Sustainable Pattern Library

Facilitating Designer's Shift to Sustainable Design Practices

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Abstract

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As the demand for digital products continues to grow, prevailing design methods that largely ignore ecological or societal wellbeing have become an urgent problem over the last two decades. These methods of creating have led to digital products that exploit human vulnerabilities, weaken our collective view of reality and decouple the digital from the physical. This reality, blended with the energy-intensive infrastructure underpinning the internet, has resulted in an ecological footprint of the internet that rivals some of the world's highest-polluting countries. Looking at prominent design practices through the lens of their societal and ecological impacts over the last twenty years, we can see how current design processes serve to “defuture” us by damaging our planet and societal wellbeing.

Perpetuating this issue, is the fact that there are few resources for designers to aid them in alternative ways of creation. This dearth of resources that could help designers understand how to create sustainable digital products, led to the investigation of pattern libraries and ultimately the research question of “how might design patterns, in the form of a pattern library, persuade designers to shift to more sustainable UX practices?”

To develop the pattern library, a collection of research was consulted, to translate the theoretical knowledge into a set of interface patterns that can lead to more sustainable outcomes when implemented. The goal of this pattern library was to develop a tangible resource that can practically assist designers in adopting more sustainable methods of creation. This library was then tested to understand how well it achieves these goals and where the areas for improvement exist to ultimately create a tool that designers across all industries can turn to. These patterns demand that the powerful technologies that we use daily are designed for humans – and the planet we depend upon.

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Introduction/Background/Context

Internet technology has transformed most aspects of our society – much more than could have been predicted over twenty years ago at the precipice of the ubiquitous technology era we are currently in. This transformation began with the early adoption of computers in commercial spaces in the 1980's, grew to widespread global and personal expansion in the early 90's (Cohen-Almagor, 2013) and now into ever immersive and integrated internet experiences. This technology continues to bring new changes to social lives, business processes, education, healthcare spaces and the planet itself.

As the internet was expanding into daily personal and professional lives, understandably much emphasis was placed on the possibilities to improve human connection, efficiency and access to information. Much less investigation was spent on the potential negative impacts of illimitable internet access on the planet and personal wellbeing. Ahmed and Sharma (2006) in the early 2000's, discussed the possibility the internet brings to strengthen inter and intra community relations. They also highlighted the potential for "internet technologies [to] facilitate a shift from representative democracy to a more direct democracy, as the technology provides the ability for wide range participation by people outside existing power structures". Though these optimistic expectations have proven true in many senses, with the assistance of time, further examination into the true impacts of internet technology shows a darker picture.

Features and interactions that are now a staple in our online experiences that were introduced to encourage positivity and facilitate navigation such as the "like" button and "auto-scroll", have over time been demonstrated to exploit human vulnerability and promote profit over well-being (Emery, 2021). Algorithms that were crafted to prioritise important information and the personalization of the internet, have been shown to create a uniquely curated version of reality that is more sensational than real life. This method of designing the internet and its features, not only reduces cognitive functions (Brady et al., 2017), but serves to weaken our collective view of reality — an effect that hinders society's ability to collectively address global crises and organise effectively (Bak-Coleman et al., 2021).

This situation has been perpetuated by the dominating "persuasive design" zeitgeist (Nodder, 2013) — characterised by its focus on influencing human behaviour (Fogg, 2009). Nir Eyal

(2021), a pioneer in this design approach, explains how this approach greatly benefits businesses, as companies “increasingly find that their economic value is a function of the strength of the habits they create”. This means that the consequences of businesses creating products that reduce the need for a user's cognitive functions, to further their own financial gain, are more prevalent than ever. This also means that technologists are trained to design according to these frameworks, as their livelihoods are tied to the ability to design in these ways. We see the effects in our fractured societal response to crises related to mental health, global health, and the environment (Bak-Coleman et al., 2021). These design patterns and others, detract from Ahmed and Sharma’s hopeful perspective on the macro societal impact of the internet.

Posing another threat to early optimism around the benefits of an increasingly digital world, is its impact on the environment. In an excerpt from Ahmed and Sharma’s 2006 paper, they outline how the internet holds the prospect of reducing energy intensity by replacing activities such as commuting, shopping, printing material, travel with the internet alternatives (video calls, online shopping, digital information etc.). Many still believe this to be true in today’s age. Pixels and virtual information stored in a cloud are completely intangible and feel untethered from earth’s planetary limits. Almost a decade and a half later, however, it is evermore clear that unlimited internet takes a toll on limited natural resources.

The internet comprises the data centres, transmission networks, the production chains to transport end user devices like cell phones and laptops as well as the energy used to power them. More concretely as an example, the carbon impact of the internet is made up of the energy used to create a cell phone, transport it to a user, render and store content that is displayed to the user and power the cell phone to continue its use. This same internet infrastructure is on track to emit levels of pollution that top the six highest polluting countries in the world (Sustainable Web Manifesto, 2022) – or around the same impact as the aviation industry (Griffiths, 2022). Despite this staggering effect, the bloated digital ecosystem continues to grow exponentially to meet the demands that manufactured reliance has created. The digital ‘replacement’ activities such as storing and sharing information on the cloud versus printing documents and the ever-growing online activities such as streaming, scrolling social media, posting and messaging etc. continue to strain planetary boundaries rather than reduce the carbon impact of our day to day activities.

Undeniably, there is a strong relationship between unsustainable ways of creating digital products that exploit and harm mental wellbeing and exploit and harm planetary resources. As businesses are incentivized to create digital products that encourage users to consume more (content, goods, device upgrades) through persuasive design techniques, this in turn stretches the internet infrastructure to support these actions. The outputs of these techniques (often referred to as dark patterns) have become staples in our regular digital products and thus we have habituated ourselves to navigate in an internet that is simultaneously destructive to both our planet and societal wellbeing.

What these patterns have in common, is that they are all designed with careful thought to how users will interact with them and have end results that can be studied. Research into information technology ethics reveals a tenet that is key to understanding how even technology that was designed with the best of intentions, has been found in practice to have disastrous impacts (Boers et al., 2019; Lindsey Barrett et al., 2023; Sims et al., 2020). As detailed by Jeroen van den Hoven in "Ethics for the Digital Age: Where Are the Moral Specs?":

> The first thing we need to realize is that the technologies we end up using are consolidated sets of choices that were made in their design, development and implementation. These choices are about e.g. interfaces, infrastructures, algorithms, ontologies, code, protocols, integrity constraints, architectures, governance arrangements, identity management systems, authorization matrices, procedures, regulations, incentive structures, monitoring and inspection and quality control regimes. (van den Hoven, 2017)

In other words, technology is never neutral. The internet products we design are embedded with our values, biases and ideas about the world. These ideas, values and assumptions that are hidden within these digital tools, over time, influence the options, behaviour, thinking and feelings of the people that use them (Center for Humane Technology, 2022). This technology influences society at large, through mechanisms such as filter bubbles (Samuels, 2012), automated interactions that keep users online longer, search result manipulations (Epstein & Robertson, 2015) and much more. Our society in turn continues to shape our technology and so the loop continues. Thus, many of the existential issues our society encounters today, from climate change to disinformation, mental health crises to authoritarianism are exacerbated as a function of the technology we've created.

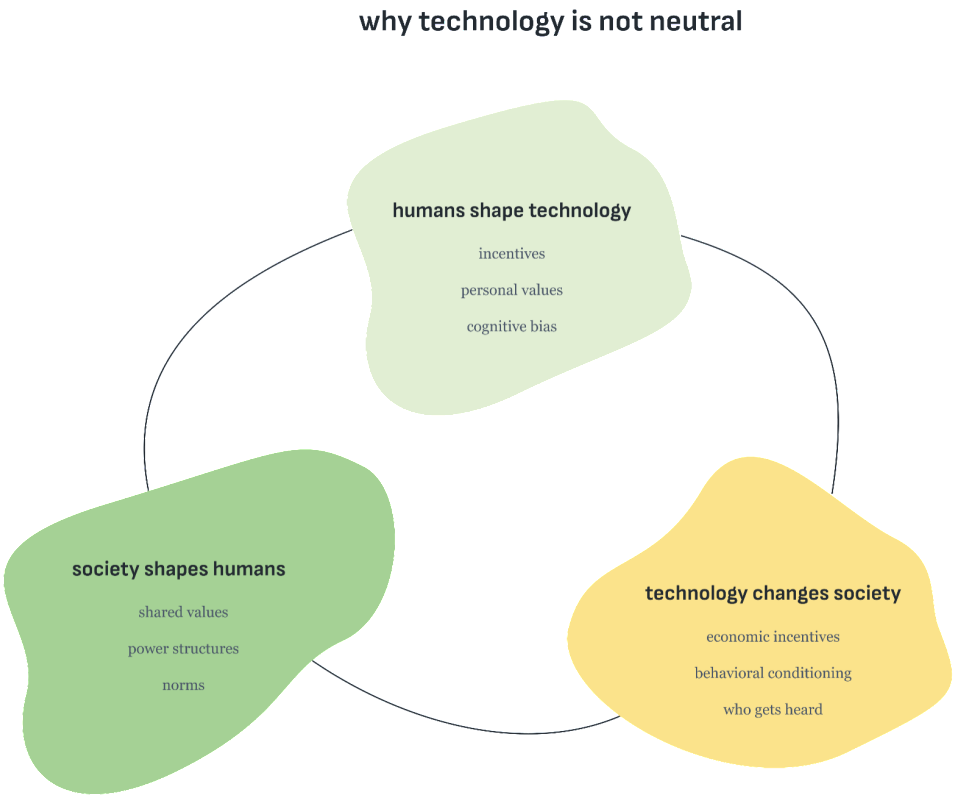


FIGURE 1: Why Technology is Not Neutral (Center for Humane Technology, 2022)

As more research emerges about the negative effects many common design patterns in our digital products have on our collective wellbeing, policymakers are starting to take notice. Work from the European Data Protection Board (European Data Protection Board, 2022), legislation from California (Vincent, 2021) and the European Union's Digital Services Act (DSA) (2022) are examples of government initiatives designed to address issues of data privacy and protect citizens from deceptive patterns that are designed to trick users into handing over their information. More recently, proposed regulations from the United States called the SMART act (Social Media Addiction Reduction Technology Act, 2019) aims to prohibit social media companies from using practices that exploit human psychology and to take measures to mitigate the risks of internet addiction and psychological exploitation.

These proposals are limited in that they often can be too slow, playing a reactive game of catch up. Like whack-a-mole, such policies are often using the legal tools of yesterday to limit digital products of tomorrow while companies continue to innovate and invent new ways of shaping our

society. This begs the question, therefore, how can we create a digital world that reflects and meets the needs of an optimally functioning society? One approach is to design products within frameworks that require the creators to confront the psychological and environmental impacts of their designs throughout the process. This would be in keeping with more modern conceptualisations from the same pioneers of Human Computer Interaction, that emphasise designing for a “better world” instead of focusing solely on task completion, reduced friction and ease of use (Nielsen, 2009; Norman, 2023). This lessens the need for reactive policies and can ultimately bear fruit to a new set of standard design patterns that users can expect to see implemented across the internet that respect human vulnerabilities and autonomy. These design patterns can replace existing exploitative ones and be continuously improved upon and measured to better understand their impacts on society.

Drawing from disciplines such as Slow Design, Seamful Design, Humane Technology Principles, and Sustainable Web design, technologists can be empowered with the knowledge to create products that work in response to the limitations of our planet and with consideration of human vulnerabilities. When these disciplines are combined, designers have the theoretical knowledge to rethink commonly accepted web best practices from the onset and recreate internet experiences that are truly sustainable from both a social and environmental perspective. These re-worked design experiences can be codified into updated design patterns that can become part of any digital designer's standard practice. This can allow designers to ensure that the powerful technologies we use daily are designed for humans — and the planet we depend upon.

This approach fits well with current methods that most designers use to create interfaces. As a primary function of a good user experience designer is to create intuitive experiences, designers are therefore practised in reusing existing design patterns that society has collectively deemed normal and to be expected (Joyce & Tankala, 2023; UI Patterns, 2023). As creators who have a direct say in how products will function at the beginning of the product building process, this practice of reusing common patterns can help society and designers alike become familiar with newer, healthier ways of interacting in our digital world.

It is important that the design community treat the need for a new way of creating as an area of concern and a matter of urgency. Currently, the majority of the design community lauds immersive, engaging and complex interactions (Awwwards, 2023) while largely ignoring these

issues of sustainability. Similar to the way that web accessibility has become a standard discipline and area of consideration that complements standard design practices, sustainable web design should be treated in the same way. It is another area of consideration that must be brought to the forefront of designers' minds alongside the aim of meeting business goals and creating captivating user interfaces.

The design community is starting from a place of scarce resources. Developers and engineers have concrete resources and tools that can help them figure out how to build products in a lighter way. Offerings such as code libraries, implementation tutorials, blogs, explainers help developers understand what building a sustainable digital product looks like (Lewis, 2023; GreenIT, 2023; Green Software Foundation, 2022). This can be extremely impactful from an environmental perspective, though as developers are not typically part of the ideation and early creation process, they often have limited say in how the designs will function, more-so how those functionalities will be built. We can see the negative effects on the environment when we look at the growth of typical page weights despite technology efficiency gains. This means that although developers may have an effect on the carbon intensity of a product by how they choose to implement a design, they don’t typically tackle these questions earlier on in the product development lifecycle. Despite efficiency gains in processing power and storage functions, the carbon impact of the internet is still only growing exponentially. This points to a clear place in the chain of creation where designers must carry their weight in creating more sustainable products.

The primary impediment is that there are few resources to consult to know what it looks like for designers to tangibly create products that are healthy for humans and the planet. As this is an under-researched area and currently requires much investigation through blog posts, check-lists or theory heavy research papers, my research question emerged. I wanted to investigate how might design patterns, in the form of a pattern library, persuade designers to shift to more sustainable UX practices?

Designers are often tasked to design under time constraints or required to design to promote business objectives over what might be healthy for the planet and the users, having concrete examples and rational structure in the form of a pattern library can be one way of answering this need. Pattern libraries offer ways to articulate the problem and the solution that the pattern is designed to address (Alexander et al., 1979). An additional factor to consider is how such design

knowledge is disseminated: to this end, I also wanted to explore the use of highly popular design tools as vehicles for knowledge dissemination. By housing a sustainable digital design pattern library in designers tool of choice to create the work, this makes these solutions available, tangible and integrated into the creation process. This ultimately offers readily available sustainable alternatives to unsustainable digital patterns that have become part of designers daily toolbelt.

In order to create a version of a sustainable digital design pattern library, I began by conducting research into areas of design that together comprise a fulsome definition of sustainable design. This included research into carbon-aware design, slow design, values based design, responsible tech, and humane technology principles. In addition to this, I researched pattern libraries as a concept to understand how best to present the material I was researching. I also compiled examples of existing sustainable web design patterns that are live to have visual examples to start the patterns from. This research comprised the first version of the pattern library that included design patterns that were tested on a cohort of young designers currently studying interaction design at Concordia to understand how easily they were able to use them in a redesign challenge. The results of this testing informed the future direction this library will take to ultimately be a useful tool in shifting designers towards a sustainable creation process that is less business/task oriented.

To detail how I came to the first version of the pattern library as well as my testing methodology, results and conclusions I will start by outlining my theoretical framework. This offers insight into the resources that shaped my definition of "sustainable digital design", the form of the final product (pattern library structure) as well as the theoretical basis for creating the patterns themselves. I will then discuss my creation methodology and user testing process. Finally I will discuss the insights gained from the user testing as well as directions for improvement moving forward.

Literature Review

The concept of "Sustainable Digital Design" that grounds the pattern library, is based on research from converging topics that together comprise a holistic perspective on the term "sustainable". To this end, I have broken down the intersecting topics involved in the literature and constructs

related to my study thematically into four categories: Ecological user experience design, Slow Design and Designing for Friction, Humane Technology and Nature-Informed Design (the psychosocial impacts of design) and Pattern Libraries in UX Design. I will discuss the literature that I have categorised within each theme that contributed to the development of the pattern library.

Ecological User Experience Design

In order to introduce the concepts of ecological user experience design, I will begin by presenting the problem and reason for its existence. Though it paints a bleak picture, it's important to frame why there is a need for such a discipline, and emphasises the problems with current digital design approaches.

Ecological digital design, also known as “Sustainable Interaction Design” (SID) “Sustainable Web design” or “Sustainable User Experience” (SUX) engages with different concepts of ecology and sustainability (Blevis, 2007; Greenwood, 2021). Though still a relatively under researched field, recently technology professionals and researchers have contributed to a growing body of knowledge around sustainable digital design practices. At its core, sustainable web design is an approach that prioritises the health of the planet, by designing to reduce carbon emissions and energy consumption (Greenwood, 2021). One of the most difficult challenges of the ubiquitous tech era we are currently living in, is understanding the impact the digital world has on the physical world – and that the former necessarily relies on the health of the latter. Gerry McGovern (2020) puts this impact into context by explaining how many trees would need to be planted to offset a particular digital activity. For example:

- 1.6 billion trees would have to be planted to offset the pollution caused by email spam.
- 1.5 billion trees would need to be planted to deal with annual e-commerce returns in the US alone.
- 231 million trees would need to be planted to deal with the pollution caused as a result of the data US citizens consumed in 2019.
- 16 million trees would need to be planted to offset the pollution caused by the estimated 1.9 trillion yearly searches on Google.

Sustainable digital design recognizes that although pixels, cloud storage and digital information seem purely virtual, internet infrastructure has a real and tangible environmental impact. As society uses exponentially more data and web services, it is projected that communication technology will use 14% of global electricity by 2040, up from under 4% in 2020 (Belkhir & Elmeligi, 2018). Jain & Wullert (2002) observed that "the severity of this problem is unprecedented because none of the previous 'revolutions' (e.g., industrial, etc.) faced the scale and growth-rate similar to this problem."

Like many conversations around sustainability, it is easy to shift the burden onto the individual, despite the fact that only 100 companies are responsible for over 70% of carbon emissions (Griffin, 2017). Sustainable web design therefore understands that "the responsibility for reducing carbon and energy use in the digital world should start with the companies and teams designing and building this digital technology" (Jarrett, 2019). Design teams can employ techniques that minimise emissions throughout the design process, while the user is interacting with the product, and encourage future sustainable decisions across all users. As explained by Tim Frick, sustainable digital design aims to address this growing issue by examining each step of the design process, and investigating if it is promoting "accessibility, renewable energy, and breaking down socioeconomic barriers, or perpetuating a system of inequity" (2016).

The Sustainable Web Manifesto (2019) defines the core tenets of a sustainable web project as being: clean, efficient, open, honest, regenerative and resilient. At a closer lens, to understand these principles in practice, Tim Frick (2016) defines SUX as examining the sustainability of the different layers involved in the design process:

Presentation Layer	How the experience looks and feels — the visual design language.
Task Layer	How the application flows and how users interact with it.
Infrastructure Layer	What the base technology product uses. Does it help or hinder UX?

Device Manufacturing	Do the devices we are designing use conflict minerals? Are they created with fair labour practices? How much hazardous waste does the manufacturing process produce?
Power Sourcing	Does the electricity that powers our applications come from renewable sources?
Device Disposal	Are we creating products for devices with built-in obsolescence? Does our work support or hinder that obsolescence?

FIGURE 2: Sustainability of Different Layers in Design Process (Tim Frick, 2016)

Research into sustainable web design, however, reveals it to be a practice that is hard to exact. It can incorporate business decisions made while in the process of designing a product, to the type of device the end user employs to interact with the product. Estimates for carbon emissions, energy consumption and climate change are all interlinked and almost impossible to measure (Jarrett, 2019). Knowing the amount of CO2 produced by a web product involves measuring emissions out of power stations potentially continents away, the energy required for data to travel, and the embodied carbon created through day-to-day operations (Greenwood, 2021). As detailed by Gauthier Roussilhe (2021) measuring the environmental impact of our digital ecosystem is incredibly complex for several reasons, namely:

- A lack of reliable, timely, and open environmental impact data that hinders accurate modelling
- The approached used to calculate impact are often accepted at face value and place emphasis on the positive environmental effects, without discussing the tradeoffs made
- Much focus is placed on measuring the operational emissions of a company where the emissions from the use of its services must be examined as well

Demonstrating the vast domains in which designers and other technologists alike may better understand how their actions play a role in evaluating the sustainability of a product, Frick (2016) identifies questions to ask at the outset of a project:

- How many workstations and devices are being used throughout the process? What are their electricity needs?
- How long are computers running during design and development?
- How big are source files? Do they live on an internal server or in the cloud?
- How big are the files uploaded to the server? What's the total amount of this data?
- How many users on average does the product have per day? How much data do they download? How long do they stay? Where do they come from?
- What devices do they use? What are the power requirements of those devices?
- How many unused files are taking up space on the servers? How much time/effort/electricity does it take to delete them?

The complexity in this however does not negate the need to "rethink the dogmas of infinite growth as well as the wasteful development and design that could hinder our ability to build a technological future that works within our planetary boundaries" (Jarrett, 2019).

To better understand the different facets of sustainable design, I have organised the literature regarding ecological user experience into four main categories:

1. Tools and processes of the designer
2. Energy costs of storing/rendering data
3. Societal impacts of digital designs on collective behaviour, and
4. Manufacturing, use, and disposal of end user devices.

Tools and processes of the designer

Most creation processes result in some waste, however the initiation of a sustainable web project begins with the processes, tooling and principles of the creators.

Examining a designer's work process can lead to a reduction in emissions by altering working habits and introducing newer and more sustainable ones. Cleaning out unused project data and duplicate files, for example, can reduce up to 90% of an organisations' digital waste (McGovern, 2020). The facility of limitless cloud storage and search engines to sift through endless data can make reducing and organising project data seem unnecessary or too challenging (Chin, 2021). Not only does this reveal an opportunity for designers of such systems to design in ways that promote decluttering e-waste over simulated limitless storage, but can instil the sense of responsibility in designers to clean up after themselves in this easily contaminative environment.

Reducing wasteful time online and in carbon intensive internet activities is another clear way designers can create with more sustainable processes. Using tools such as Carboanalyser (2019), designers can better understand the relationship between data and carbon to understand how energy intensive certain activities are. One hour of videoconferencing can emit between 150 and 1000 grams of CO2, depending on the service (by comparison, a car produces about eight thousand grams from burning a gallon of gasoline) (Travers, 2021). Features such as recording to the cloud can increase this cost, as the meeting will remain accessible – costing energy resources to maintain. Changes such as turning off the camera, recording to local devices or turning off email services when not actively looking at them could reduce up to 10% of weekly digital C02 output (Jarrett, 2019).

Collaborative working processes are another opportunity where sustainable working practices can be introduced. Traditional waterfall project management approaches tend to create more waste, as changes in scope or definition of a project can occur more frequently in processes that do not account for ideas that come up as the project progresses (Frick, 2016; Simader, 2013; Mersino, 2021). Wasted efforts as discussed above and ultimately wasted features and functionality harms not only companies but the planet as well. Anecdotally, it is often shown that continuously building on top of existing and older software structures can increase unnecessary complexity and create opportunities for digital bloat. Designers who work on legacy products, can advocate to revisit these older features to build something newer and lighter where possible.

Selecting tools and design patterns that promote sustainability is another way designers can contribute to sustainability in their projects. Much has been said about open-source softwares' contribution to sustainable development practices. Recently, the UN's Economic and Social

Council adopted a draft resolution, noting that open source technologies can contribute to sustainable development goals (United Nations, 2021). Open source tools can contribute to sustainability in the following way: they invite a mass to contribute to the design and development of tools organically and on an as-needed basis, unlike the case of proprietary technology, where design and development happens within a black box environment (Frick, 2016). Because a community is involved in their upkeep, "best practice" often emerges as a guiding factor in design making. In parallel, designers can centralise design patterns that have been proven to meet sustainable design criteria and share these to allow them to be modified and refined by the design community over time. This promotes the increased adoption and refinement of the sustainable design practice, and introduces exponentially more end users to the concepts by virtue of interacting with the product. Some innovative initiatives such as Branch Magazine (2023), as depicted in Figure 3, or Organic Basic's Low Impact Website (Organic Basics), as depicted in Figure 4, demonstrate ways to make common design patterns less energy intensive, i.e., reducing the energy required to store and display information on the screen. They employ sustainable design patterns such as showing images on click, showing vector images primarily, carbon aware design patterns that adjust depending on energy availability among others.

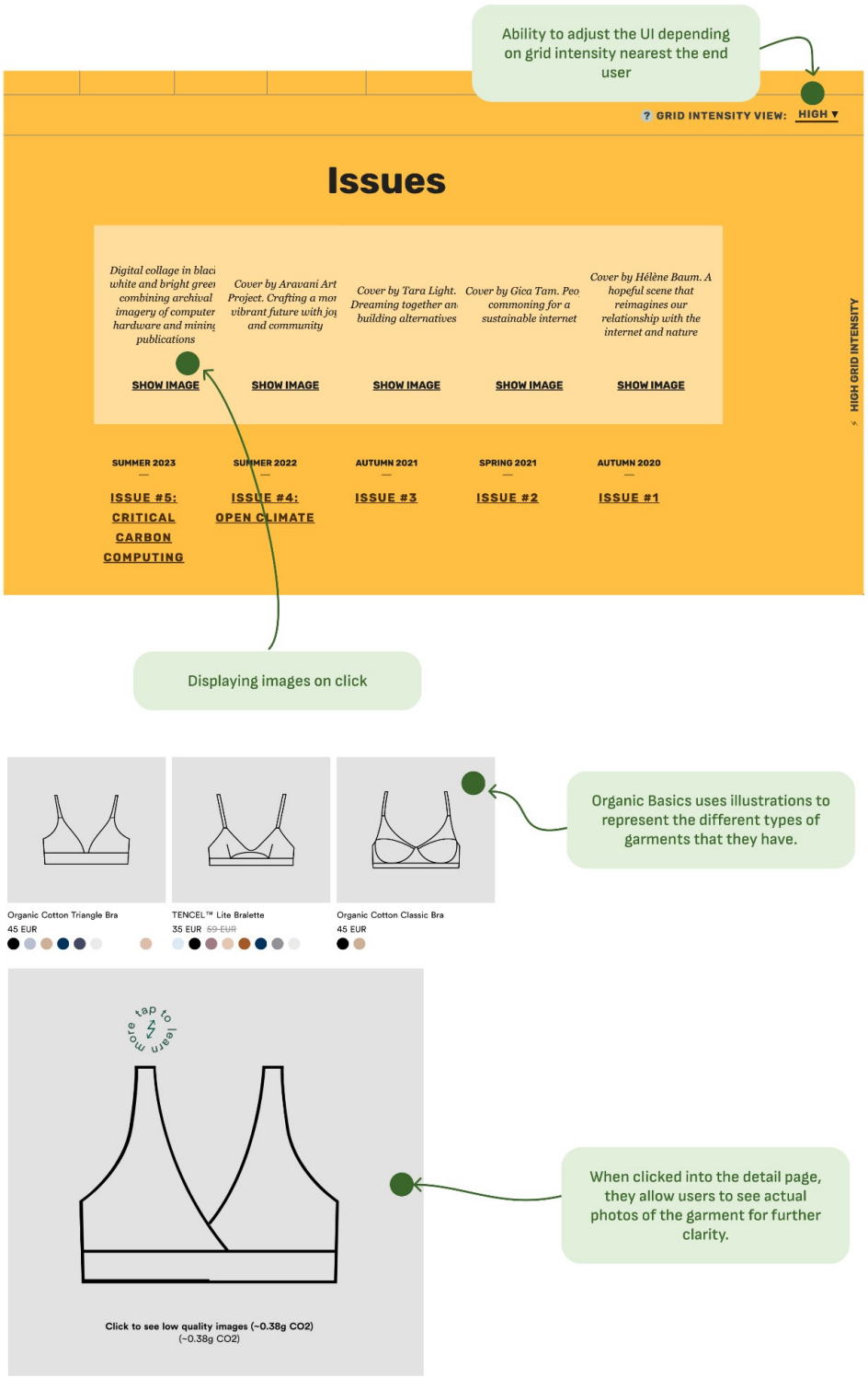


FIGURE 3: Branch Magazine Sustainable Features (Branch Magazine, 2023), FIGURE 4: Organic Basics Sustainable Features (Organic Basics, n.d.)

These initiatives suggest that the same patterns could be employed across differing industries; the methods can therefore be used as components in a library from which designers of all specialties can draw.

Energy costs of storing/rendering digital services

Two primary ways that sustainable digital design can measurably reduce the carbon emissions in digital products is to minimise the amount of data transfer, and electricity required to store the site or application (Greenwood, 2021; Frick 2016). Further beyond the scope of design, measuring the carbon intensity of a service can provide key indicators to determine the sustainability of a product.

Data transfer, meaning the information that is being sent to and received by the server, is a key metric for understanding how sustainable a web product is, and directly relates to the design decisions involved in creating the product. Measuring data transfer as a metric for energy consumption and carbon emissions is especially insightful, because "as a rule of thumb, the more data transferred, the more energy used in the data centre, telecoms networks, and end user devices" (Greenwood 2021). It has been demonstrated that as efficiencies are made in computing architecture to store data (Malmodin & Lundén, 2018) inefficiencies continue to increase in the design and development of the websites that use this infrastructure (Teague, 2022). Internet connection speeds are getting faster, and the hardware used to interact with these services, such as computers and phones, are also becoming increasingly powerful. This exposes the culpability of the digital professionals such as designers and developers who are making our digital infrastructure less efficient by designing unnecessarily heavy interactions. By designing with page budgets in mind, designers can contribute to the reduction in page weights (and therefore data transfer), and move away from this trend of bloated web pages.

Data traffic (the amount of data moving across a network at a given point of time) plays a large role in measuring a web products' efficiency when discussing the cost of data transfer. As an example, a developer creating Wordpress plugins noted that removing a 20 kB JavaScript dependency in a Mailchimp for Wordpress plugin, would reduce emissions by 708 tons per year (Van Kooten, 2020). Similarly, low efficiency and high traffic websites are shown to create more

than 4 times more carbon emissions than a round trip flight from London to San Francisco (Greenwood, 2021).

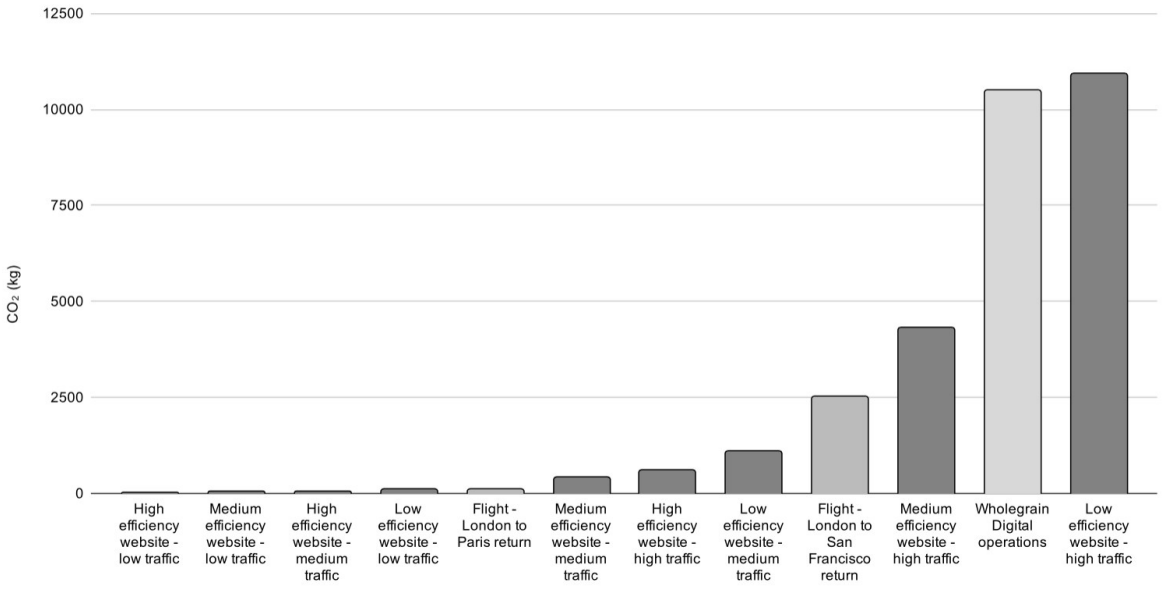


FIGURE 5: Low to High Efficiency/ Low to High Traffic Website Emissions (Greenwood, 2021)

Though data traffic is not directly proportional to emissions, Jevon's Paradox, when applied to internet infrastructure, explains the need for digital designs to begin matching the efficiency progress of the server infrastructure supporting it (Bauer et al., 2009). As explained by Preist et al. "growth in the internet's infrastructure capacity allows for new data-intensive services and applications; these offer more affordances to users, driving demand for the services and therefore further infrastructure growth" (2016). High traffic is often regarded as an indicator of business success and therefore will likely continue to be a goal of web projects in the future. Therefore, it is more critical than ever for designers to design for efficiency when considering the volume of users of a digital product.

Usability and findability are critical factors that designers can consider when reducing the emissions from data transfer in a website. Foundationally, the better search engine optimization and navigation a site has, the faster the content will be found, and the less energy that will be used to load pages in the search process. Demonstrating the impact search can have, a thousand

Google searches is equivalent to one kilometre of driving in a car (Hölzle, 2009). Though Google claims to have been carbon-neutral since 2007 (Google, 2022), their numbers do not take into consideration the time users spend bouncing from result to result finding the information they are looking for. Content-lean digital products, and optimised navigation and search, are clear ways that designers can contribute to reducing emissions from data transfer.

Another facet of sustainable digital design that can be measured, is the carbon intensity of the product. Carbon intensity is a term used to define the grams of CO2 produced for every kilowatt-hour of electricity (Greenwood, 2021). The carbon intensity of a digital product can change drastically depending on where the service is being hosted. Using a tool such as Tomorrow (2023), it is clear how choosing a data centre in France for example, will have significantly lower carbon emissions than a data centre in Poland.

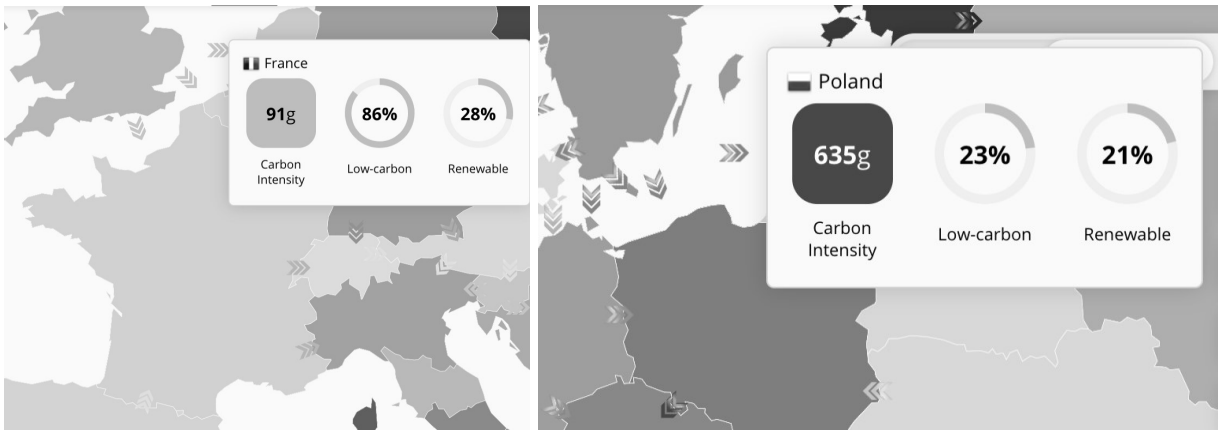


FIGURE 6: Carbon Emissions by Hosting Centre (Tomorrow, 2023)

Data centres are optimised to keep services live at least 99.9% of the time, and employ failsafes to avoid the enormous costs that can occur when servers go down (Alsop, 2022; Monserrate, 2022). This has extremely costly effects as most data centres in North America “draw power from ‘dirty’ electricity grids, especially in Virginia’s ‘data center alley,’ the site of 70 percent of the world’s internet traffic in 2019” (Monserrate, 2022) As a result, data centres collectively devour more energy than some nation-states (Burrington, 2015), and consume precious water resources leaving some communities strained for water (Hogan, 2015). This reality is occurring as experts in the internet technology space are predicting a slowing down in the server hardware efficiency (Freitag et al., 2020). Likely, “data centres’ power consumption will likely rise as

increasing demand will no longer be counterbalanced by increasing efficiency (Freitag et al., 2020). This comes at a time where this makes it evermore important for designers to not only design to reduce storage needs, but to garner awareness in the larger public around such issues.

Rather than designing to imply that cloud storage is a purely virtual and therefore limitless form of data storage, designers can introduce ways to promote awareness of the physical implications – while companies work to reduce their impact through renewable energy. This can be seen by smaller initiatives such as Branch Magazine (Branch 2023) and Low Tech Magazine (2023).

FIGURE 7: Branch Magazine Carbon Aware Design (Branch Magazine, 2023)

Both of these websites offer ways to highlight the energy usage required to power the internet, and contribute to the growing awareness and appetite for a carbon-aware internet. This outlines one of the core principles of sustainable web design: resiliency. A carbon-aware internet may not always be online 100% of the time. This creates opportunities for designers to think about how to create experiences in a web browser that works even if internet connections are lost. In tandem with a carbon-aware internet comes the need for designers who can create offline experiences for scenarios where applications experience downtime. Chris Bolin's Offline Only (2022) is a website that can only be accessed when the user is disconnected from the internet. Experiences like this create a foundation for other aspects of design that are currently ignored by the paradigm of always-online internet habits.

Balancing where the server is located, when considering both renewable energy resources as well as user location to reduce data transfer miles, is the best way to ensure a website is minimising its carbon impact. From a design perspective, using tools such as Carbon Calculator (2022) creates awareness of digital sustainability and an incentive for all creators of the project to lower their impact score. As the burden of reducing the carbon impact of a digital product rests largely on the companies behind the service, designers can therefore highlight efforts made by the company while facilitating ways users can interact with the service sustainably. Not only does this avoid compromising the core requirements of a product, but creates a deeper connection to the end to end infrastructure that keeps the internet working.

Normalising the concept of sustainability – societal impacts of digital designs on collective behaviour

Another branch of sustainable digital design addresses the societal impact of our current technology and its "defuturing" effects. Ontological design as outlined by Fraga (2020), explains that "we design our tools, and then they design us in return". Through this lens, it is clear how designing a digital service without promoting sustainability from a societal context, can in turn, create a society that behaves in an unsustainable way. This can be seen through social media's adeptness at encouraging consumption (Alghamdi & Bogari, 2020) — at the benefit of the tech and fashion companies and detriment to the planet to meet these demands. Tony Fry (2019) discusses "the economy of manufactured wants obscuring recognition of the fundamental need for social wellbeing" — an element critical to preserving our collective future. This perspective reveals digital designs' role in promoting social and planetary wellbeing. Societal sustainability in digital design can also be discussed through Greenwood's (2021) principles of sustainable design mentioned earlier: open, honest, redemptive.

Openness primarily serves to normalise the concept of sustainability, particularly in the digital sphere where it is less widely understood. Though concepts such as inclusive and humane design are much more widely understood amongst designers, anecdotally, I have experienced that many professionals in the tech sphere have never considered the environmental impact of internet technology. Organic Basics (n.d) website offers an example of how an e-commerce store, one of

the most energy intensive of online activities (Pickens, 2021; Jarrett, 2019) can highlight their efforts at reducing their internet carbon impact.

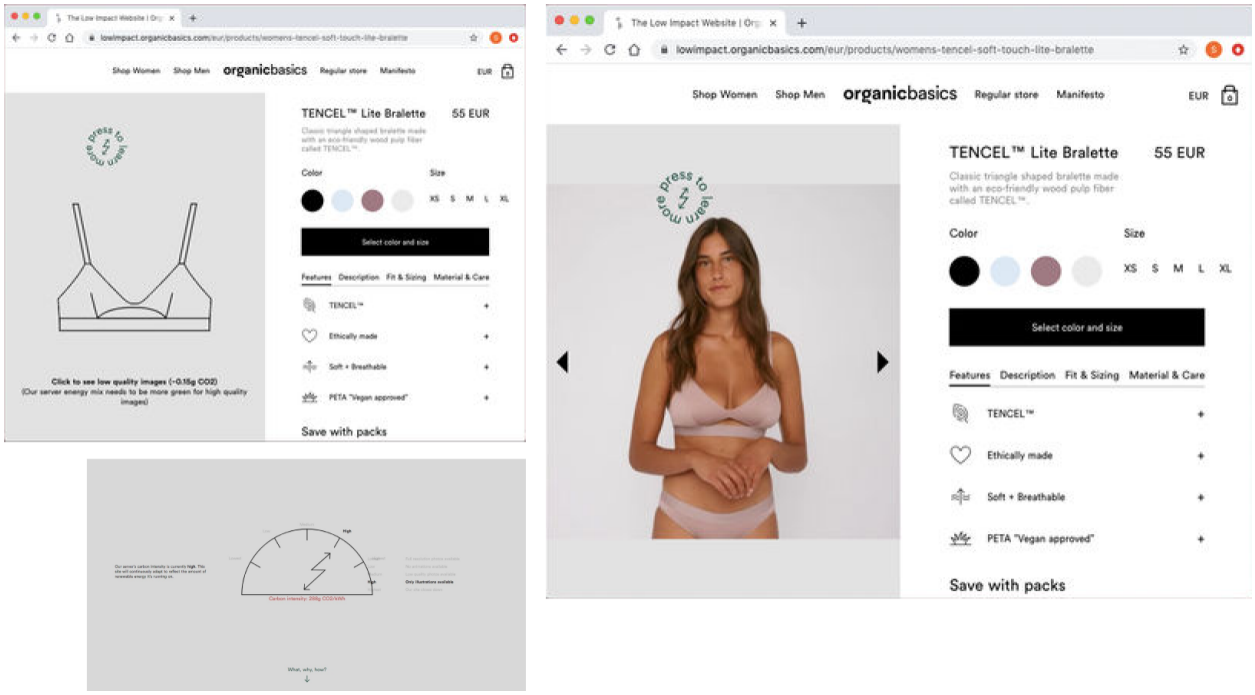


FIGURE 8: Organic Basics Sustainable Image Pattern (Organic Basics, n.d.)

Similarly, BBC Future (2020) displays the carbon cost of each page view of their article.

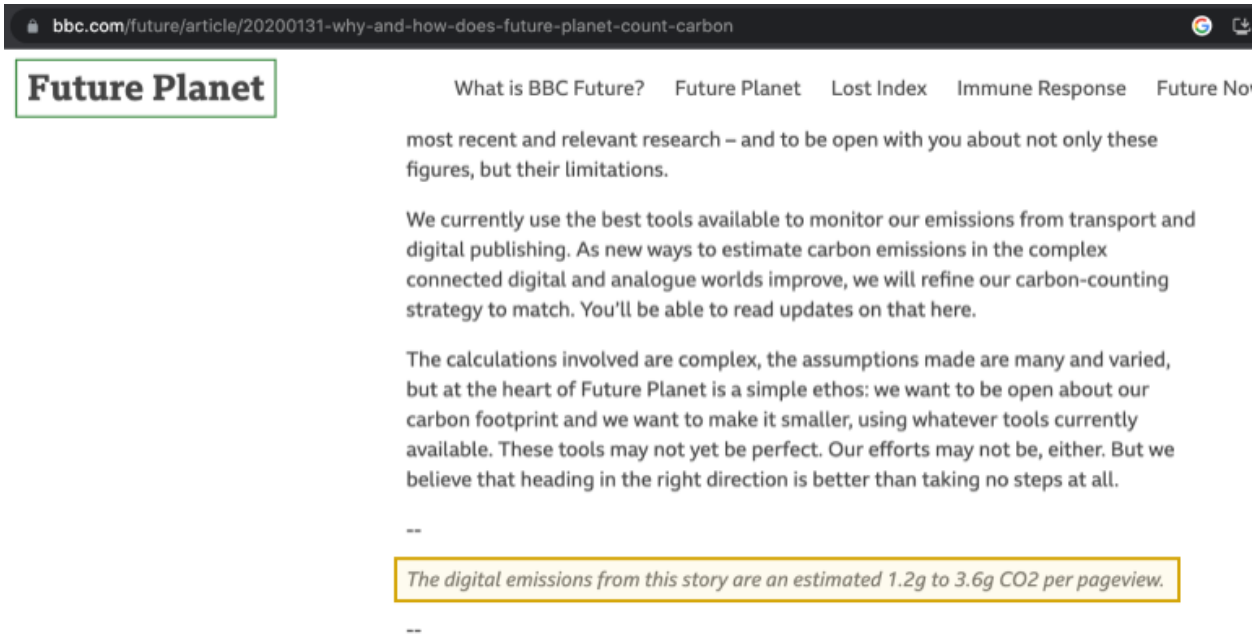


FIGURE 9: BBC Sustainable Design Pattern (BBC, 2020)

For companies and designers, outwardly showcasing these metrics can offer an incentive to reduce their carbon impact. It also creates a broader understanding in the general public around the impact of their browsing behaviours. Approaches to showcasing a web product's efforts at sustainability, while highlighting to users options that will encourage their own sustainable interaction are limitless. Firstly, however, an awareness and understanding amongst technology professionals must be gained around the severity of the current situation, and ways to approach rectifying it.

With this openness comes a need for honesty. Large digital companies have much to gain from obscuring the true costs of our ubiquitous tech infrastructure. The “attention-extraction economy” largely built on capturing users' attention to generate ad revenue comes at an enormous cost for the environment. The average online ad campaign generates 5.4 tonnes of CO2 emissions – equivalent to around 13,000 miles of car travel (Jackson, 2016). This figure is only set to grow as the percentage of video ads grew over 79% in a year (IAB UK, 2021). The cost of losing this revenue could be devastating, as ad sales make up 89-98% of total income for some of tech's biggest companies like Youtube, Google and Facebook (Olson, 2022). To expand the pockets of tech companies, persuasive design (Nodder, 2013) and design methods popularised by books such as “Don't make me think” (Krug, 2006) have dominated the design industry for the last two decades. In fairness, these approaches were less harmful when the sheer scale of the audience was smaller than it is today.

Part of this approach necessitates the manipulation of beliefs and behaviours, and obfuscates the value system behind the design. This can have diverse and far-reaching consequences ranging from mental health issues, societal corruption of democracy, reduction in cognitive function, reduction in a collective view of reality, and inability to address global crises (Brady et al., 2017; Bak Coleman et al., 2021). Designing for transparency around the intentions and values behind the design decisions, can not only help increase users’ trust in the product, increase a user’s agency with how they choose to engage in a product, but create services that are environmentally sustainable from a societal perspective.

Lastly, redemptive technology defined by Ursula Franklin (1990) describes how technologies can be created to help heal people and the planet. Holistic technologies, as she articulates, benefit the

collective and the creators are tasked with making a product for the good of the collective. This is in contrast to ‘prescriptive technologies’ that are rigid and requires its users to conform and comply with them. Similar to Fry’s perspective of technology contributing to “the economy of manufactured wants obscuring recognition of the fundamental need for social wellbeing” — an element critical to preserving our collective future. Through these viewpoints, they reveal designers' roles in creating digital products that empower people to take meaningful action, to connect with one another, and connect to our planet – rather than serve as a point of disconnection, waste, and conformity.

Manufacturing, use and disposal of devices

Lastly, we must consider the materials required to create the machines that enable us to interact with our ubiquitous computing world. The hardware-software development cycle historically has forced users to upgrade to the newest device to support new innovations in digital technology. It has been proven that these non-backwards compatible developments are intentional and very much by design – a practice plaguing mobile and tablet industries particularly (Bisschop et al., 2022). Apple, one of the largest producers of cell phones, argued that purposefully slowing down older iPhones via software updates was necessary to avoid unforeseen shutdowns. They argued this, even though such a program would disable the utility of a device well before its physical product lifetime (Bisschop et al., 2022). Practices like this may explain why the over 7 billion smartphones in existence have a lifespan of less than two years (Jardim, 2017). This reality has a devastating social and environmental cost. Various life cycle analyses find the manufacturing of devices is by far the most carbon intensive phase of smartphones, accounting for nearly three quarters of total CO2 emissions (Green Alliance, 2021). The term for “the carbon emitted in producing the product and getting it to the consumer” is called “embodied carbon” (Greenwood, 2021). Looking at the embodied carbon of an iPhone, reveals its life-long carbon footprint to be 64 kg of CO2, 84% of those emissions being from the manufacture, transport and end of life disposal (Apple, 2021).

The humans working to extract the required resources to create these devices are also exposed to life-threatening conditions and illness due to hazardous chemicals (Frankel, 2016). The thirst for

innovation and flashy new features affect more than the hardware, as browsers are forced to update to keep up with the latest web design innovations. When done poorly, this can lead to millions of broken websites that take up space on the server, but are not usable to the public (Tonsky, 2017). Current design patterns fostered by business objectives promote a cultural impetus for technological novelty and increased consumption — resulting in disastrous societal and ecological effects (Blevis, 2007; Greenwood, 2021). Designers trained in ecological design methods can reverse this phenomenon by promoting an aesthetic of "well-cared-for systems" and "structure-preserving transformations" in the words of Christopher Alexander (2002). Designers can create experiences that fit within the bounds of existing technology and layer optional features that can be utilised by those with the means to use them. This strategy, known as "progressive enhancement" can make digital products and services accessible to more people, and reduce the waste associated with the current craze for innovation.

Another facet of sustainable digital design involves the understanding the computational load of the product, or the energy use by end users' devices. As designs become more stylized and complex, "the computational load is increasingly moving from the data centre to users' devices" (Greenwood, 2021). This means that with these 'advancements', more energy is required of the device to display these experiences. Not only does this have a cost environmentally, but this serves to exclude users who do not have the most up-to-date, powerful devices that can handle such stylized designs. Though designers do not have control over how end users treat their devices, or what they run on the, conveniently, strategies that aid in creating more inclusive and accessible experiences, tend to make a difference when addressing web's ecological footprint. By creating lighter pages, designers can make interfaces that reduce their carbon impact, while being accessible to those with the fewest access to the latest technology.

Implementing sustainable digital design tangibly

There is much to uncover around the concept of sustainability in digital design. More challenging, however, is understanding what it means in terms of interface elements and user interface and experience decisions. Resources such as Sustainable Web Design (2021) and Designers Ethiques (2022) offer a starting point for designers looking for references on how to

practise sustainable design. Across other literature general recommendations can be used as well as a starting point for understanding this practice tangibly. Writings from other experts, including Greenwood (2021), Frick (2016) also articulate best practices. I have synthesised these practices together below:

- Adopt minimalist design: Minimalist design requires an "assessment of every detail of a design solution from images to text to pages and content" (Greenwood, 2021).Through this approach, the designer must justify the existence of every element, rather than asking if it would be a nice feature to have. This falls in line with the principles of lean UX, of streamlining the design process and cutting out waste. Many heavy features can be simplified by taking this approach, and is one that can be incorporated into each step of the design process.

- Reduce page loads: Designing to reduce page loads can involve information architecture decisions, to creating page overlays and navigation styling to reduce users jumping from page to page. Using a mega menu for example, as opposed to landing pages that lead users to child pages, can be a way to make a more accessible navigation while reducing page loads caused by yo-yoing users between different pages for navigational purposes.

- Pay attention to SEO: As with many accessibility and usability best practices, sustainable design recommendations align well to create a holistically positive experience for all users and the ecological structure that supports it. Web services that follow updated SEO best practices, can reduce the energy required to use the service, by allowing users to quickly find what they are looking for – reducing the required page loads when interacting with the product.

- Use lightweight imagery: Images are the resources that are used the most on the web, and the average weight of the image can represent almost half of a page's weight (HTTP Archive, 2022). Images when used carelessly, therefore, can greatly increase the carbon impact of a web product. By optimising images and reducing their size, designers can easily make image heavy pages lighter and more efficient. Similarly, choosing the correct format for photos, images and icons can exponentially increase the energy efficiency of

the web page. Designers can also opt to use vector images and glyphs wherever possible. Not only do these visually communicate to the user that the site is energy optimised, but affords the designer creative constraints to work within that can push current design practices beyond the image heavy bloated zeitgeist. Bam collective (Thomas Thibault, N. M. & L. P., 2022) suggests selecting icons that represent the true digital impact of an action, for example: “connect to another computer” instead of “transfer to the cloud”. This can be a strong tool for designs to use visuals to emphasise to the users, the cost of their actions.

- Consider colour choices: Colour choices can significantly impact an interfaces’ accessibility and energy efficiency. Darker colours require less energy to illuminate, therefore making black the lowest energy colour and conversely white the most energy intensive. Surprisingly, blue pixels use around 25% more energy than red and green pixels (Sustainable Web Design, 2021). UI features such as dark mode have been proven to reduce up to 63% of screen energy compared to standard mode on phones with OLED screens (Greenwood, 2022). For designers working in UI and branding, helping clients implement sustainable brands can help signal to users that they truly care about accessibility and sustainability through the colour and aesthetic design choices of the service.

- Reduce the use of animations: Another fixture of modern web design is increased use of motion and animation to communicate actions or create emphasis around the impact of a user's action. Animations require larger files to load, and increased need for processing on the end user’s device to render the animation. Ensuring animations are necessary, don’t reduce accessibility, and add value and clarity to the interaction should be requirements for introducing animations to a design.

- Consider video implementations: “Though video is used less commonly in web design than imagery, when used, it almost always constitutes the largest use of energy on the website” (Sustainable Web Design, 2021). Ensuring videos are compressed when necessary to display them is a simple way to reduce the otherwise heavy impact of videos

on the web. Similarly, ensuring features such as autoplay are excluded, will result in a more usable and energy optimised experience. Using plugins to avoid embedding videos into pages themselves can reduce page weights, and avoid users loading them unless expressly interested in the content.

- Rethink interactions: Though reusing common interactions in the web has facilitated the ease of use, and lowered the barrier to use for the web, it has also led to the acceptance of environmentally harmful interactions. Features such as infinite scroll are designed to increase the amount of time someone spends on a page, and therefore increases the amount of resources required to interact with a service. By replacing this feature with pagination, or a "load more" button, this friction will prompt users to think if their action is in fact necessary, and not simply a reactive response to manipulative design methods. Similarly, auto-complete, though easy to use from a user perspective, requires many server calls and increases the energy consumption of a search input. For services that are less complex, using techniques such as examples, error prevention and validation methods can assist users in their actions without increasing the network demand to support users searching (Ecometer, n.d). Both of these interactions, when improperly used, can be viewed as a future relic of the "don't make me think" design era that currently dominates most digital design practices. By rethinking searching, scrolling and other common design patterns from a sustainable lens, a new wave of design patterns can be introduced that encourage users to think, understand the ecological impact, while facilitating an easy user experience.

- Be selective with typography: Fonts can be a powerful communicator of brand emotion and design significance. However, this flexibility can come at a cost. The average weight of a web font has now increased by over 50 times between 2010 and 2017 (Designers Ethiques, n.d) and a typical custom font file can be over 200kb only including a single weight (Frick, 2021). By using standard/system fonts that are pre-installed in most devices, this prevents users from having to download a font each time a service is loaded. When not using a system font, using font hosting services such as Google Fonts or

Fonts.com can reduce some of the performance, and therefore energy efficiency issues that are introduced with custom font files (Stopper, 2020).

Slow Design and Designing for Friction

Alternative design methods to Persuasive Design have emerged that complement the principles of ecological digital design, and can therefore be considered part of the digital sustainability equation for designers. Through each of the subsequent sections in the literature review, patterns will emerge, where it is clear that alternative design methods directly impact the environmental sustainability of a digital service, in ways discussed above. Slow Design and Seamful design address aspects of user autonomy, agency, and examine ways that interfaces can support users in only the actions they want to complete, without being nudged into actions that serve businesses primarily.

Slow Design

Slow Design, in contrast to Human Centred Design (HCD) focuses on "reflection and moments of mental rest rather than efficiency in performance" (Hallnäs & Redström, 2001). Human Centred Design, arguably the foundation of UX as a practice, prioritises reducing friction, shortening the time it takes for users to achieve their task, and designing for habitual actions (Nielsen, 2009; Norman, 2013; Raskin 2011). Focusing solely on efficiency, however, introduces opportunities for exploitative experiences that encourage users to act in ways that benefit the service provider (often financially), rather than engaging substantively and thoughtfully with the interface. An example of this can be seen through common ways of presenting "terms and conditions" online. In 2017 a study was conducted by Deloitte (Cakebread, 2017) that found that 91% of people do not read the terms and conditions. Through the lens of HCD, reducing friction and helping users complete a purchase or sign up flow in the quickest way possible is the goal. This can be seen by common design patterns of presenting terms in a scrollable area, with a checkbox at the bottom to confirm they were read. However, by introducing friction into the process, either by breaking up the terms into sections, adding summary text in plain english, and introducing check-points within sections, users are encouraged to engage in a thoughtful way. Disrupting this focus on efficiency, allows us to design not only for task completion, but a more

conscious, slow and reflective interaction experience. Equally, this benefits the user in that they are able to better understand the impact of their actions, and are afforded greater agency in how they choose to interact with the service.

Slow Design represents a way to embed new values into a design and "contribute to the shift toward sustainability" (Strauss & Fuad-Luke, 2008). Instead of evaluating a digital product's design by the efficiency of task completion, where designer/business values can be easily concealed, Slow Design "aims at supporting people in doing things at the right time and the right speed, in order to give them time to understand and reflect about their actions" (Grosse-Hering et al., 2013). This presents a concerted move away from design patterns that try not to "make users think". Slow Design correlates with the principles of Ecological Design by promoting experiences that engage users cognitive functions, and empower them to make informed choices that can reduce or eliminate thoughtless time spent on the internet. Strategic friction, can be utilised therefore to create positive user experiences while people are online, and limit time where users do not need to be online – thus reducing the carbon impact of services.

Through this perspective we see how interactions and components can be reexamined to verify if they allow for moments of reflection and encourage cognitive functions. Using the Slow Design method, interface components can be added to screens that empower users to make conscious choices when interacting with the platform and reduce automatic behaviour where not necessary. This can be done through the use of tooltip messages that communicate the impact of an action, rethinking automatic navigational mechanisms such as "autoscroll", and incorporating accurate button labels that illustrate the real action that it employs.

Seamful Design

Seamful design falls similarly within this theme. Seamful design, as introduced by Chalmers and Galani (2004) and expanded on by Matt Ratto (2007), incorporates the importance of viewing "the seams between systems" in ubiquitous computing. Ratto explains that doing so grants us as users agency when interacting with information systems, as we will then be "allowed the ability to decide when and how we engage with them."

Design Frictions for Mindful Interactions: The Case for MicroBoundaries" (Cox et al., 2016), expands on this topic by advocating for the use of "Designed Friction" or "MicroBoundaries".

The paper defines these as “small obstacles prior to an interaction that prevents us from rushing from one context to another”. The authors found that these moments of friction can cause the user to reflect on their actions, and in doing so, shift from mindless to considerate interaction, increase value-alignment and meaningful engagement. These designed moments of friction were also shown to lead to positive health-behaviour change, which correspond directly with goals of Ecological Design. An example cited in their work, discusses how users created workarounds that increased the friction in their habitual actions of checking and interacting with work related emails after hours. This was shown to address the stressful consequences of constant connectivity (Mazmanian & Erickson, 2014) and allowed users to limit their impulses to mindlesses interactions with their devices. This illustrates the direct connection between seamful design, and Ecological Design’s goal of limiting unnecessary carbon costs of interacting with popular data-heavy services that are designed for quite the opposite.

Translating this perspective to a sustainable UX component library, means exposing the impacts, values, and incentives of the design wherever possible. A “seamful” interface is thus one that affords the user agency to decide when and how they want to engage with the system, rather than blurring the impacts of the platform to fit the standards and goals of the business behind it. In this way, designers can help people make informed and thoughtful choices as they engage with digital systems.

Humane Technology and Nature-Informed Design (the psychosocial impacts of design)

The term “Humane design” has shapeshifted over time and has adapted with the evolution of computer technology. In this context, I marry it with concepts from “nature-informed design” disciplines to elaborate on social aspects of design sustainability. Together these perspectives contribute to a definition of designing sustainably that considers nature and support rather than exploits human and non-human vulnerabilities.

Humane Design has its roots in Human Centred Design (HCD), popularised by Jakob Nielsen (2009), Don Norman (2013), and Jef Raskin (2011). HCD focuses on making interfaces usable and simple through scientific methods. HCD, beginning in the 80’s is a design practice that

focuses primarily on the individual people for whom the design was intended (Norman, 2019). The four basic principles of HCD are:

- Solve the core, root issues, not just the problem as presented (which is often the symptom, not the cause).
- Focus on the people.
- Take a systems point of view, realising that most complications result from the interdependencies of the multiple parts.
- Continually test and refine the proposed designs to ensure they truly meet the needs of the concerns of the people for whom they are intended.

This approach provided the foundation for designing interfaces that are optimised for the human experience, and offered a rich ground for design practitioners to build on. As technology has become increasingly integrated into daily life, and further mediates many human and business interactions, the gaps in this approach begin to appear. HCD fails to address issues of sustainability (both ecological and psycho-social), issues of equity and inclusivity, and issues of transparency and embedded value systems. Interestingly, Don Norman, one of the primary practitioners of HCD, recently published a book advocating for a shift from Human Centred design to Humanity Centred design (Interaction Design Foundation, n.d). Norman argues that "Humanity-Centered Design accepts the basic framework of these four principles but expands them so that they are far more explicit about coverage of all living things, for the ecosystem, and looking at the long-term future impact" (Norman, 2022). This speaks to the growing awareness designers are beginning to have, of the importance of designing technology that will in turn design a society and planet that is liveable and humane – to borrow the framework of Ontological Design (Fraga, 2020).

The Center for Humane Technology concretizes the above mission into core principles and lessons for technologists of all disciplines. This results in a more contemporary stance that speaks directly to the need for a value-based, holistic, and community-centred approach to meet the complexities of our social technology capacity (Center for Humane Technology, 2021). The principles from the Center for Humane technology are:

- Obsess over values, instead of obsessing over engagement metrics

- Strengthen existing brilliance, instead of assuming more technology is always the answer
- Make the invisible visceral, instead of assuming harms are edge cases
- Enable wise choices, instead of assuming more choice is always better
- Nurture mindfulness, instead of vying for attention
- Bind growth with responsibility, instead of simply maximising growth

These principles encourage designers to recognize that their design and content choices will necessarily influence users, and therefore they should bear in mind that technology is never neutral. These principles allow designers to shift away from the separation of designer and user, and instead grapple with the design's implications in a more personal way resulting in prioritising human needs (i.e., the users) over manufactured wants (created by the designers to serve the businesses that employ them). In this way, designers are required to think beyond task completion and user-friendly interfaces, and to consider the broader impact of the design on a user's actions on and off the platform.

Design approaches like Positive Design extend on the idea of designing for more than usability. Positive Design offers a framework for creating interfaces that instead increase reflection, happiness, and emotional welfare. Desmet and Pohlmeyer describe Positive design as an "umbrella term for design that has explicit focus on research and development of solutions that increase people's subjective well-being, their happiness. It strives to stimulate or enhance positive emotions, and reduce or overcome negative emotions" (2013). This is a useful extension to the humane design approach, as it brings a focus to the emotions that a design should elicit, and offers a framework for designers to consider this as a piece to the humane design equation. A humane or humanity focused approach can therefore, promote task completion while incorporating a pleasure-based, virtue-based design approach that enhances personal significance to improve users' well-being (Desmet & Pohlmeyer, 2013; Hallnäs & Redström, 2001; Coyle et al., 2012).

Even more holistically, a category of digital designs inspired by nature merits genuine consideration when thinking of how best to design in a humane way. Across disciplines and industries, wisdom accrued over billions of years of ecological development can provide baseline patterns for solving key problems. This practice called Biomimicry, "learns from and mimics the strategies found in nature to solve human design challenges" (Biomimicry Institute, 2022).

Designers have much to gain by using nature as the inspiration for how they create products – as demonstrated by current examples of digital solutions inspired by nature. 7Vortex community platform (Ecosystems Platform, n.d), is an example of a knowledge management software inspired by ecosystems. The software follows “the principles of biological patterns, evolutionary strategies and ecosystem dynamics” and serves as an “information system that provides the ability to store, retrieve and compute data in a naturally connected way.” Following the design process presented by the Biomimicry Institute (2022), designers can learn how to incorporate these methods into a sustainable digital design practice:

- Define: Clearly articulate the impact you want your design to have in the world (i.e. the challenge you want to solve) and the criteria and constraints that will determine success.
- Biologize: Analyse the essential functions and context your design solution must address. Reframe them in biological terms, so that you can “ask nature” for advice.
- Discover: Look for natural models (organisms and ecosystems) that need to address the same functions and context as your design solution. Identify the strategies used that support their survival and success.
- Abstract: Carefully study the essential features or mechanisms that make the biological strategies successful. Restate them in non-biological terms as “design strategies.”
- Emulate: Look for patterns and relationships among the strategies you found and hone in on the key lessons that should inform your solution. Develop design concepts based on these elements.
- Evaluate: Assess the design concept(s) for how well they meet the criteria and constraints of the design challenge and fit into Earth’s systems. Consider technical and business model feasibility. Refine and revisit previous steps as needed to produce a viable solution.

Biomimicry and good UX have much in common. Both the natural laws of the world and the discipline of UX favour replicating proven patterns and value aesthetics as a core tenant of attracting attention or proving value. Biomimicry also provides “biologized” explanations for why certain interaction design tropes endure, for example using progress bars and micro-interactions to display feedback loops (the “biologized” term for communicating UI states). Differently put, feedback loops can be understood as a response to a stimulus or change

in the environment that helps the system to function well (Open Learning Initiative, 2021). In the context of digital products, feedback loops can help users understand where they are, what has happened, and what will happen next (Royal, 2016). It also serves to help designers look at the world from different eyes. Instead of viewing the world as a warehouse of resources, it can allow us to look at it as a source of inspiration and timeless wisdom – encouraging the creation of solutions that respect the earth rather than exploit it. Most importantly however, UX designers following the Biomimicry design process must consider the interconnected nature of a digital solution when emulating nature's "forms, processes and ecosystems" and requires not only being inspired from living systems, but supporting them as well (2022). The implications of digital solutions inspired by nature can be better projected over time, since they work *with* human and non-human natures rather than trying to reshape them.

These perspectives in humane design share a common thread — a focus on designing technology for the person and planet — but the question of *how* to do so has expanded as the scale of technology we use in our everyday lives has increased rapidly and exponentially.

Pattern Libraries in UX Design

Those familiar with the core tenets of UX practice, understand the fundamental importance of reusing interactions, components and flows to create consistent experiences across different services. Patterns facilitate the work of designers in creating consistent experiences for users as they offer rules for approaching and navigating common interfaces. Methods for dictating these 'rules' for designers to follow have been solidified by reusing interactions originally proposed by tech services, and codified through the use of design pattern libraries and guidelines. Elements most end-users may now take for granted such as 'breadcrumbs' for clear navigation, primary calls to action buttons, or using the trash can icon as a delete action are all examples of such codified interaction patterns.

Beyond facilitating user experience, design patterns promote the uptake of design methods that would otherwise not be broadly implemented in the greater UX design industry. An example of this would be accessible interaction design. Pattern libraries such as Simply Accessible Examples (2022), A11y Styleguide (n.d), or Accessible Solutions (2020) facilitate designer's

education and adoption of accessible design. With increased adoption of such design methods, end-users become increasingly comfortable and expectant of such patterns – contributing to a wider expectation and understanding in accessible design practices.

Today, many professionals and businesses have created interaction design guidelines for their unique or generalised purposes. Guidelines have recently become a way for brands to distinguish their design team's maturity by offering resources to the broader community, as well as promoting the uptake of iconography, unique patterns or approaches from that business (seen by Shopify, Canada Post and Microsoft to name a few) (Shopify Polaris, n.d; Mercury Design System, n.d; Fluent Design System, n.d). From early versions of best practice UI/UX guidelines published at the Computer-Human Interaction (CHI) conference (Bayle et al 1998), to current day Google Material Design Guidelines (2022), guidelines have become common solutions for the growing requirements of the computing age. It is important, however, to distinguish between ‘guidelines’ and ‘patterns libraries’. As explained by van Welie et al., “guidelines are usually very compact, but their validity or appropriateness always depends on a context.” Instead, pattern libraries explicitly focus on context and tell the designer when, how and why the solution can be applied” (van Welie et al., 2001).

Originally developed by Christopher Alexander as a method of capturing and communicating good architectural design, design patterns provide solutions to recurring design problems in specific contexts (Alexander et al., 1979). As ‘A Pattern Language’ written by Alexander explains, “each pattern describes a problem which occurs over and over again in our environment, and then describes the core of the solution to that problem, in a way that you can use this solution a million times over, without ever doing it the same way twice.” It is clear then how pattern libraries became such a useful tool in digital design communities to align best practices, describe the elements of good designs, and assist designers in reusing good solutions. Interaction Design Patterns (patterns created for user interfaces) therefore empower both users and designers to communicate design solutions across various fields (Dearden et al., 2002).

Creating a library that promotes the uptake of sustainable UX practices will be critical to familiarising users with new ways of interacting and providing designers with a consistent set of tools to begin using. The “Intro Guide to Eco Design” (n.d) and “Sustainable Web Design” (2021) remain the closest resources to a pattern library for digital components, as they both offer

categorised tips and recommendations for handling a variety of design-related scenarios. To date however, a comprehensive library has not been created for sustainable design components that include reusable UI components — and that consider both societal and ecological impacts.

Creation Methodology

To arrive at a first version of a pattern library that demonstrates sustainable design patterns I began by following a methodology that supports designers in turning research into practice, or one that can generate new ideas and creations through research. This method of design synthesis, described by Kolko (2007) is the process by which designers "organize, manipulate, prune and filter gathered data into a cohesive structure for information building".

Documenting the library

I started the creation process by cataloguing key points and themes from the literature that could translate into sustainable design patterns. I catalogued key sentences, quotes and themes by common interface elements, such as: navigation, images, videos, icons, fonts etc. This allowed me to have a starting point for generating ideas for how this research could relate to an improvement in that interface item's pattern. Once I had completed a preliminary structure for my synthesis containing research insights organised by interface item, I added notes as ideas for how this might appear on a screen. For example, research regarding the importance of showing the user the impact of their browsing behaviour on the planet, could translate to updating common icons and calls to action to better describe their impact and use more accurate language. This is the last step of Kolko's synthesis model, the step of taking the "best guess intuitive leaps" to start visualising the relationships between the research.

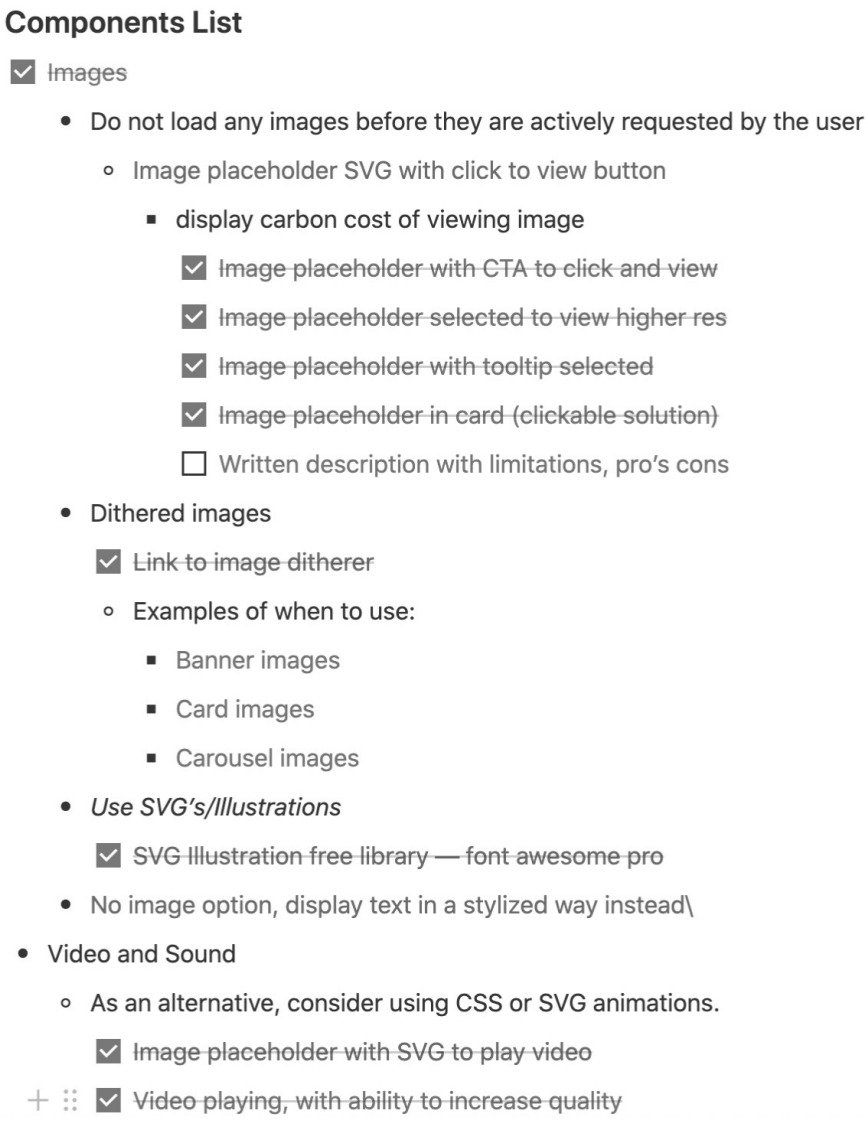


FIGURE 10: Early Draft of Planning the Components for the Library in Writing (Joanis, 2023)

Secondarily, I reviewed existing sustainable web solutions and added them to the growing written inventory of possible patterns. I wrote the description of the pattern as a bullet point under the same interface elements that were emerging as the organising principle for the library. For example, a website that included a carbon indicator in the footer menu, was added as a possible pattern under the "navigation" section. At this point, the research and existing solutions were synthesised into the same catalogue of potential patterns to implement in the library.

From there, I began to write the content for the library (see Appendix A). This seemed a logical next step as it required me to articulate why certain interface elements were important for designers to consider as part of building a sustainable interface. It also allowed me to articulate the different patterns that would be created within the different categories, thus bringing more structure to what would eventually be a library with multiple patterns per section.

With the aim of tying the patterns closer to the research that grounded them, I ensured to add a "tag" on each pattern in the document to tag it to the area of research that it came from. For example, readings into Slow Design that generated patterns related to it were tagged with that term. All patterns were catalogued with either "Slow Design", "Humane Design" or "Ecological Design" or a combination of any of them.

In addition, I added a section for designers to reference existing patterns they should try to avoid for each page of the library. For example, on the image page, recommended patterns that are commonly seen such as carousels that are best to avoid if possible. The intention for this section is so that designers could recognize if common patterns for the element they are designing has been flagged as a concern from the sustainability perspective. In this way, they aren't required to use patterns existing in the library, but at least can look at patterns to avoid for their implementations. The patterns that were added as ones for designers to avoid came from the same research that generated the sustainable design patterns in addition to less formal sources such as blog posts that currently make up the majority of the current literature around sustainable web design.

Lastly, I added a section that can serve as a checklist for designers to use when designing a certain interface element, to ensure they have considered the key factors that can make the patterns sustainable or not. This includes making sure captions are used, or lowest quality is playing first for video patterns as an example.

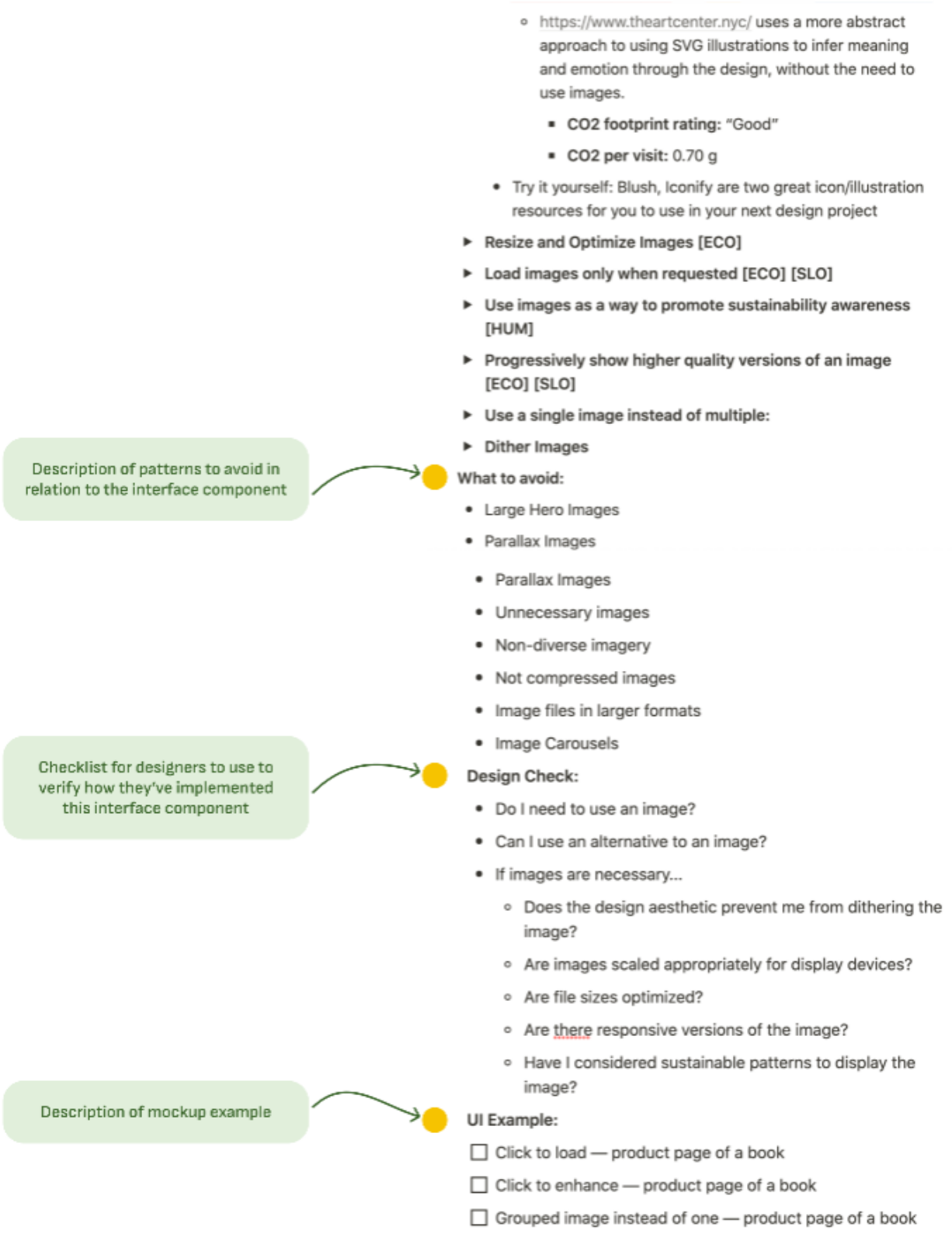
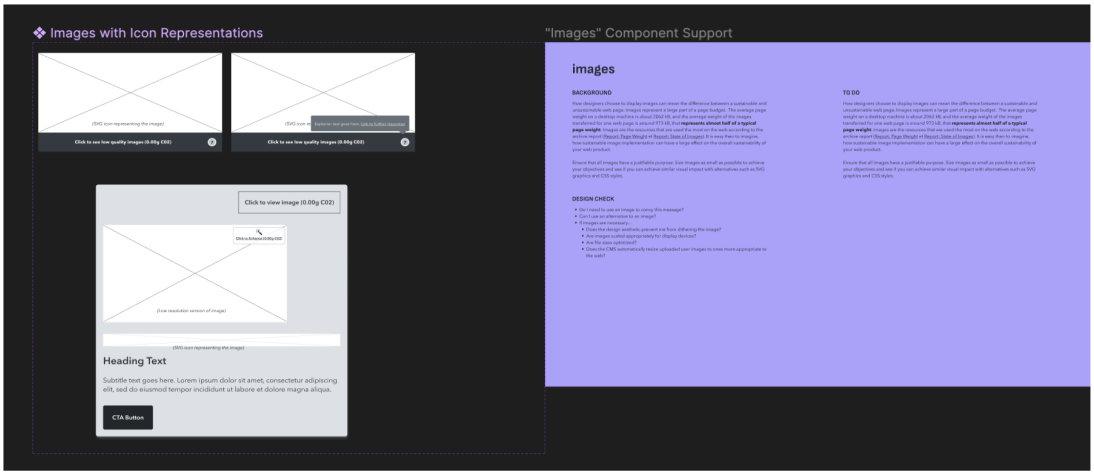


FIGURE 11: Written Pattern Content (Joanis, 2023)

Creating the library

Once the written content was completed, I began to create the patterns in Figma based on the written details from my document. I created a file structure that is similar to how most designers organise a design file. The top page consists of a “cover page” that serves as a thumbnail for the file that will be visible when published to the Figma Community. Secondly, an instructions page that held details for how to use the library, how to contribute to it, additional resources as well as background on the topic of digital sustainability. This page was intended to be an orientation for designers who may happen upon the file without much introduction to the subject or for those who are newer to Figma that may need assistance in navigating through it. I then set up the subsequent pages that matched the structure of the written document. Each page matched a common interface element that would include a collection of sustainable patterns, background information, a checklist and a list of things not to do in relation to it. This structure was a main component of the user testing sessions to understand how easily designers could navigate through the various pages and sections.

When starting to create the patterns themselves, the process of translating ideas to artefacts proved difficult for a few reasons. Primarily, I wanted designers to utilise the patterns for their design work, however the patterns as standalone entities were often not self explanatory. It was also important to make them generic enough that they could be used for low-fidelity design planning that could then be customised to fit the look and feel of whatever digital product the designer would be creating. With these constraints in mind, I realised I would need to design both low-fidelity patterns as well as high-fidelity mockups within the context of a fake webpage to allow the patterns to be understandable to designers using the library while still allowing them to be discrete enough to plugin to another person’s design file.



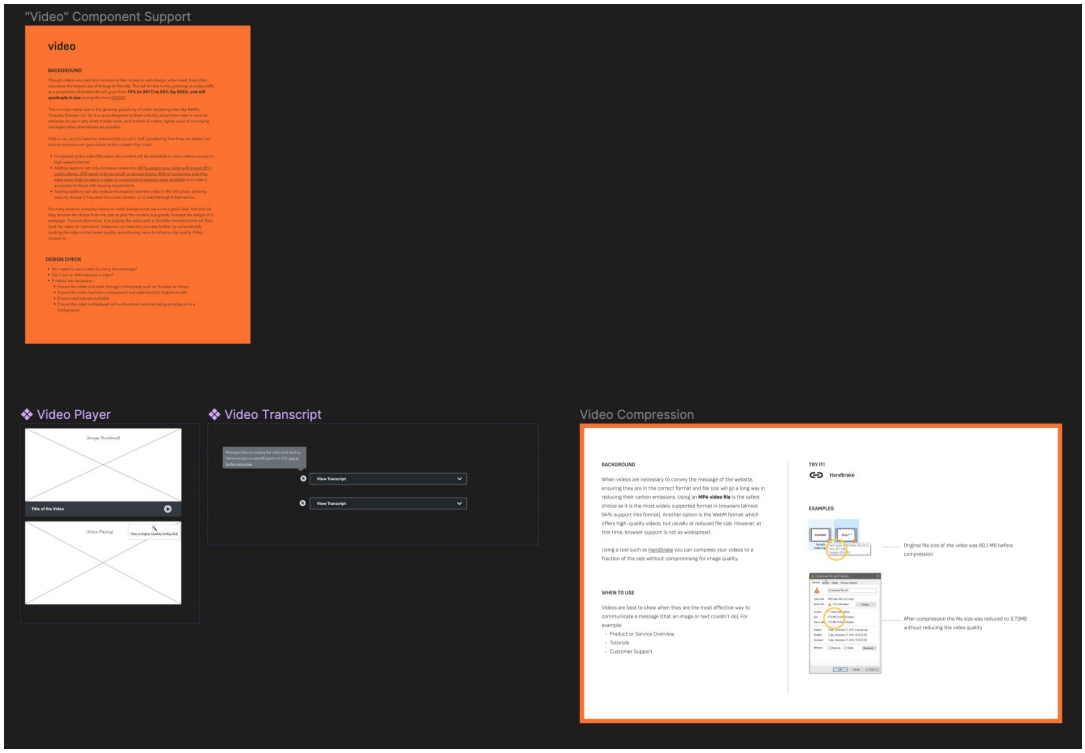
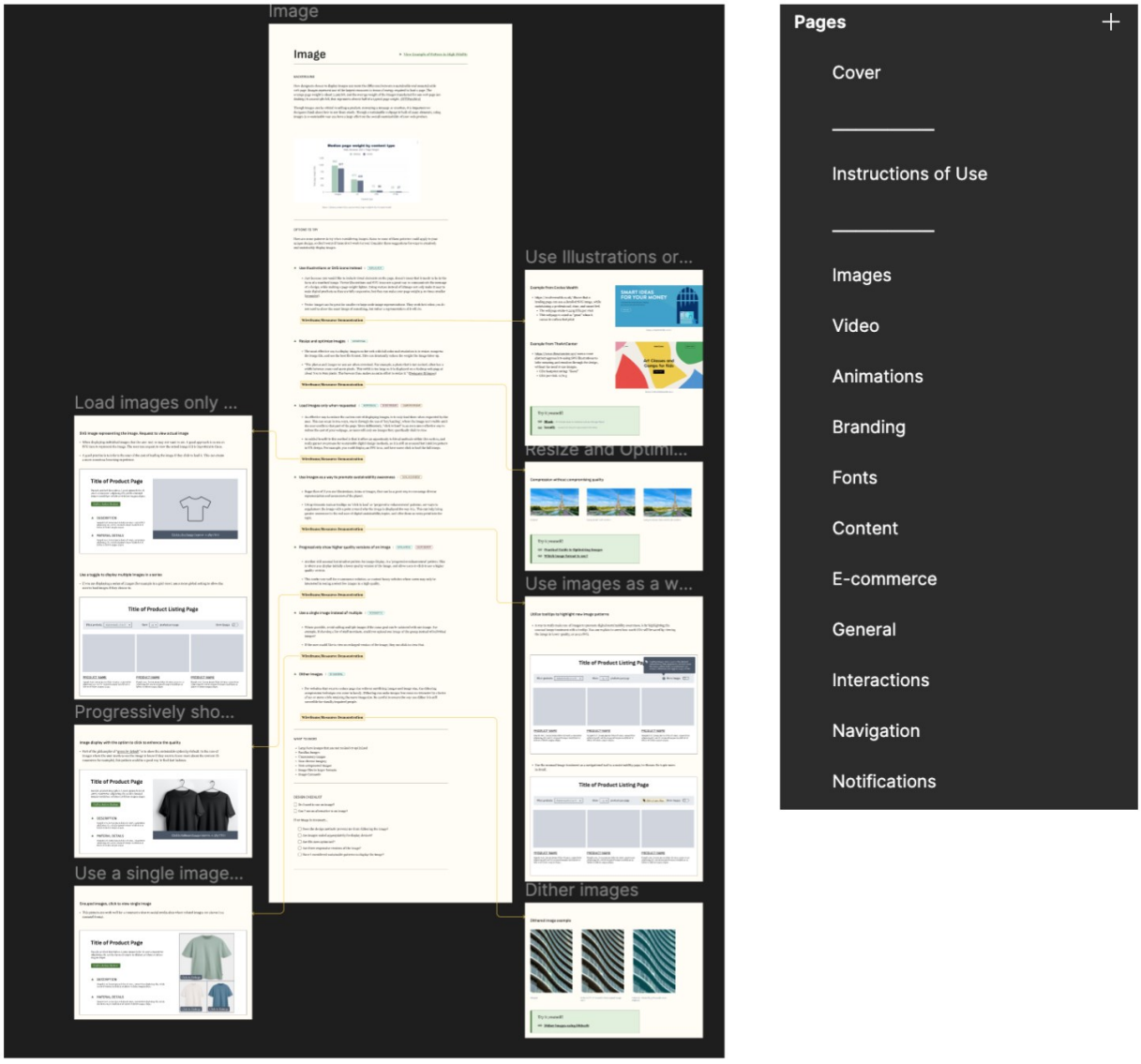
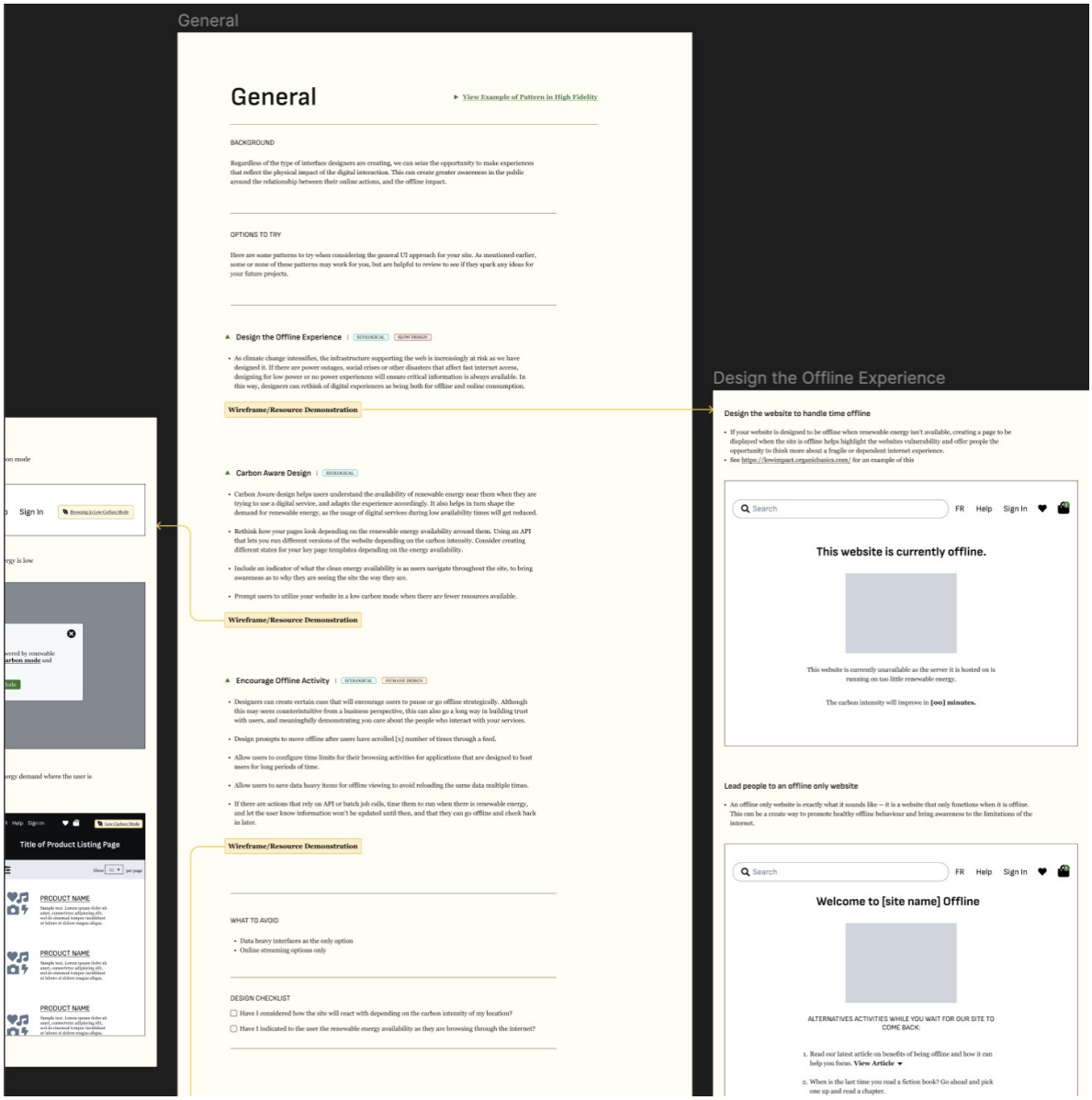


FIGURE 12: Draft of Patterns (Joanis, 2023)

Shown above are several draft versions of the patterns. When the patterns were just presented by themselves, they were difficult to understand and lost most of their meaning. I realized then that I would have to situate the patterns within pages that gave them context for designers to understand. For example, I created a header area on a webpage to situate image patterns in, or a search and filter interface to showcase different search patterns. Following several false starts, I approached the creation as I would the design of a website. I created components that could be

reused throughout the wireframe and mockup pattern examples to allow the library to be more visually cohesive and easy to build on. I used these pieces to create wireframe examples of each pattern as well as a high-fidelity mockup example of the interface element on a fake webpage that combined multiple patterns to illustrate how they could be used in practice. The goal with this structure was to create a means for designers to understand how these patterns can look in "the real world" while keeping them separate enough to be used as units in an actual project. See Appendix B for visuals of the library.




General
General
View Example of Pattern in High Fidelity
BACKGROUND
Regardless of the type of interface designers are creating, we can seize the opportunity to make experiences that reflect the physical impact of the digital interaction. This can create greater awareness in the public around the relationship between their online actions, and the offline impact.
OPTIONS TO TRY
Here are some patterns to try when considering the general UI approach for your site. As mentioned earlier, some or none of these patterns may work for you, but are helpful to review to see if they spark any ideas for your future projects.
Design the Offline Experience
ECOLOGICAL
SLOW DESIGN
As climate change intensifies, the infrastructure supporting the web is increasingly at risk as we have designed it. If there are power outages, social crises or other disasters that affect fast internet access, designing for low power or no power experiences will ensure critical information is always available. In this way, designers can rethink of digital experiences as being both for offline and online consumption.
Wireframe/Resource Demonstration
Carbon Aware Design
ECOLOGICAL
Carbon Aware design helps users understand the availability of renewable energy near them when they are trying to use a digital service, and adapts the experience accordingly. It also helps in turn shape the demand for renewable energy, as the usage of digital services during low availability times will get reduced.
Rethink how your pages look depending on the renewable energy availability around them. Using an API that lets you run different versions of the website depending on the carbon intensity. Consider creating different states for your key page templates depending on the energy availability.
Include an indicator of what the clean energy availability is as users navigate throughout the site, to bring awareness as to why they are seeing the site the way they are.
Prompt users to utilize your website in a low carbon mode when there are fewer resources available.
Wireframe/Resource Demonstration
Encourage Offline Activity
ECOLOGICAL
HUMANE DESIGN
Designers can create certain cues that will encourage users to pause or go offline strategically. Although this may seem counterintuitive from a business perspective, this can also go a long way in building trust with users, and meaningfully demonstrating you care about the people who interact with your services.
Design prompts to move offline after users have scrolled [x] number of times through a feed.
Allow users to configure time limits for their browsing activities for applications that are designed to host users for long periods of time.
Allow users to save data heavy items for offline viewing to avoid reloading the same data multiple times.
If there are actions that rely on API or batch job calls, time them to run when there is renewable energy, and let the user know information won't be updated until then, and that they can go offline and check back in later.
Wireframe/Resource Demonstration
WHAT TO AVOID
Data heavy interfaces as the only option
Online streaming options only
DESIGN CHECKLIST
Have I considered how the site will react with depending on the carbon intensity of my location?
Have I indicated to the user the renewable energy availability as they are browsing through the internet?
Sign In
Browsing in Low Carbon Mode
Help
Sign In
Save Carbon Mode
Title of Product Listing Page
PRODUCT NAME
PRODUCT NAME
PRODUCT NAME
Design the Offline Experience
Design the website to handle time offline
If your website is designed to be offline when renewable energy isn't available, creating a page to be displayed when the site is offline helps highlight the websites vulnerability and offer people the opportunity to think more about a fragile or dependent internet experience.
See https://lowimpact.organicbasics.com/ for an example of this
Search
FR
Help
Sign In
This website is currently offline.
This website is currently unavailable as the server it is hosted on is running on too little renewable energy.
The carbon intensity will improve in [oo] minutes.
Lead people to an offline only website
An offline only website is exactly what it sounds like -- it is a website that only functions when it is offline. This can be a create way to promote healthy offline behaviour and bring awareness to the limitations of the internet.
Search
FR
Help
Sign In
Welcome to [site name] Offline
ALTERNATIVES ACTIVITIES WHILE YOU WAIT FOR OUR SITE TO COME BACK:
1. Read our latest article on benefits of being offline and how it can help you focus. View Article
2. When is the last time you read a fiction book? Go ahead and pick one up and read a chapter.

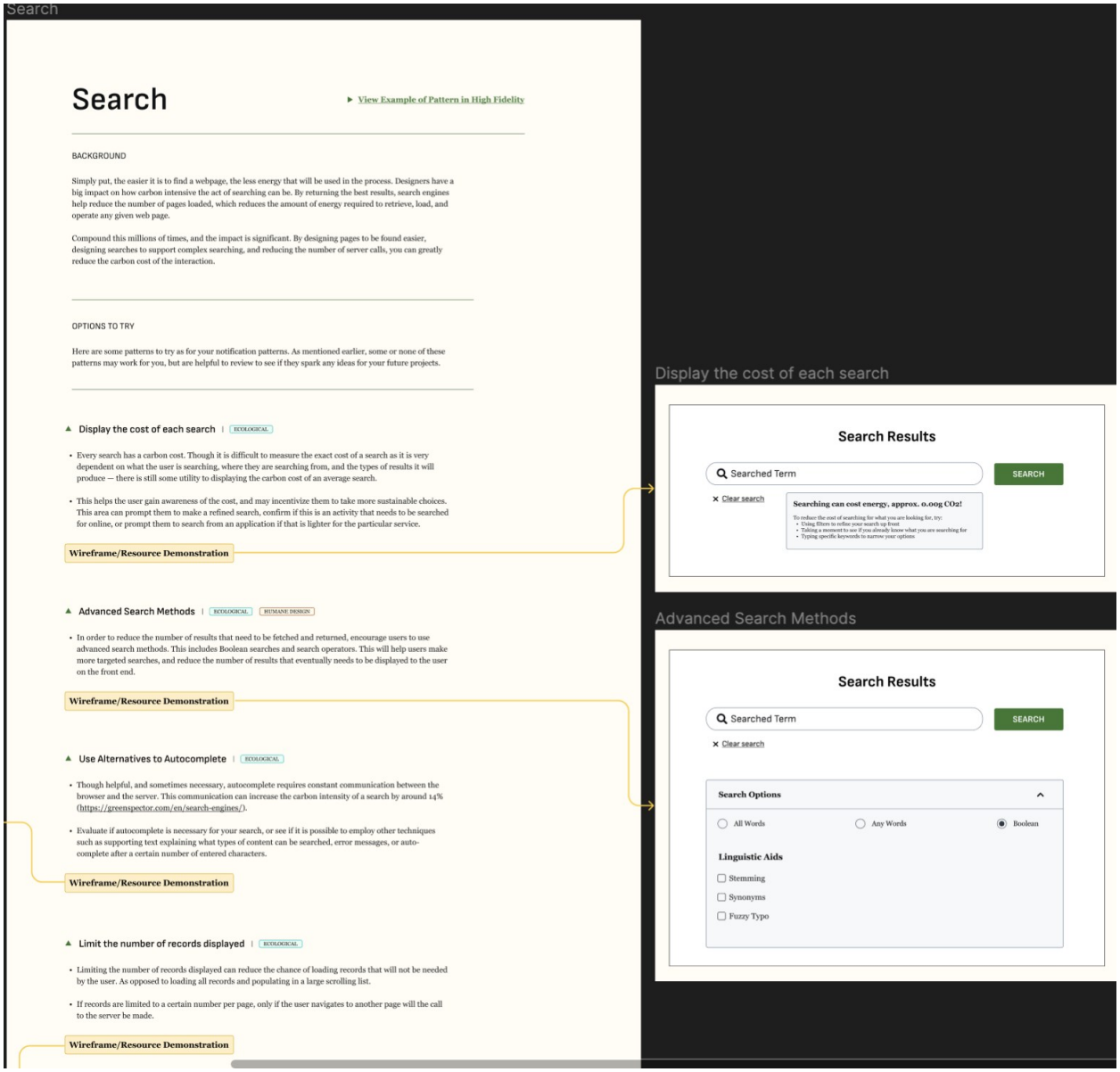


FIGURE 13: Images from Pattern Library (Joanis, 2023)

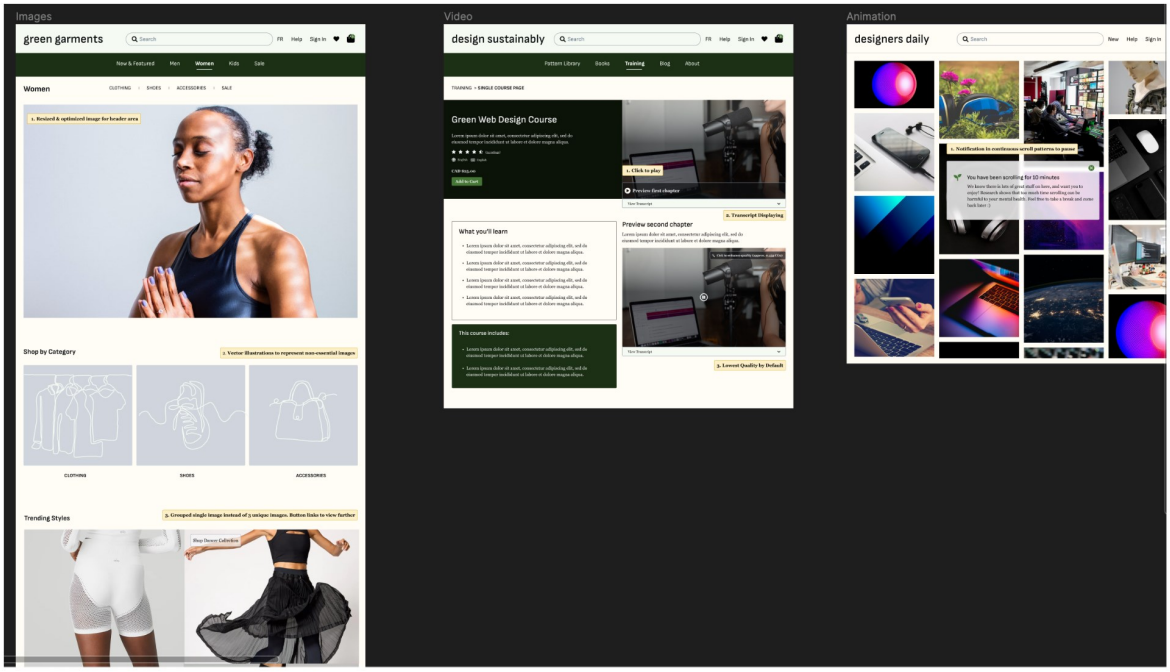


FIGURE 14: Mockups from Library (Joanis, 2023)

The pattern library included patterns for:

1. Images
    a. Use Illustrations Or Svg Icons Instead
    b. Resize And Optimise Images
    c. Load Images Only When Requested
    d. Use Images As A Way To Promote Sustainability Awareness
    e. Progressively Show Higher Quality Versions Of An Image
    f. Use A Single Image Instead Of Multiple
    g. Dither Images
2. Videos
    a. Compressing The Video File
    b. Add Captions
    c. Display Video On Request

    d. Display Low Quality By Default

3. Animation
    a. Micro-Boundaries Through Animations
4. Branding
    a. Colour Palettes
    b. Display Options On The Site
    c. Sustainability Page
5. Fonts
    a. Convert Font Files To Woff2
    b. Use Standard Fonts
    c. Subset Fonts
    d. Try A Unicharacter Logo
6. Content
    a. Reduce Unnecessary Content
    b. Make Content Searchable
    c. Explain Impact Of Choices
    d. Fact Checking
    e. Highlight Privacy Issues
7. E-Commerce
    a. Integration With Philanthropic Component
    b. Choice Editing
    c. Product Sorting And Differentiation
    d. Reduce Returns
    e. Encourage Good Behaviour For Offline Care
    f. Eol Requirements
    g. Cart Overlay
    h. Sustainable Advertising
8. General
    a. Design The Offline Experience

    b. Carbon Aware Design
    c. Encourage Offline Activity

9. Interactions
    a. Progressive Enhancement
    b. Management Of Media Files For Download
    c. Inform User Of The Impact Of Their Behaviour
    d. Rethink Scrolling Patterns
    e. Positive Feedback When Making Sustainable Choices

10. Navigation
    a. Mega-Menus
    b. Carbon Impact Indicators In Navigation

11. Notifications
    a. Display Cost Of Each Search
    b. Advanced Search Methods
    c. Use Alternatives To Autocomplete
    d. Limit The Number Of Records Displayed
    e. List Low Carbon Options At Top Of The Search

12. Search
    a. Don’t Use Urgent Colour Schemes (Unless Necessary)
    b. Mindful Notifications
    c. Personalise Notifications

Reflecting back on the process of creation, I found it challenging when working on the mockup pages, to create examples of websites to showcase the patterns that looked appealing, but were also adhering to sustainable design principles. I wanted other designs to use these as inspiration, therefore creating the mockups were the slowest part of the creation process as I wanted them to also be attractive. Working from the written content, some patterns I anticipated making, didn’t translate as I originally imagined and needed to be modified as I began creating them. Ultimately the library ended up being a tool I found to be clear, easy to navigate and understand. I felt this

was a solid base for a first version of the library that could be improved upon with collaboration and user feedback.

Testing and Analysis Methodology

To understand if this preliminary version of the library was able to achieve the research goal of creating an artefact that aids in facilitating User Experience (UX) Designer's shift to sustainable UX practices I needed to test it with users. My objectives for the investigation were to: 1) understand if designers were able to understand the design patterns, 2) understand if they could utilise them in a design regardless of industry, 3) understand if the format was conducive to easy utilisation of the patterns.

Research methods

For this type of investigation, I took an embedded mixed methods research approach (Robinson, 2007) where I tasked a group of designers with re-designing a key landing page from any digital product or website using at least two patterns from the library. Subsequently, I provided them with a questionnaire consisting of open answers, multiple choice and subjective evaluation questions to understand how they were able to use it. I also evaluated the effectiveness of use by reviewing the designs they created as they each provided me a link to their redesigned page. By using this approach, I was able to have a more nuanced understanding of how the designers used the library through the primarily qualitative approach, while supporting those findings with quantitative data that could speak to the breadth and scale of the insights I was uncovering.

Participants and testing process

The participants were a group of around twenty design students from the CART 310 Interaction Design class at Concordia University. They are designers with varying levels of experience and diverse backgrounds, almost all of whom were brand new to the topic of digital sustainability which made them an ideal sample to test the library with. Following a presentation on the topic that included information found within the "introduction" section of the library, the students were tasked with the redesign activity. They were given around forty-five minutes to complete the

activity and fill out a reflection questionnaire through google forms which comprised the qualitative and quantitative research data (See Appendix C).

The questions in the form were designed to answer the research objectives. Some sample questions include:

- When navigating in Figma, how easily were you able to find patterns that related to elements you were trying to design?
- If a client asked you to design them a sustainable website, would this library be a resource you would consult in your design process?
- Was there some information that you wish was there, but was missing, regarding how/when to use a pattern?

Additionally, I included subjective evaluation statements that participants were asked to agree or disagree with on a scale of 1-5, such as:

- It is easy to find patterns that are useful to me.
- I don't understand the utility of this library.
- I feel I would be better equipped to create humane/ecologically friendly interfaces if I had this tool.

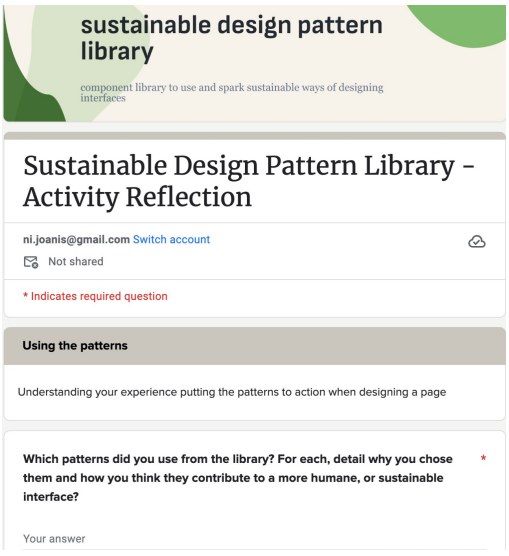


FIGURE 15: Image from Questionnaire (Joanis, 2023)

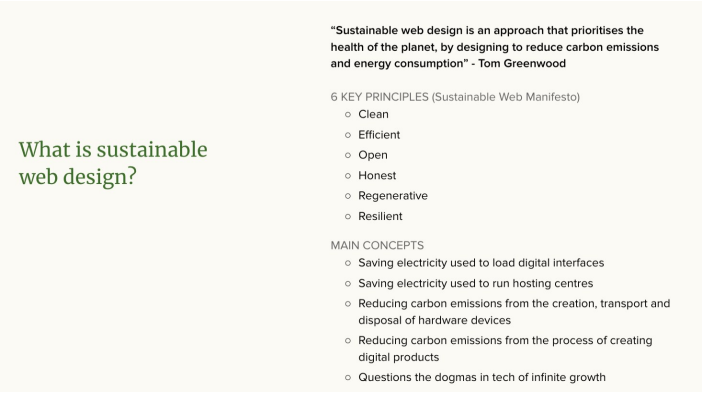


FIGURE 16: Image from Presentation (Joanis, 2023)

Analysis

As the majority of the data was qualitative, I opted to use a thematic analysis approach in order to pull and consolidate insights with greater ease and have the ability to view key themes visually as well. As explained by (Guest et al., 2014)

> "Thematic analyses move beyond counting explicit words or phrases and focus on identifying and describing both implicit and explicit ideas within the data, that is, themes. Codes are then typically developed to represent the identified themes and applied or linked to raw data as summary markers for later analysis. Such analyses may or may not include the following: comparing code frequencies, identifying code co-occurrence, and graphically displaying relationships between codes within the data set.

In order to most effectively identify themes, visualise them and integrate these qualitative insights with the quantitative data, I opted to use a tool called Dovetail (2023). Dovetail easily supports the codification of data into themes, as well as the ability to visualise them and consolidate them into broader insights. I started by importing the seventeen survey responses into the tool to code them using tags. I then consolidated the tags into groups that would help me understand some broader themes in the responses. The tag groups that I ended up creating out of the collection of responses were:

1. General Sentiment: This tracked general sentiments from participants that seemed positive or negative to get a sense of the overall view of the library.
2. Patterns Used: This tracked the patterns most commonly used and therefore ones that either were easiest to grasp, most frequently needed in designs or most clearly portrayed as a pattern.
3. Challenges: This tracked the various difficulties participants were having with the library.
4. Opportunities: This tracked the areas where the library could be improved, through new ideas given by participants or through some expressed wishes or challenges.
5. Positives: This tracked the various aspects of the library that participants particularly found useful and beneficial.

6. How They Were Used: This tracked the different methods that participants used the library

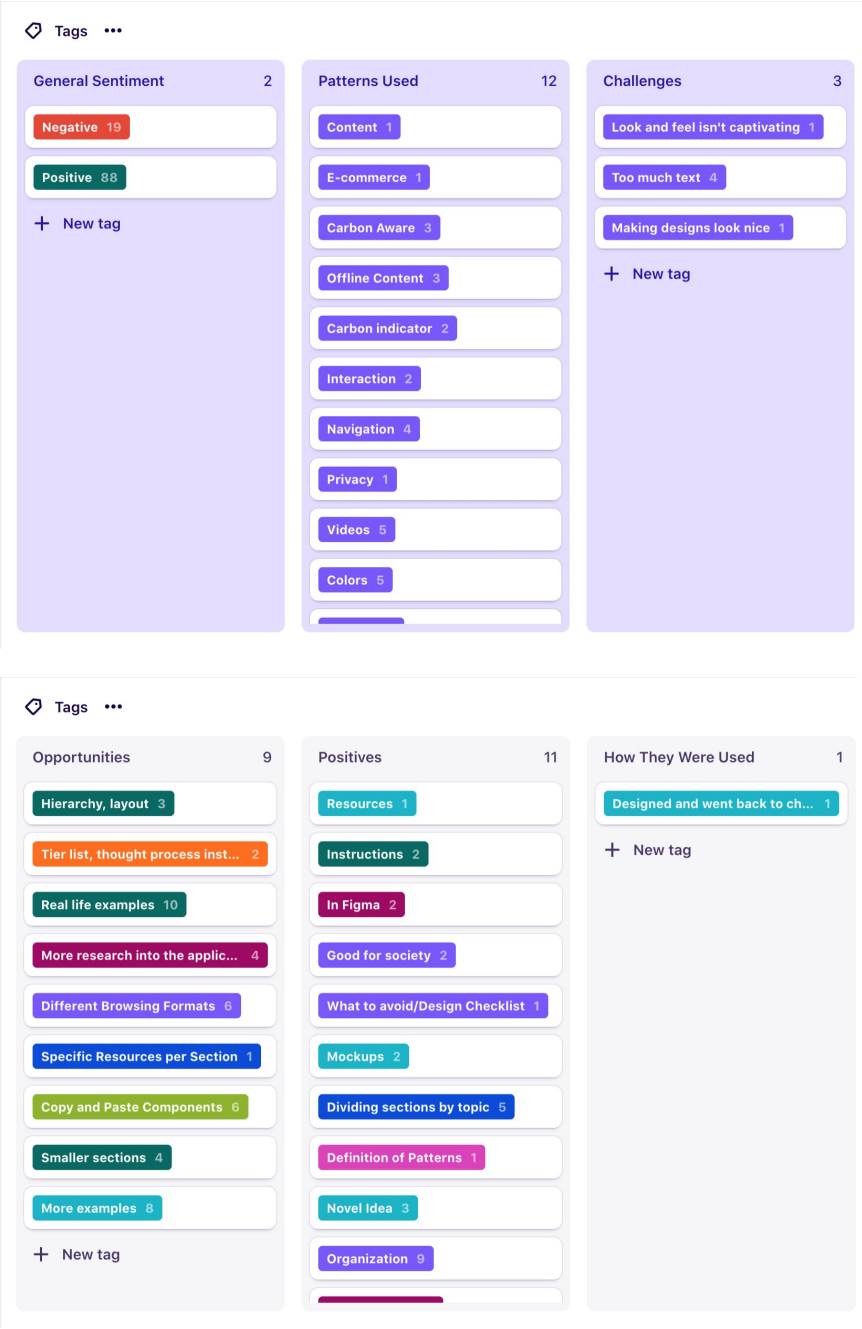


FIGURE 17: Tags from Dovetail Analysis (Joanis, 2023)

This mixed method research design was proven to be effective in uncovering the answer to my research objectives. The questionnaire allowed me to efficiently capture the insights from

participants in their own words. When analysed through Dovetail, I was able to confidently understand if designers could understand and utilise the patterns and if the format of the library was conducive to their adoption of sustainable design methods.

Results

Overall, when analysing the general sentiment participants had towards the pattern library, it was overwhelmingly positive. Positive commentary (sentiments rated positively tagged eighty-eight times) vastly outweighed negative sentiments (tagged nineteen times). Some examples of positive commentary include quotes such as “I see a lot of utility in this library” or “the library feels very comprehensive and detailed”. Examples of negatively tagged sentiments include “I don't like the horizontal layout” or “I honestly don't think you can 'use' the patterns in the form that they are in at this moment. You need to read, educate yourself on the issues and how to solve them, and the patterns make that easier of course, but I cannot say I would consider them tools.”

As part of the positive commentary, participants expressed that they appreciated the organisation and structure of the library. They were able to easily navigate through the various sections and find patterns they were looking for. When asked if the patterns were organised in an intuitive way, 76% said they were and 89% said it was easy to find patterns that were useful to them. The instructions were helpful to many as it helped them orient and navigate through Figma. The choice of housing it in Figma was a positive to many, as they found it helpful to have this information in a tool they would use for the design work so it was all in a single place. They felt overall the library was important as it was a novel idea and that there is a big need for something like it in our society. When asked if they would consult the library if tasked to create a sustainable website, 100% of participants said yes and 82% said they would be better equipped to create sustainable interfaces with this library.

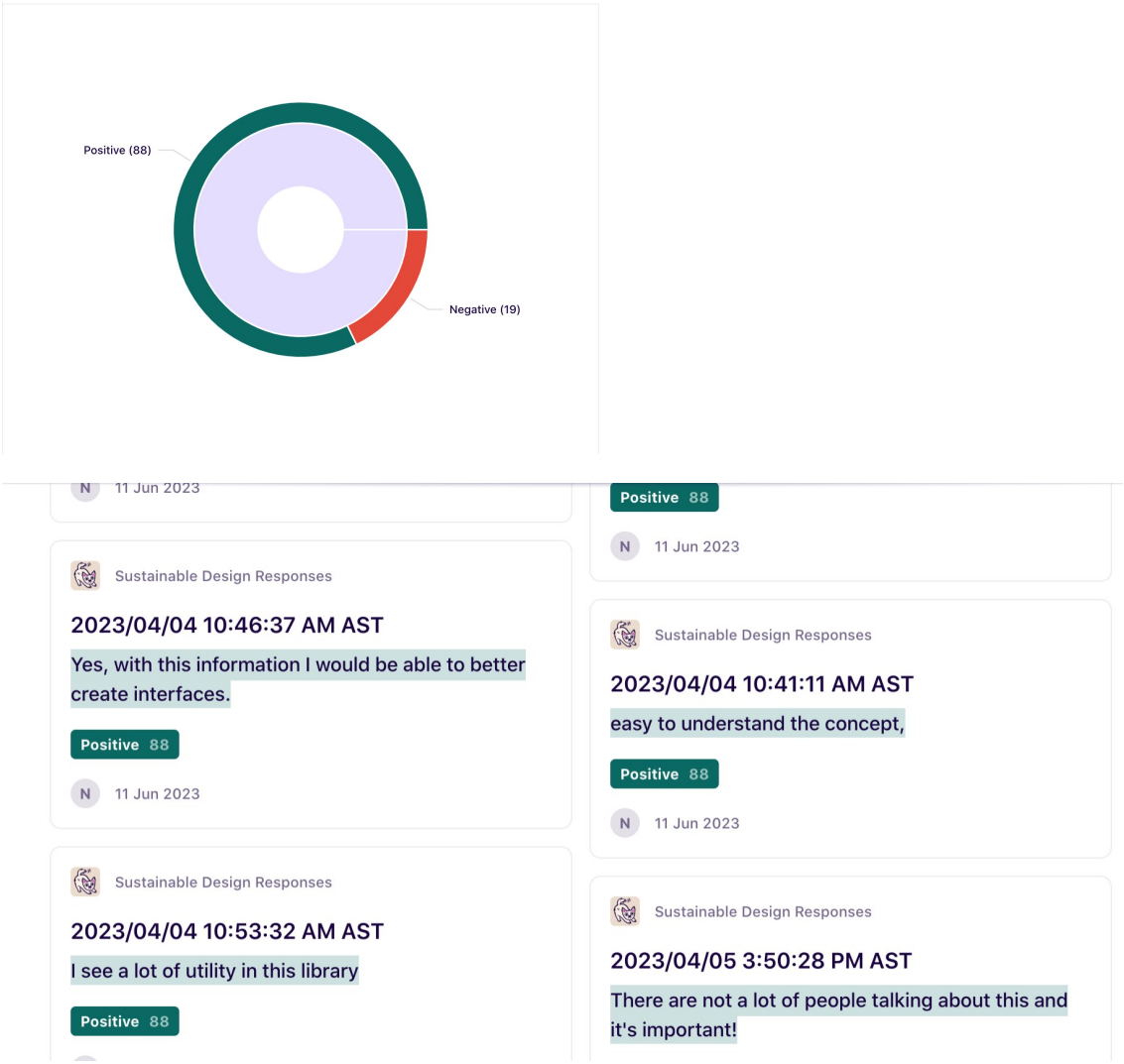


FIGURE 18: Positive Tags from Dovetail (Joanis, 2023)

In terms of the patterns that were most frequently used in the redesign task: image patterns, colour patterns and videos were the top pattern sections that were used by participants. Patterns related to privacy, content and e-commerce were the least frequently utilised.

The primary challenges participants had with the library was that there was a lot of text that many skipped over and similarly that the look and feel of it wasn't as inviting. Another key issue was that it was difficult to use the patterns and have their designed artefact look visually appealing. Participants struggled to "make designs look nice" using patterns from the library.

Their challenges revealed some opportunities, chief among them: showing more examples of how these patterns could be used in daily practice. Participants wanted to see how these patterns that were shown largely in isolation in the library can be used within a real product to understand how to leverage them. 58% of participants said that they found the library relatively hard to use on a scale of 1-5, indicating that there is work to be done to improve the ease with which designers can utilise the tool. To help facilitate designers using these patterns, many expressed the desire for them to be able to be copied and pasted to other design files to avoid needing to recreate them from scratch in their working file. This opens up questions about visual uniformity and if that would require the pattern library to include basic user interface (UI) elements such as lines, colours, icons and other components to create wireframes with a consistent look. Lastly, users wished for the library to be able to be presented in different formats as well. Some desired a PDF handout so they could add personal notes, others requested a digestible format outside of Figma. Understanding the different use cases behind these requests would assist in understanding how the library can be improved.

Discussion and Next Steps

Despite the library being in the early stages of creation, the user testing confirmed that the library is an artefact that would help designers adopt sustainable design practices as well as spread further awareness regarding the topic. Designers indicated that it is a unique, necessary and helpful tool in creating sustainable digital products and one they would consult in the creation process.

These findings align with Jarrett's definition of Sustainable Web Design (2019) as an approach that understands the responsibility for reducing carbon and energy use starts with the teams designing the technology. By participants expressing that the library supports them in creating sustainable interfaces and bringing awareness to this issue, this pattern library was shown to help designers create tools that follow sustainable web design methods. This also connects to the theory of Ontological design outlined by Fraga (2020), by facilitating designers to create products in a sustainable way, that will then create a sustainable society.

Several themes emerged when looking at the shortcomings of the library. Primarily, it was hard for designers to create a nice looking interface with the patterns and they needed assistance in translating the patterns to real life examples. I experienced this same difficulty as well, so more work can be done to support designers in this way. There is also a chance many did not arrive at the "mockup" page, which was created to address this issue. However, it may suggest that more effort should be put into creating real example pages with the patterns on display to show users how they can look in practice. It also could mean that the "mockup" page is not useful as a standalone page without the context of the patterns and discussion and should be moved to its respective page.

Another point of note is that privacy, content and e-commerce were the least frequently utilised patterns. They are necessary and useful components to many web products. This finding points to either the patterns themselves being confusing to participants, or they may not have been relevant to them based on the participant demographic. As all participants were students, most likely not yet working in the industry, they may have fewer points of reference to how critical these aspects are to a digital product. Further testing with broader demographics may yield different results in relation to which patterns were used more frequently.

Another key avenue for developing the library further, is to build it out as its own wireframe kit. This means that in addition to standard UI elements in the file, it would include these patterns with layers properly named, following a standard specification format and autolayout to them to be fully responsive. This would allow users to only rely on this file as their resource for creating cohesive wireframes, without the extra work of translating the patterns to a style that fit their individual wireframes. By building out this functionality in the library, it would help better achieve the goals of interaction design patterns as outlined by Dearden et al. (2002) by more concretely communicating the "information and knowledge" to support designers in this practice.

Lastly, some participants questioned "how well" the patterns tangibly addressed issues of sustainability. As the patterns have not been tested to understand what their impact is environmentally or socially, this is a valid concern. This is a critical area that will need to be explored to legitimise and further develop the library. Currently, the patterns are educated guesses as to what a sustainable pattern could be based on current digital solutions and research on the topic. To indeed prove they are sustainable design patterns, they should be tested in live

environments in comparison to their “lesser sustainable” counterparts, to understand how much energy is saved, or the social implications of the solution. For example, this would mean taking two implementations of an image, one following a sustainable design pattern and another following a pattern discussed in the checklist as a pattern not to follow. The energy intensity of both could be measured to understand how much energy is saved with the sustainable pattern. As highlighted by Greenwood and Roussilhe (2021, 2021) measuring the environmental impact of our digital ecosystem is incredibly complex, so an accurate testing plan for the patterns would require much thought and planning to dive deeper into that aspect. Not only would this solidify the reasoning behind the patterns, but would equip designers in defending their design decisions by discussing the logic behind choosing the approach they chose when working with clients or on a project. While all of the above points merit further research, they lie beyond the scope of this Masters thesis

Ultimately, I would argue that the library is an important and novel addition to current resources for designers around the topic of digital sustainability. Not only does the library synthesise existing literature on the topic in a way that is organised and catalogued for designers to access easily in relation to an interface element, but it shows designers what this looks like in practice. Designers currently have very few resources to rely on to show them tangibly what a sustainable interface can look like. This library, therefore, is a meaningful contribution to resources on the topic and provides at least a starting point for designers in adding this skill to their toolkit.

The findings from the user testing, though insightful and useful for answering the research question, are limited by some flaws in the research methodology. Most obviously, the participant sample size and skill level. There were approximately twenty participants, seventeen of whom responded to the questionnaire. It is hard to confidently come to conclusions about the library’s utility with such a small sample size. In addition, all participants were all students of design. This means that they more than likely have varying levels of experience in their design practice which could theoretically make the pattern library more challenging than for designers at a different stage professionally.

Additionally, the format of the testing session may have affected the results given through the questionnaire. Before designers were tasked with using the library, they were given an introductory presentation on the topic of digital sustainability. The presentation contained

examples from the library as well as visual examples of patterns to follow or not to follow from real life examples. If this study were to more accurately assess if the pattern library can be useful to designers as a whole, it would be wise to test on designers with no prior knowledge of digital sustainability as that is more likely to be representative of the design population. This format as well may have inhibited fully honest responses from participants as well. Although I had no visibility into participants' responses as they were answering the questionnaire, and all responses were anonymous, I was physically present in the room. This may have influenced participants to be kinder in their reflections about the library as they were aware this was a personal project. Perhaps a reflection asynchronous from the testing sessions would have yielded different responses that may have revealed a different outcome.

Lastly in terms of limitations in these findings, is the fact that I was not able to triangulate them with observations of how the participants used the library. The questionnaire relies solely on first hand accounts of how they used the library, however, had I been able to observe them directly, these findings may have supplemented their responses. Witnessing how participants navigate the library, where they click, where their eyes are drawn to and what they return to, is all helpful information that would supplement future areas for developing the library. Future testing with a different research method will be required to more conclusively understand how participants use the library and how it should be improved upon.

Conclusion

In this work I sought to address the pressing challenge of integrating sustainable design practices into the standard creation methods of the UX community. The purpose of this study was to help bridge the gap between sustainable design theoretical knowledge and practical application. In a field where resources for learning sustainable design techniques remain limited and where the current dominant design methods do not factor these considerations into the process, the pattern library serves as a focal point for designers to hone this skill.

In the pursuit of answering the research question, “how might design patterns, in the form of a pattern library, persuade designers to shift to more sustainable UX practice?” I was able to expand on the currently available research and artefacts for designers on this topic. The creation

process allowed me to gather the available literature and summarise it into key themes that were then embodied into tangible patterns. Put differently, I synthesised existing research into forms that are more accessible and actionable to practising designers. Through the mixed-methods research approach, I was able to conclude that the pattern library is a tool that will serve designers in developing their skills in sustainable design, and that can complement existing design methods that will continue to be required by the industry. The research also revealed valuable insights into areas that warrant refinement and enhancement. These valuable suggestions, collected from the user testing phase, present opportunities for iteratively improving the library's usability and effectiveness, thus strengthening its utility for fellow designers.

As we progress into an ever immersive digital lifestyle, where the negative effects of technology on our planet and collective wellbeing are increasingly exacerbated, equipping designers who have the power to influence a change in this sphere is not just a preference but a necessity. The implications of this research extend beyond the confines of this study and hopefully can expand to create broader changes in the UX community in terms of how we approach design practice and the techniques we use.

In order to achieve this, I hope to continue refining the pattern library through the feedback given from the participants and solicit more information regarding how designers use the tool in different methods. Ultimately, when a more usable version of the tool is created I will publish it to the Figma community, as well as make it available in other formats. This will allow me to continue shaping it as a resource that will be informative, usable and influential with regards to how designers contribute to solving the growing crisis of unsustainable tech.

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Appendices

Appendix A - Written Content

Content Pattern Library d847345ead04491a963e756142d62ae7.pdf

Appendix B - Pattern Library

https://www.figma.com/file/sl2OehEK5dNugTFDkqjQTJ/Sustainable-Digital-Pattern-Library?type=design&node-id=1%3A7&mode=design&t=X5OVthO3pfWX1hC7-1

Appendix C - Questionnaire

https://docs.google.com/forms/d/e/1FAIpQLSfYAlZsStx14ARMsygXmLThA1cEulgYMNvJqgxUmAFZMWJcuQ/viewform?usp=sf_link