and a tweeter. The housing was custom designed and 3D printed for the prototype.

The structure of the concept design separates the electronics from the drivers. By disconnecting these two parts of the speaker housing (grey and white respectively), one can exchange or remove the exterior grille and gain access to the electronic PCBs, the battery and the drivers. This, as well as the removal and replacement of PCBs, can be done entirely without tools. Only the drivers are attached with common screws.

In this concept design, I combined the following strategies for sustainable design:

Original speaker, disassembled.

Top: 3D printed parts of BLOK speaker. Right: detail of 3D printed part.



Design for durability

The almost monolithic design is made to have no protrusions, handles or other parts which can easily break off or be damaged. Meant to be made in a simple homogeneous material such as aluminium, every component of the speaker is meant to last as long as possible, without little plastic bits or faux leather straps that can deteriorate and make the speaker look older than it is. The hope is that this design would mean that a patina, gained over time through scratches and subtle discolouration, would add to rather than subtract from the speaker's aesthetic value.

Design with a replacement strategy

Using high quality components also means that every part of the speaker should last for as long as is feasible. That being said, components do need to be replaced at some point. The following replacement strategy was utilized.

The highest likelihood for replacement was given the battery. The chemicals in batteries degrade over time and from use, meaning that this tends to be a part that needs to be replaced every few years.

The second most important part to replace is the exterior of the speaker. Besides dwindling battery performance, the general look of the speaker is thought to be a frequent reason for speakers to be replaced. Over time, the owner's preferences for colour and materials might change, or the speaker might become scratched or dirty to a point that the user no longer perceives it as valuable enough to maintain. For this reason, the speaker was designed so that the front facing grille can easily be replaced. The idea behind this is that various colours and materials can be made available for the grille, while the rest of the body always stays the same.

Next, the speaker's input and output connectors (I/O) are the most likely cause for the product to be replaced. Over time, we see new standards come and go. Currently Bluetooth is the most commonly used wireless transfer standard for audio. For wired power and data connections, USB-C is standard while analogue audio signals are still often transmitted via 3.5mm audio cables. As these standards change, users might see a speaker using old I/O ports as outdated, or it may no longer be able to function with their more up-

Detail view of battery and driver blocks, back shell removed.

to-date collection of devices. For this reason, it should be possible to swap out the PCB boards containing wired and wireless I/O. Since the prototype was built using hardware from an existing product, this function was not implemented entirely. However, all PCBs can be removed easily in a few steps, without the use of any tools.

In a low-end speaker, a common reason to replace the product might be that the user wishes to own a speaker with a better audio quality. In this case, high end drivers were already used - so it was deemed the least likely reason for the speaker to be replaced. That being said, the drivers and especially the tweeter are fragile outward-facing components. Additionally, developments in technology might see an improvement in driver quality which could make the current generation obsolete – a recent example being the adoption of neodymium magnets, which increased the performance of small drivers significantly. For that reason it was decided to make the drivers replaceable. However, in order not to compromise the sound quality they are the only parts that require a screwdriver to replace.

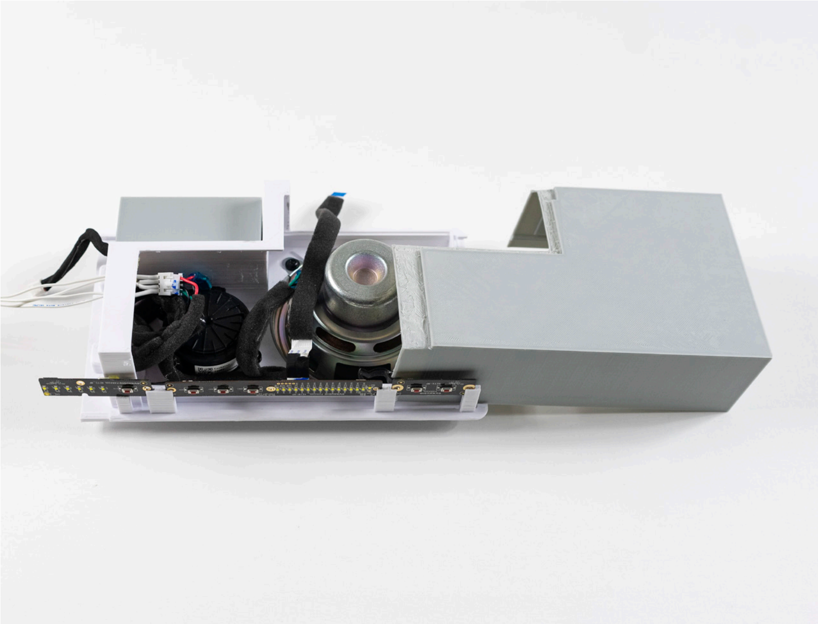
Design for tool-free disassembly

As mentioned under point number 2, almost the entire speaker can be disassembled without the use of tools. The first step for disassembly is the removal of two rubber feet on the back of the speaker. These feet keep the speaker a few millimetres above whatever surface it is standing on, and also keep the assembly of speaker components together. After they are removed, the back cover of the speaker can be removed. This reveals the interior of the speaker, which is divided into blocks. One block contains the drivers, another the battery and a third contains almost all the PCBs (due to the design of the speaker which was used for parts, the buttons had to be arranged outside of the electronics box, which would ideally not be the case).

Each of these blocks has its own cover. These covers can be removed by sliding them to the side, which reveals the contents.

The electronics box is slightly different. Anticipating that not all users would be comfortable dealing with electronics, it was designed so that this box could be removed without opening it, after disconnecting the wires from the

Removal of the feet, which allows the blocks to be removed from the speaker body.



Top left: components of driver block.
Bottom left: assembled driver block without cover.
Top right: assembled driver block with battery and input PCB, half assembled cover.

drivers and the battery. Again, due to prototyping constraints the ideal design was not embodied by the prototype. Instead, the electronics box does need to be opened to disconnect these components. However, in an ideal design these components would simply have wires which plug into the side of the electronics box. After disconnection, this box could be removed and replaced.

That being said, the electronics box also simply slides open to reveal the PCBs inside. None of the PCBs are screwed in place. Instead, they slide into one half of the electronics box and are held together by the two halves of the electronics block being slid into each other. These in turn are held securely in place when attached to the other part of the speaker.

After the electronics block is removed, the front grille can slide out and be replaced.

Design for modularity

Having the ability to remove the entire electronics block, also opens up the possibility for these blocks to be designed to be modular. This was not implemented in my concept design, but the idea is that you would for example be able to change to another type of electronic block, that can for example be connected to a larger number of drivers. Perhaps multiple BLOCKS speakers could be daisy-chained together, or a non-portable version of the speaker could be developed as an alternative. Especially if the blueprints for the speaker are made publicly available, a community of DIYers could continue to develop innovative and useful solutions for a community of BLOCKS users.

Design for upgradability

This point is really not so different from the one about modularity. But, beyond just the ability to replace and upgrade modules, it could even be thinkable to take individual components out such as the drivers or the battery and replace them with more capable substitutes. The possibilities for upgrades is designed into the concept, but the actual execution would further rely on the company which launches the product to enable this through future product launches and a logistics system which supports the delivery of components to customers who previously bought this product.

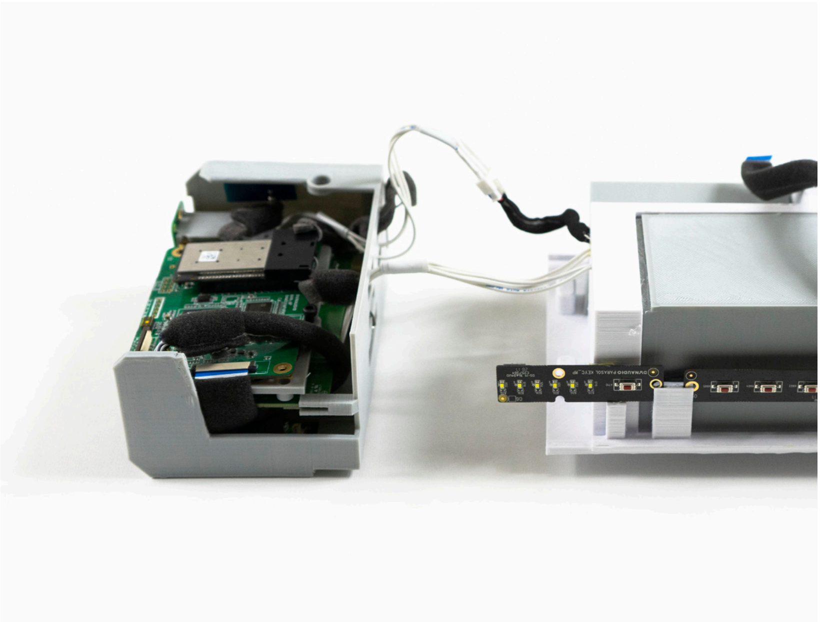
Design for customization

Really not so different from 'upgradability', this point focuses more on the adaptation of the product to the user's individual preferences, without clearly increasing its capabilities or functionalities. In this case, the exterior grille and the back cover can easily be replaced to change the look and feel of the product with another material, Colour or surface finish.

Design for recycling

Designing the entire product for easy disassembly also means that it will be more easy to separate materials and components to enable efficient and cost effective recycling. Besides easy access to the battery, it is expected that most parts will be shredded before recycling. By not attaching the PCBs with screws, this makes it more likely that the entire PCB board will be separated from the housing, which creates cleaner recycling fractions.

Since this concept design does not include final decisions on exact materials to be used in production, the actual design for recycling should be included in the next steps towards putting this product on the market. For this it will be essential to work with recycling companies to learn about the challenges they face when recycling electronics, and ensuring that the materials which are chosen are compatible with existing material streams. One can assume here that using common aluminium alloys and common plastics such as ABS or PP will make the product as recyclable as possible. The recommendation is also to work with these materials, although it is outside of the scope of this concept design to define exact alloys, polymers and filler (e.g. glass fiber) percentages.



Top left: components of electronics block.
Bottom left: assembled electronics block connected to drivers and battery.
Top right: all blocks assembled without outer shell.

Conclusion and Discussion

The questions that I defined at the beginning of this project are:

> *How can designers influence the impact their products have on the environment and on people, throughout the product's life cycle?*
>
> *How can an established hardware company make the shift towards becoming a responsibly operating organization?*

Since beginning this project in 2019 I have had plenty of time and opportunities to think about these questions, discuss the topic with professionals from various industries and experiment. With the main goal to learn more about responsible design and question why we design and make products the way we do, I have crossed through philosophy, ethics, sustainable policy, circular economy, human rights activism and sustainable design methods. My main takeaway would be that there is so much more I have yet to learn about all these topics. But I also carry a strong conviction that there is a different way to do things, and that defining this will be the main challenge for our generation of designers and engineers to rise to. We face a fundamental change in our system of objects, which is both a daunting and an immensely exciting prospect.

I do not know that I have a direct answer to the questions defined at the beginning of the project. The title of this thesis reflects what I think about that. We need to talk. We need to remain critical and hungry for new knowledge and communicate openly about what we know – and what we don't.

The design strategies which I implemented in the concept design of the BLOK speaker reflect the latest insights into circular design. They show both the opportunities and limitations of a theoretical concept design. Clearly the embodiment of the speaker is shaped by placing a priority on the sustainable design strategies. However, one can see in points such as 'design for customization' that there is a limit to what a designer can do in the early stage concept design phase. To really make a difference on points such as this which are so heavily reliant on the way a product is marketed, the brand's business model and the behaviour of consumers, the designer must be involved in processes outside of the design team and become an active proponent of sustainable values throughout various departments in a company.

This is also where a divide becomes apparent. A designer isolated within the design and engineering team might be best served to focus on a point such as 'design for recycling' or 'design for tool-free disassembly'. These are areas in which they can make a considerable impact. Other points, that are more related to the overall strategy of the company such as 'design for upgradability' should be addressed by individuals in management positions, that can influence the strategy of one or multiple departments.

For future work, it would be interesting to define the exact role of the 'designer' in the first research question more clearly. Designer can do many different things and work on any level within a company. As such, the things that they can do will vary depending on their role and specialization. The attempt of this thesis then to create a general insight into what 'designers' can do, is limited by its own lack of specificity.

The second research question was explored in more detail during a case study with the company Dynaudio A/S, a high-end audio company located in Denmark. Due to a change in management after completion of the project but before publication of this thesis, it was not possible to receive permission to publish data about the company. Therefore specific insights have been left out in this thesis. Additionally, interviews conducted with industry professionals working with the design of electronics and development of sustainable materials were left out since the thesis will be published several years after the interviews were conducted. Other work, such as the below illustrated analysis of evolving user needs related to speakers, was left out because it was – although educational – not an essential part of the final concepts.

Investigation of evolving user values and needs

At the start of this project I specifically defined the scope of my work to be responsible design, which beyond environmental sustainability also encompasses social responsibility. I must admit that although there are clear and actionable things designers can do to address sustainability, I did not manage to get a clear view of what designers can do to develop more socially responsible products. So much depends on how and where a product is produced, transported and disposed of. I also did not spend much time on the social responsibility designers have to their users; for example, by not developing products which have unnecessary leasing contracts. This was necessary to keep the scope of the thesis manageable, but would be a priority for future work. After learning more about the ethics of sustainability and the fundamental philosophy behind ethics in a globalised society, I stand by my point that social responsibility and environmental sustainability are two sides of the same ethical coin.

In conclusion, the sustainable strategies identified in the literature study are useful and can further be developed by distinguishing between strategies which can be implemented by designers and engineers, and strategies which are more in the domain of design managers and professionals developing business strategies.

The approach to develop design concepts to explore the implications of individual design strategies before developing an integrated design concept which addresses multiple design strategies at once was successful and allowed for a well-integrated product design process with a focus on environmental sustainability. Along with a focus on social responsibility, some of the design strategies remain open for implementation in later stages of the product development process.

The final integrated design concept, the BLOK speaker, is an interesting concept embodied in a physical model which can allow an early-stage evaluation of the design and its commercial potential. The main value of the design might lie in its inspirational function to show what a speaker might look like when an emphasis is placed on environmental sustainable from the very early stages of product development. Secondly, the experience I have gained working with theoretical insights into sustainability and ethics and implementing them in the design of a product and discussing them with a company during an unpublished case study, has given me a hands-on understanding of the challenges we must overcome when attempting to develop more responsible products.

Appendix 1:
Material choice: the beginning and end of sustainability

Adapted from my presentation at Elmia Subcontractor Fair in Jönköping on 15-11-2019

Although academic research into the causes and complex factors of the sustainable impact of product design and the global manufacturing industry has increased steadily since the 1970s, the same can not be said for industry adoption of the proposed solutions resulting from this academic work. I believe one of the causes to be that it is incredibly difficult for companies - especially with limited resources - to gain enough insight into these complex issues to formulate strong visions and set attainable and effective goals. Another factor that might contribute to this 'gap' between academic research and industry practice is that a comprehensive approach is required, whereas individual companies only really directly control a small portion of their supply chain.

Partnerships between brands, environmental organisations and suppliers can be crucial to navigate the complexity of manufacturing supply chains, gain data and develop relevant innovations to tackle the most pressing problems. A starting point for sustainable innovation could be material suppliers seeing the growing demand for sustainable materials from brands that are interested in targeting the growing group of consumers that consider aspects of sustainability in their purchasing decisions. From my case study with Dynaudio, I found that it can be somewhat frustrating for manufacturers to find what they are looking for in terms of sustainable materials.

It is therefore important for material suppliers to understand what product brands/manufacturers are looking for. This will allow them to offer competitive options to clients, as well as enabling the creation of more sustainable products. Innovative new materials that offer more sustainable properties are not the only thing manufacturers are interested in. Additionally, if innovative new materials are indeed offered, manufacturers require certain information to make the materials interesting, and some added benefits can be offered by material suppliers to make the materials worth the extra cost or risk.

So, what do companies and designers look for from manufacturers and material suppliers to enable the development of sustainable products? The three main categories I have defined from my case study are: Innovative materials, Data and Stories. Innovative materials are new material offerings that provide improved sustainable properties. Reliable data about the material's (sustainable) properties and origin is required for companies to make informed choices about what material to opt for in their products. Stories about the origin or manufacture of a material can increase the value of a material to a brand, thereby making it possible for them to use a sustainable material even if it is more expensive than a conventional alternative.

Materials innovating on sustainable properties tend to provide benefits in some or all of three categories: Source, Components and Properties. Quite common already are materials that adhere to a certification such as FSC certified wood. Although this is (usually) a reliable way to ensure materials adhere to a baseline of sustainable properties, these certifications are often not very ambitious and are not very highly trusted nor understood by consumers. Materials sourced from waste streams and/or that are recycled can be important if the conventional alternative is scarce or if the extraction of the virgin material is harmful and/or energy intensive. Renewable materials can be a good alternative for scarce and non-renewable materials. In some cases it can also be beneficial if a material is sourced locally, keeping supply chains transparent and reducing required transportation.

The second category, components, is relevant for materials that contain multiple materials or chemicals. Examples of this are plastics with a filler such as glass fibre and particle boards made out of wood chips and a binder. For these types of materials, it is important that none of the components are toxic or create toxic waste or fumes when burned or otherwise disposed of. It is also important that when different materials are mixed, that they are separable or compatible. Separable means that a recycling company could realistically separate the materials and recycle them accordingly. Compatible means that the materials could safely and efficiently be recycled together through the same processes.

In the third category we look at the actual properties of the material. Naturally, the lower CO2 footprint a material has, the more interesting it becomes to brands looking for sustainable materials. It is also important that the material be recyclable or compostable. Products that gain a patina over time can help brands make longer-lasting products, as can self-healing materials. Finally, we are seeing the rise of an aesthetic of natural or recycled materials. This aesthetic is not comprised of certain materials or forms, but rather of materials that by their nature tell a story about where they're from, how they're made and/or what some of their properties are. An example of the increase of this aesthetics' popularity can be seen in the design of milk cartons in Scandinavia, which increasingly show the bare cardboard - a material that shows its natural origins and particular properties through its colour and texture. Similarly, large fashion brands such as H&M have released clothing lines that show impurities in their fabric because they were made of recycled materials.

Appendix 2: The most sustainable speaker, a practical approach

The complexity of the topics that this report tries to cover can sometimes get in the way of defining clear and actionable conclusions. Although it is important to understand that the nature of responsible design is such that one can never really simplify to a black and white conclusion, this chapter aims to provide an overview of the findings that are most relevant to the practice of designers and companies working with consumer electronics today.

Quite simply put, the most sustainable speaker would be no speaker at all. If we assume, however, that this is not an option and that a physical speaker is absolutely necessary, the second most sustainable option left to us is to use an existing speaker instead of producing a new one.

Although it may seem that both options are not interesting for a company whose core business is to manufacture speakers, they do warrant some serious thought. Imagine a hypothetical situation in which the company would be forced for some reason to stop manufacturing speakers. This framework for ideation; 'how might we create value for the company without manufacturing speakers?' might prove to be instrumental in developing business strategies and/or products that would not only be sustainable but could also strengthen the company's portfolio by adding diversity and inimitability and could make their business more capable of navigating the risks of a competitive hardware-based industry.

Even though a single company might manage to shift their core business and stop manufacturing new speakers, this drop in production numbers would likely be compensated for by increased production by other companies. Ultimately the consumer still demands new products, many markets have a growing number of consumers and on a fundamental level our economic system is based on growth and production. The sudden and complete disappearance of our global manufacturing industry is not just unrealistic, it would also bring our global economy to a halt - the ramifications of which are not in line with the ethical aspects of responsible design.

Given our economic system and the simple fact that speakers are currently being produced, and having concluded that an idealistic pursuit of 0 production is not a desirable direction we must finally ask ourselves: ‘how might we produce a speaker which is as sustainable and ethical as possible?’

Firstly, there is the basic concept of the speakers. When starting from scratch, a designer can think about the thing they are putting out in the world. Rather than building the product on assumptions of what a speaker is, a fundamental investigation into what a speaker could be and what value it provides users should be conducted. Different ways in which it can fulfil its multitude of functions and different forms to enable certain behaviour can be explored at this stage. Should a speaker be repairable, then this is not just a question of making it easy to take apart. It is also about building a speaker that clearly communicates - in every detail and in every part of its interaction with the user - that it can and should be repaired. An engineer can make a product repairable; a designer can make it likely to be repaired. Other examples of things to be considered at this early stage in the product’s development are allowing the user to form a relationship with the object, utilizing an aesthetic which is not tied to fast-changing fashions, making the product durable, making the product so that its function can change or evolve over time, allowing users to customize the product, designing the product to enable local business development and more.

Then there is the consideration of physical features. What things are absolutely necessary for the product to fulfil its function? Must the speaker have a battery, multiple LED indicators, microphones, Bluetooth, Wifi, etc.? Especially when committing to sourcing parts responsibly, adding extra (electronic) components can potentially add a lot of complexity and cost to the product when sometimes it seems, features are only included to conform to the market, rather than to make a good product.

Before defining the shape of the product, one must evaluate what materials could be used. Some materials such as PVC can easily be eliminated from the pool of options due to their toxicity. Currently bio-composite plastics are used on an experimental basis. In the near future, as these materials reach maturity, choosing what currently would be considered unconventional materials can radically change the way we interact with our products. This also highlights the importance of having a clear and realistic vision for the entire extended life of your product. Do you want it to be repaired? Do you want to make it durable so it lasts longer? Or do you want to make it for temporary use, but in such a way that it can decompose in its entirety? Although this last option will not be realistic for entire speakers anytime soon, it can be an interesting concept for packaging or other products that do not contain electronics.

In the material choice we also start to see the nuance and balancing necessary to create sustainable electronics. For example, if using a commodity plastic will make the product last twice as long, does this not make up for the use of a finite resource? Yet if you do this, how do you ensure that the product will actually be used twice as long, and that the user doesn't get tired of it before it needs to be replaced? These types of questions are the reason that it is not possible to simply follow guidelines or a few 'easy steps' to achieve sustainable design. In its very essence, sustainable design should always be a discussion, an ongoing investigation framed by critical questions.

There are two main differentiators that are important to look at when evaluating material options. Where the material is sourced, and how it is disposed of.

When materials are sourced, they can be renewable, recycled and/or organic. One must also look at the impact of the material's extraction on the natural environment and on the people involved. Finally, materials that can be sourced locally can have a different impact and open up new possibilities for product concepts than materials produced by a globalised industry.

The three desirable characteristics in a material's end of life are recyclability, biodegradability and compostability. If a material is none of these, it will have to be burned or landfilled. The nuance here is that the desirable characteristics can have negative externalities such as the release of toxins when improperly recycled, or by destroying the balance of a natural ecosystem while biodegrading.

On the other hand, burning materials can be a viable source of energy if the emission of greenhouse gasses is balanced out and fine particulates are filtered out of exhaust air. Here too, we see the importance of thorough data and ongoing investigations during and after the development of a product.

Decisions that influence the environmental impact of the product are also made while detailing the design of a product. At this stage it is important that there is a solid conceptual vision for the life cycle of the product. For example, a strategy focused on longevity will result in very different detailing than one centred on the recycling of the product. In general, the use of adhesives and resins should be avoided. Materials should also not be mixed in ways that they cannot realistically be separated. A soft grip that is moulded onto the hard shell of a product is a clear example of two materials that cannot be retrieved after production.

In the detailing phase of a product that should be repairable one should also investigate the main failure modes of the product. This way the parts which often cause issues can be made easily accessible for repairs (e.g. making the battery in a portable product replaceable without tools and in just a few steps).

The manufacturing of a product often has a large impact on the CO2 footprint of consumer products. Research has shown that it is not possible to simply determine some production methods to be more energy efficient than others. Instead, it is critical to build lasting relationships with manufacturers. This allows for the long-term gathering of data and optimization of production lines, as well as enabling work on structural improvements to the value provided to factory workers. The reliability of data concerning energy use, waste production, and working conditions is critical to the ability of a company to make informed decisions. Especially when working with overseas manufacturers, it can be useful to work with NGOs, worker unions and research institutions on the ground. On the side of energy consumption, a clear measure that can be taken is to work with manufacturers that use renewable energy sources.

When marketing a product, the customer can be nudged towards placing value in different attributes of the product. This could be obvious attributes such as the technical specifications, but also attributes that are less obvious or immaterial can be highlighted, such as the precision of a watch or the lifestyle associated with a certain brand of product. In order to create products that people will take care of by repairing and ultimately disposing of them properly, marketing of the product must place value on the actual hardware, the materials and the longevity of a product. After all, if a customer buys a product for its associated lifestyle, in the next season the customer will desire the next iteration of said product and is likely to completely disregard the inherent value of the hardware of the older model. If a customer buys a product because they know it can be repaired and/or upgraded they are more likely to expect the product to last longer, and invest in this longevity. Likewise, by understanding the value of the hardware the customer is also more likely to recycle the components at the product's end of life.

Another avenue that can be explored in the marketing of products is to utilise the story and work behind the efforts towards creating a responsible product as a means of marketing itself. This could potentially build trust, target the ever-growing consumer base that cares about sustainable and ethical products, and free up budget for more thorough research.

Building trust cannot be achieved through marketing alone. Proper documentation as well as honest and open communication of efforts is required not just to build up credibility with consumers, but also to hold your own organization =accountable. If the premise of this documentation is that mistakes can be made, but they need to be admitted openly, then this approach to responsible design can survive inevitable setbacks, not just internally but also by retaining or even strengthening the trust of consumers.

The topics covered in this overview are not rocket science. But even when simplifying everything down, it is clear that there are no quick and easy fixes to issues of sustainable and ethical design of consumer electronics.

Working towards responsible products required a willingness throughout an organisation or company to challenge the status quo and to question business as usual. For long-term success, a company or designer's approach must be rooted in the firm belief that good design provides value to everyone who touches the product during its life.

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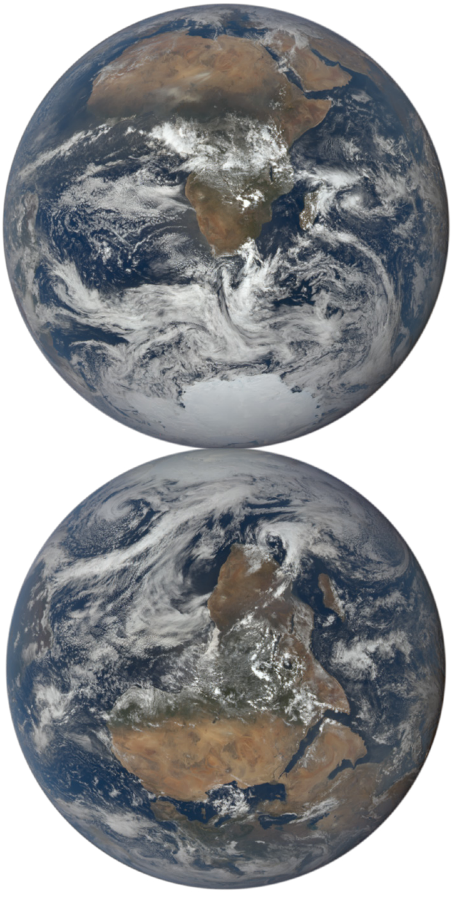

Images of Earth, taken January 1st 2018(t) and September 26th 2023(b)
Source: https://epic.gsfc.nasa.gov/