Solar Literacy: exploring joyful energy-aware digital experiences

Anna Maria Puchalska
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Umeå Institute of Design, Sweden
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1. Abstract

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The Internet is rapidly growing in complexity, with increasing negative environmental and social impact. While heating and lighting are tangible examples of energy consumption, internet usage is not perceived as such. Therefore, it opens up opportunities for new, energy-efficient, slower, resource-saving and mindful protocols for the Internet to emerge.

I propose Glow OS - an operating system enabling individuals and communities to align online activities with intermittent solar energy to accelerate the transition to a fossil-free internet in the spirit of joy.

Through the mix of user-centred and speculative design methodologies, the project identifies design opportunities and creates concepts to map various facets of green Internet.

Unlike other existing design approaches and strategies, I use joy as a driving force for addressing large-scale and sustainable change.

Although the primary deliverable is a proposal of Glow OS, its value lies in mapping digital sustainability and visually representing its various values. By taking this step, the project addresses the perceived complexity that may have hindered progress in this area.

2. Introduction

2.1 What is Digital Design Sustainability?

“Digital sustainability is the process of applying social, economic, and environmental stewardship principles to digital products, services, and data delivered via the internet. Designers and developers might interpret this as a call to deliver more resource-efficient digital products, and they would be right.” (Frick, 2022)[1]

Digital design sustainability is an increasingly important area of focus for designers and developers. Although the concept may seem straightforward, creating truly sustainable digital products and services involves many aspects that urgently need to address environmental and social sustainability and building applications that are, according to Sustainable Web Manifesto[2] and Gerry McGovern's Digital Earth[3].
- **Clean**: powered by renewable energy;
- **Efficient**: both energy-efficient and carbon-efficient;
- **Minimal**: consuming electricity with low carbon intensity;
- **Resourceful**: designed to use the least amount of energy and material resources possible;
- **Compatible**: with older hardware;
- **Demand-driven**: shape demand to match supply rather than shaping supply to meet demand;
- **Regenerative**: designed to support an economy that nourishes people and the planet;
- **Resilient**: able to function when and where people need them most;
- **Honest**: designed to heal, sustain, and empower communities seeking liberation from oppressive systems;

Addressing these points is difficult within the current socio-economic system, driven by big tech businesses and growth models prioritising "business as usual". Nevertheless, these same entities are the most influential in shaping future visions of technology.

In her review of alternative approaches[4] (de Valk, 2021), Marloes de Valk addresses several key points within sustainable and responsible computing practices that hold power to challenge the status quo. Marloes highlights low-tech approaches that recognize the value of past knowledge and technology in creating a sustainable society. She also discusses "computing within limits", which is the practice of designing and using computer systems that consider their environmental and social impact, including energy consumption, e-waste, and the use of conflict minerals and embracing degrowth principles.

### 2.2 The relevance to Interaction Design

Traditionally, UX designers aim to create "linear, perfect user journeys that delight users and simplify their lives" [5](Ammer, 2018). However, regarding sustainability, we could all benefit from making friction visible and addressing them rather than simply making things go smoothly and easily. There are ethical implications to sweeping information under the rug, so we should reflect on the impact of these simplifications and consider how technology makes people and the planet more vulnerable.

While I believe that certain actions do not require technological assistance, I argue that technology can help us establish systems that promote positive change and address the call from the Sustainable Web Manifesto to help people adapt to incoming changes in the face of the climate crisis. However, I believe the next few decades will be about taking action to balance the digital and organic worlds - which does not necessarily mean shrinking the growth of the digital but rather calibrating our experiences within it. Interaction design can be of great help in achieving this goal.

### 3. Background

"Every design has physical implications, from the amount of energy that it takes to power an experience to the real-world choices users make based on the information we present and the stories we tell.”

[6] (Friedman, J., Romano, R. 2022)

#### 3.1. Everything digital - information, data, experiences - is also physical

Digital infrastructure has nothing in common with a real cloud - the Cloud is not ethereal; on the contrary, it is “relentlessly” material, manifesting as a massively hot warehouse filled with flashing lights, spinning discs, cooling fans, and the only aspect resembling the real cloud is black smoke, produced in factories from fossil fuels that are still a central part of the energetic supply chain [7](EESI, 2021). Internet traffic needs electricity, air, metals, minerals, and rare earth elements to sustain global digital consumption. The infrastructure of our networks consists of rare metal-based telephones, computers, servers, and various other devices, all of which increase in complexity and
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computing power and are not adequately recycled if recycled at all. Additionally, numerous antennae, transmission equipment, transoceanic cables, and similar components are installed continuously, despite the current capacity being already substantial.

New technology, informatics, and communication systems are used to solve real societal and environmental problems. Increased connectivity drives UN Sustainable Development Goals (SDGs) to become achievable, advancing healthcare, science, and knowledge databases through greater precision and speed. However, I would argue that some online activities are relatively unproductive (if not unhealthy) - scrolling through the mediocrity of social media content, a tsunami of auto-played videos, spam, "ultracconectivity" normalising and encouraging our digital avatars to be constantly available, being bombarded with a constant flow of updates and news, addictive mechanisms evolving techno-dependency, can be argued for the internet being a double-edged sword.

Nowadays, our online actions cost 3.7% of global emissions [8](Freitag et al., 2021) more than the aviation industry. While flying in a public debate is associated with an environmentally destructive practice, the notion of the Internet being pollutive remains unfamiliar [9] (Borning, Friedman and Logler, 2020).

In recent years, designers focused on connecting physical experiences to digital services through digitalization.

Reflecting on this undeniable materiality of the Internet, I raise a question of how design can explore ways of reconnecting digital experiences back to the physical world to reflect ecological limits.

3.2. Rebound effect guaranteed

Surprisingly, the increase in energy consumption is not due to the growing amount of people using the network; rather, it is caused by growing energy consumption per internet user (Kearns, S. 2021)[10]. The ever-increasing demand plays a fundamental role in the growth of the Internet's environmental impact. In my observations, the Covid-19 pandemic has accelerated binge-watching behaviours, and increased video calling, resulting in prolonged screen time and increased consumption.

Making technology more efficient results, paradoxically, in using more energy, not less, according to the rebound effect, also known as Jevons paradox (Wikipedia Contributors, 2019)[10]. A modern example is replacing light bulbs with energy-efficient LED lights, significantly accelerating energy use.

Over the years, kilobytes have turned into megabytes, replaced by terabytes and, most recently, exabytes when referring to monthly global internet usage. In 1995, Microsoft's Windows 95 weighed 19MB, while today, a typical inbox weighs almost 300MB, while the whole Wikipedia, with its 21GB content, would fit on a single Apple Watch.
We need both to counter the rebound effect; energy efficiency must be paired with the reduction in digital consumption. How can interaction design play a role in both minimising consumption and creating energy-efficient solutions?

3.3 From an Industrial Mindset to One of Stewardship

“Information technology is obviously the field where the level of our ambitions is the most fanciful, where the usual assumption of infinite resources on the planet is most obvious”
(Bihouix, F. 2020)

The Industrial Revolution irreversibly changed the societal perception of energy. People moved from the lived experience of dependence on the sun to light up the room’s darkness and wind to perpetuate the windmill to unlimited, always-available, unconstrained usage of energy and blissful not-knowing how, when, and where it is produced. Nowadays, when massive emissions become a threat, and as a result, renewable energy is rapidly advancing - that brings a question of whether people can re-learn the intermittent nature of these sources in the digital space.

There is also an opportunity (a design opportunity) to change the mindset from “dig, burn, use” and perceiving the environment as separate from humans to caring and recognizing that we all are active actors in this complex system. “We should think in terms of stewardship of the natural cycles of abundance and scarcity of resources around us, and this sensibility is something we can build into the internet itself.”[12] (Adams, 2021)

“How if the Internet is a space for million flowers to bloom? What if these rectangles of glass are filled with interactions that nurture and care for us?” [13](Gentle, 2020). What if Internet is a bicycle and not a highway to the mind? According to a hacker and artist Joseph Gentle, the Internet can be all of the above and more.

How to design digital experiences in the abundant present for a future of scarcity?

3.4. Out of sight, out of mind? Climate action in disguise

Initially, my assumption was that raising awareness and making end-users of digital experiences aware of the environmental impact would directly lead to a positive outcome. However, according to Shunying An Blevis and Eli Blevis, authors of Non Linear Design Thinking, it might not be the case, hence only the most aware take action. Ideally, climate care actions shouldn’t be dependent on human awareness. [14] (Blevis & Blevis, 2022)
How can we design a system that engages users on multiple levels beyond cognitive awareness? Furthermore, how can we make climate actions effortless?

3.4. Digital is unjust

The initial inspiration for this project was learning that digital infrastructure is unevenly distributed and how it is a deeply conflicting matter where human rights and environmental rights meet.

Today, 3.5 billion of the global population has access to the internet [15] (Murphy, Roser and Ortiz-Ospina, 2015), and it’s predicted to reach universal access by 2050 [16] (Sample, 2019). The internet connects diverse communities around the world. Global access to these (inter) networks is crucial to minimise digital inequalities. However, these same digital systems consume energy and resources that harm the ecosystem, eventually affecting arguably the most vulnerable groups. For example, a massive amount of toxic e-waste currently occupying the landfills [17] (Geneva Environment Network, 2021) of Ghana [18] (Stowell, 2019), data centres drying up more rivers [19] (Copley, 2022) if the massive carbon footprint of digital technologies continues to be ignored.

Technological innovation is taking an environmental toll, and many communities affected the most by the climate emergency continue to lack access to digital resources needed to mitigate these effects.

Unfortunately, I have decided not to address climate justice directly in this project due to its complexity and a limited time frame that would enable me to do justice to justice.

4. Approach

4.1. Strategy

Initially, I intended to use a value-led participatory design framework [20] (Kheirandish, 2020), in order to engage all stakeholders involved in creating and consuming digital experiences (product makers, end-users, green software experts) with environmental sustainability as a driving force for design activities. However, after the research phase, I have decided to focus solely on end-users, from which I gathered the most actionable insights. I anticipated using a mix of methodologies and reacting flexibly to what emerges in the process.

Human Centred Design + Speculative Design

I used a mix of methods in this process, utilising a human-centered design approach in a non-linear iterative process combined with speculative design [21] (Barendregt and Vaage, 2021) to create future imaginaries.

To be able to work on a holistic concept of environmentally-aware digital experiences which is highly systemic and complex, and also intrinsically human, I needed to gain a better understanding of different perspectives of consumers of digital experiences, their challenges, needs, hopes and limitations; therefore Human-Centred Design as a framework [22] (Borthwick, Tomitsch and Gaughwin, 2022) seemed to be appropriate as a foundation of my work.

Considering that I was looking into the future of green Internet, as well as critically on the current system of attention economy ingrained in the modern format of Internet consumption, I used speculative design methods to explore preferable future scenarios for people and the planet, even if that would, as a consequence, question this pillar of the economic landscape.
4.2. Outline of the process

Research

To begin my research on digital sustainability, I immersed myself in the topic by reading relevant articles, blogs, magazines, and books about the environmental impact of computation.

I engaged in various ways with two active communities on Slack - Climateaction.tech and Sustainable UX. I conducted semi-structured interviews, informal coffee chats, and group reading discussions and participated in a communal screening of relevant movies with members of these communities.

Through these activities, I gained a deeper understanding of the landscape, the current status of digital sustainability, and its future visions. To gain a more comprehensive understanding of the environmental and societal impact of Internet consumption, I used Planetary Boundaries framework [23] (Rockström, 2009) and Doughnut Economy framework [24] (Raworth, 2012) and discussed them with the experts. Furthermore, I mapped out the existing and emerging tools and solutions.

In order to gain deeper insight from end-users, I conducted an experiment using an existing digital product Carbonalyzer [25] (The Shift Project, 2019), which enabled me to generate user stories. Later on, I synthesised the findings into design opportunities and principles to use them meaningfully in the next stage of the process.
Design Exploration

Since the project's scope narrowed from environmentally-aware to energy-aware digital experiences, it still remained novel to me. Therefore, I needed additional research on renewable energy transitions and alternative internet formats. I accomplished this through reading articles and playing an online simulator game that gave me an experiential understanding of the complexity and challenges of energy transitions over the next 60 years. I formulated speculative scenarios based on additional research to build a richer context for early concepts. These concepts were later taken to users for feedback and tested in an iterative loop. Three concept directions were formulated based on features from sacrificial concepts.

Refinement: Finding joy in scarcity

The refinement phase began by narrowing down three concepts to one. I then conducted a survey to broaden my understanding of joy as a design quality, followed by two co-creation workshops. The first workshop focused on formulating joyful user journeys, while the second prioritised tangible interactions in speculative futures within the home context. Based on the insights from the research and concept phase, a list of functional features was formulated.

Final delivery

Final delivery included producing interactive prototypes, and testing them with users for the last iteration. Lastly, a video was produced to anchor the final outcome in a believable, real-life scenarios.

5. Primary Research

I began the research with a broad question of how to design environmentally-aware digital experiences that reflect ecological limits, trusting that I will find anchors to position my project as I converge.

How to design environmentally-aware digital experiences that reflect ecological limits?

To investigate this complex topic, I worked on various levels, zooming in on particular agents of this system, such as end-users and designers, and examined their lived experiences with digital sustainability, carbon footprint, and digital consumption. This inquiry allowed me to assess further how these experiences connect on a societal and planetary level. All of these activities were performed simultaneously, generating a substantial amount of material for further analysis.

Research outline: engaging with experts, engaging with end-users, understanding the environmental impact of Internet consumption
5.1. Expert Perspectives

I engaged with 6 product makers (product designers, developers, and managers working in tech companies) working with digital sustainability (through an active community on Slack channel ClimateAction.tech[26]) in various ways: through semi-structured interviews, informal coffee chats, group reading discussions, and post-movie-screening discussions that community offered.

Experts supported me in 3 different stages:

1. defining the Internet’s impact with Planetary Boundaries (Rockström, 2009) and Doughnut framework that brought more understanding of the complexity where environmental factors intertwine with societal needs;

2. mapping out the examples of various formats in which digital sustainability is being used and expressed;

3. sharing how digital sustainability is implemented in their daily practice;

5.2. Planetary Boundaries: Mapping out the digital impact

The concept of Planetary Boundaries defines the limits within which human civilization can operate safely in the Earth system, considering environmental and social factors.

The digital infrastructure consists of highly complex elements that push different boundaries, making it an ambiguous system.

Later on, I adjusted my strategy by including the Doughnut framework since it considers both ecological boundaries and social foundations. Eventually, Digital Tech Doughnut [27] was the most helpful in assessing the digital tech sector. Through interviews and open discussions with experts from Climateaction.tech I have learnt that the Internet’s impact is attributed to the following planetary boundaries:
- Chemical pollution, which arises from mining and manufacturing, particularly in the chip industry, as well as local pollution and illegal e-waste landfills.

- Freshwater use, where mining is the primary offender, but the chip industry is also very water-intensive, and some data centres also contribute to this issue.

- Biodiversity loss, which is caused by mining and land use by hyperscalers.

- The climate crisis stems from the electricity mix during the use phase. However, it is even more significant due to fossil fuel consumption during manufacturing and mining to support and power digital infrastructure and end-user devices.

At that stage, I found it quite challenging to distinguish aspects that relate more to e-waste and physical hardware from those related to software, which I was interested in. Since the climate crisis has somewhat clearer connection to networks, I would like to provide some examples of the impact that spans from social to ecological aspects, addressing this climate crisis boundary and Internet.

- **Data centers + CO2**: Burning fossil fuels to power data centres causes significant air pollution;

- **Consumerism + Climate Crisis**: Digital tech makes it easier for consumers to access goods and services (some of which are whimsical, e-commerce), the transport, creating additional pollution in urban areas.

- **Monopolized**: Digital communication networks are typically owned and controlled by private firms, not operated in the interests of the public good, worsening existing inequalities and exclusion.

In this mapping, I aimed to highlight elements that directly connect to the unconstrained growth of the digital realm. I separated the prominent problem of e-waste as "out of scope".

Considering their visible and invisible effects, I compared the social and ecological impacts. It is a subjective interpretation of how "tangible" and "abstract" these connections are. To analyse these impacts, I separated them into three groups: energy, networks, and extraction of raw materials.

Rough mapping showing societal and ecological impacts and their visibility in a public debate from my personal point of view.

From those, I highlighted "wasteful energy use", and "internet burning fossil fuels" to further map out strategies that my interviewees shared with me earlier on.
This mapping indicated that one of the potentially impactful areas is the connection of “wasteful energy use” and the “Internet powered by fossil fuels”. After this analysis, I reformulated environmentally-aware as energy-aware.

5.3. Mapping out the signals in the digital space

Mapping of current digital space - some solutions are directed towards companies and end-users. Some of them are coming from big tech companies, and some are coming from a grassroots level.

Interviews with 6 product makers involved in digital sustainability as practitioners through climateaction.tech community captures a macro and micro scale in which product makers are working with and sources of their inspiration. It led to gaining a clearer overview of existing solutions made in the area of digital sustainability, considering end-users, tech companies, and independent creators.
A big tech company like Google uses electricitymaps.com to schedule their computational efforts when renewable energy is available on the grid. Individual creators like Branch Magazine use the same energy-aware protocol to transform their websites automatically to the lower-energy mode in high carbon intensity.

Some companies invest in efficient, highly optimised, low-carbon websites; plenty of examples can be accessed through lowww.directory. Two interviewees mentioned using platforms that calculate the website’s carbon footprint and provide a list of optimization recommendations, such as Beacon.

Many digital applications are available on the market as a tool for end-users to track their carbon footprint. Nevertheless, they often exclude internet usage entirely from the equation. Some of them provide gamified experiences with badges and progress bars to incentivize and motivate to lower consumption, recommend possible changes, and find a way to compensate for carbon footprint through carbon off-setting.

- a plugin - checker for websites if they are hosted sustainably
- a plugin showing how sustainable Amazon purchases are
- motivating users to track carbon footprint in their daily lives and recommending possible changes
- Carbonalyzer that tracks network traffic and compares it to other metrics
- a card tracking all purchases and enabling users to offset their footprint
Among these paths, there are grassroot communities creating their own networks, such as Low-Tech Magazine[32], powered by a solar panel on a balcony in Barcelona, and Solar Protocol[33]- a web platform hosted through a network of solar-powered servers that are controlled by the logic of the sun using the sun's natural dynamics with the Earth and sometimes going offline in long periods of lack of sun.

Low-Tech Magazine shares its server's status information to communicate its dependency on weather transparently.

Solar Protocol shows the location of the server powering the digital platform - as the creators would say, “it is always sunny somewhere”.

5.4. **Digital sustainability inside tech companies**

The interviewees provided me with information about the status of digital sustainability in their companies. They reported a need for more tools for designing sustainable, low-impact digital products and that digital sustainability is relatively new and at its early stage. There is also a lack of examples of how energy-aware digital products could look like in more complex digital products than a website.

No total cost of computing has been made, and a potentially negative environmental impact of the digital realm is relatively unknown.

"Even if the website has a carbon footprint calculation included, it does not include the cost of e.g. video call meetings that lead to its creation or AI algorithms that were used to run it” (p01)

"We don't have a language to talk about it, or ways to see it.” (p03)

Lack of awareness of the Jevons paradox.

“Some product makers may focus efforts solely on code optimisation and efficiency thereby missing bigger questions around tech use and how it might be a never-ending optimization-consumption loop” (p04)

No tools or processes are established to assess digital products’ impact on the environment in companies.

"We do have processes for accessibility, privacy and a product lifecycle but not for digital products” (p01)
Outcome: I gained a deeper understanding that focusing on designers working in companies can add an unnecessary layer of complexity since this field is relatively novel. Therefore it is decided to be out of scope, although that is an exciting opportunity for others to seek. I assumed that if I took up the challenge of creating a tool for designers, I could get lost in the rabbit hole that is very data and metric-driven and engineering-heavy - I recognized that this might not be where design is the strongest. I sought another “hook” to situate the project within.

5.5. Carbonalyser experiment with end-users

I tested Carbonalyser mobile app with users and learn from their experiences. I engaged with 6 people from the age group 20-50 who used it for 5 days, and followed up with a conversation afterwards. Carbonalyser app allows the visualisation of the electricity consumption of Internet browsing. It compares it to various metrics, such as CO2, a car ride, equivalent of recharged mobiles for the amount of energy used.

Outcome:
This experiment brought a lot of interesting issues and tensions to the surface that are formulated in 9 user stories.

User stories

Carbon un-savviness: Carbon as a metric is difficult to relate to, it's considered as very abstract and ungraspable.
Relatable energy: Other metrics hold “more power” but are very subjective. The pattern was that people related the most to the “recharged mobile” metric since recharging is an act they do every day. Everything related to the body’s activity, like walking, running, and doing dishes, was easier to grasp than carbon.

Numb-anxious rollercoaster: Users of Carbonalyzer were gaining awareness of the issue, but that did not help them with feeling anxious about their footprint. They did not feel like just knowing data was actionable enough.

Confession time: Users reported interest in understanding 1. what kind of impact their “non-usage” would bring and what would it mean in a bigger system. 2. who is responsible for the high carbon footprint of their digital experiences, and which ones are the least sustainable to avoid them.

Community unite: People were interested in knowing how these little changes relate to the community, local neighbourhoods, and regions to gain a more nuanced understanding of both disparities toward nature and uneven distribution of the Internet.

Swimming in the system: “If I’m in Poland, my Internet is coal-powered non-stop, in comparison to Sweden, where it runs on renewables, it’s unfair - it taps on bigger issues of the energy transition. I’m willing to make positive changes, although I am still stuck in the particular system.”

Lost tangibility: Using networks doesn’t feel pollutive. On the contrary, “everything is swept under the rug” and distanced from its tangible consequences. “When I visit a heavy website, my laptop also breathes heavily; I wish I had this type of indication every time.”

Ho(t)listic take: There is an opportunity to think holistically about the energy in the situated context, beyond mobile, beyond an individual. “It is more than just a mobile - many other devices use networks. Just like more than one person is using a wifi router.”

Digital wellbeing: some users noticed how digital sustainability intertwines with digital wellbeing and how minimizing screen time to benefit mental health can be a form of activism towards a greener Internet, a win-win.
Reflection:

This material gave me much insight into how people relate to carbon as a metric and provided leading clues to how complex and nuanced the area of behavioural change is.

Thanks to this experiment, I understood that raising awareness might be only one of many strategies leading towards a sustainable change. I should take a step further beyond cognitive knowing.

Guiding principles

I grouped the user stories based on values they represent, such as transparency, traceability, adaptability, care and togetherness. I included them as guiding principles to further build upon.

- **Transparency and traceability:** How transparent and traceable are digital experiences to us? How much do we know about their societal and environmental impact? Would people behave differently if the digital realm was more transparent about the type of energy powering it and how resource-intensive it is?

- **Adaptability:** How can the internet be more sensitive and adaptable to the type of energy available on the grid? Which societal expectations towards the internet and technology would have to change to allow for such a transformation?

- **Care:** Which mechanisms of care can help us recognize the value of digital sustainability, and, by extension, environmental protection? What if the digital experiences we engage with daily make us care about their impact, motivating us to engage in a positive change or moderate digital consumption? Are there any negative consequences to caring?

- **Togetherness:** Could environmental efforts bring us together? Togetherness is often associated with feelings of warmth, comfort, and security. What if we could unite collectively to bring a change towards environmental sustainability?

Based on user stories, formulated principles, and other insights from the research, I created research cards that helped me to summarise the research and enter the concept phase with actionable areas for further exploration.
Design opportunities

💡 Digital experiences to become more transparent
→ Visualising the relation of consumption of digital and energy usage, and extraction of resources;
→ Embedding information about the impact of digital services in a more relatable, contextual, preferably "non-carbon", non-data driven format;

💡 Digital experiences to be more energy minimal
→ Creating a low-energy version without compromising the experience;
→ Adaptable and transformable to the type of energy on the grid;
→ Challenging environmental dark patterns such as infinite scroll and autoplay videos with slower and mindful alternatives;

💡 Digital experiences to encourage to conserve rather than to consume
→ Supporting people in adapting to the quirkiness of the Internet;
→ Nudge people into attractive low-data alternatives;
→ Help people adapt to the time with green energy;

At the end of the research phase, it became clear, that addressing end-users can be more fruitful and actionable, bringing relevant examples and exploring a bigger range of areas of interest. Furthermore, I decided to address all design opportunities mentioned above and apply them in the context of the typical, daily usage of digital platforms.

How to design environmentally aware digital experiences that reflect ecological limits?

How a resource-saving, energy-aware Internet that enables, and
empowers people may look like?

6. Design Exploration

In this section, I describe activities performed in the design exploration phase. I executed additional research on renewable energy transitions and alternative internet formats to create speculative scenarios and build context for early concepts, which were later tested with users. Three concept directions were formulated based on features from sacrificial concepts.

6.1. Exploration of Internet alternatives

As the research phase ended with questions related to energy-awareness and resource-saving, I needed to expand my knowledge of concepts and movements related to alternative approaches to computing and network technology. The goal was to examine how these alternative approaches could inform the project.

**Half-Earth Socialism Game and Energy Transitions**

This online simulation game is based on a book under the same name “Half Earth Socialism” [34](Vettesse and Pendergrass, 2022). It educates players about the concept of Half-Earth, which proposes designating half of the Earth's land and sea as protected areas for the preservation of biodiversity. The game allows players to experience the challenges of a potential green energy transition and its consequences if it is too rapid. The game covered a wide range of topics, including electricity, agriculture, food, research, infrastructure, and policies, which is a fantastic foundation for creating future scenarios.

![Snapshot from the game “Half-Earth Socialism” which enables us to experience a variety of socio-economic problems related to the climate crisis in the next 60 years.](image)

6.2. Sacrificial Concepts
The activities mentioned above provided me with information and inspiration to develop three scenarios that serve as a foundation for more contextualised and grounded sacrificial concepts.

The first scenario paints a vision of the Internet running solely on renewable energy and being fully weather-dependent, therefore intermittent. It is unavailable in periods with no sun and wind and there is a seasonal pattern to its availability based on location.

The second scenario imagines energy-aware and transformable Internet, actively aligning with the clean energy available on the grid, which means it dynamically changes its functionalities and appearance if the energy shifts. It moves, shrinks and expands, almost organically.

The third scenario envisions digital experiences that are fully transparent about their ecological impact. It opens up to the economy that includes the cost of negative externalities associated with goods and services.

Representation of various concepts that were created in the concept phase.
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Reflection:

All users were consistent about how it brought awareness and appreciated how the information gets delivered since it **disturbs the consumption process and creates friction**, unlike cigarette ads that bring awareness without making the smoking process more difficult. However, it can be perceived as a form of **punishment** since it is directed towards the users of the platform. It reminds people of activist protests, targeting the general public unsure how to make the change.

👀 User’s feedback:

"After seeing it, I would like to know more about it, and why is this happening. It makes me stop and have a moment of reflection." (p07)

"I would want to be **reminded of that over time** - let it be every month. People forget so easily. It’s difficult to change behaviour and it wouldn’t change mine - I just feel like I would like to know more after seeing it but not enough to change my old ways." (p09)

Carbon Glitch visualizes a speculative scenario in which pollutive, wasteful platforms can be “hacked” by citizens and the platform’s carbon footprint can be expressed in various, emotion-evoking ways that are not data-driven. After using the carbon limit it gets more difficult to scroll, the interface glitches, pixelates, or a dark carbon cloud comes to disturb the process of browsing.

Digital Passport is a widget that provides users with a tool to learn more about digital platforms, and it traces their total cost, including energy-heavy AI algorithms used to run it, amount and location of data centres, servers and other elements of digital infrastructure. Swipeable pages focus on various facets of this system.

Reflection:
The opinions provided by users made it clear that a data-driven dashboard is more suitable for people that need detailed information for specific purposes. Users find it difficult to relate to numbers, and it is overwhelming to make sense of it so it is not easily usable or acted upon. However, it would be potentially interesting for digital designers working in companies to expand their knowledge on the topic.

👀 User’s feedback:

“It depends on what I can do with this knowledge. I like it as an option but this is a lot of numbers and I don't know a lot about it. I need a lot of knowledge to make an active use of it. As a user, I want my life plain and simple, and have recommendations on what platforms to choose based on that.” (p07)

“It reminds me of a journalist investigation, it could be useful for a collective analysis and reflection - do we need Tiktok, do we need Instagram knowing how resource and energy heavy they are?” (p10)

 UserRepository: Truth-teller is part of an onboarding experience - it guides users through the phone's components, uncovering the environmental and human impact of its sourcing, manufacturing, and recycling. By highlighting the preciousness of these materials and their negative effects on local ecosystems and labour, the app aims to raise awareness and educate users about the importance of responsible consumption. Additionally, it gives suggestions on how to keep the phone as long as possible and uncovers the planned obsolescence of its parts.

Reflections:

Based on several emotional responses, I can clearly state that I underestimated the effect of bringing difficult, emotionally loaded topics not in a timely manner. Users did not find it actionable enough to feel empowered. It might be due to the flow of user experience, that shows a “flashy” ecological damage first and actionable suggestion afterwards.

👀 User’s feedback:

“It's important to tell hopeful stories, so I would appreciate if I had the power to stop it, prevent it or leverage it. I find it even more grim because it tells a story about the phone that I just purchased. It's a dark onboarding experience, it makes me feel bad. What is actionable is to know how to make this phone invincible, repairable, environmentally-aware and conscious.” (p10)

“I like how it is a part of onboarding, and it welcomes you by allowing going inside of your phone, like an X-ray scan.” (p09)

“It's very bold, although, the conditions of people working in lithium mines, or recycling e-waste is so devastating that even hearing about it makes people bad, and then, numb.” (p08)

“It's a one-time experience, it's easy to forget about it - how can it be prolonged? What if it can span across all electronic devices?” (p10)
Reflections:

Users were given two concepts, each applied in slightly different contexts to uncover underlying patterns about the nature of agency. The first one does not allow the user to choose whether they can continue using the service. The second one, informs the user about the type of energy on the grid and presents the possibility of continuing to use the service, however, it's delivered in a guilt-inducing manner.

Overall, having the freedom to make a final decision as well as a clear recommendation on what is a better option is appreciated.

**User’s feedback:**

1. *Spotify’s Green mode*

   “I like this one a lot. I don’t have to make the decision, it just happens and it’s a good decision.” (p07)

   “I still want to have a choice to go into the normal mode, depending on the situation.” (p08)

2. *Dirty Google search*

   “I want to be environmentally friendly but I still want to have a choice, a wiggle room. I prefer to have a choice, that’s the best motivator.” (p10)

   “I have many strong emotions. I would live with the guilt every day if I knew that I’m using fossil fuel-powered Internet.” (p09)

   “There’s something about the green icon that would enable me to consume like crazy. I would not tame myself, which does not contribute to lowering my overall consumption.” (p09)
Reflections:

The proposals transform video streaming services and social media, offering in return a slower, more mindful version that opens up a possibility to still engage with platforms even in times when the network connection is slow.

The opinions were polarised - some users would not succumb to lower quality of the video - “there are certain things I can’t compromise - a high-quality video of a beautiful movie - and would rather postpone the whole experience”. In overall, these ideas have been perceived as unnecessary friction, not as an element of resilience and adaptation to slower networks.

User’s feedback:

“This is very rebellious, in a way, undermining the purpose of these platforms - no one would agree to do that.” (p10)

“That’s a lot of friction, and perhaps it’s even more time-consuming. In overall, it’s a teachable moment and it makes me more aware, although as a consequence it would completely change my current experience.” (p09)

“I love the idea of having something playful as compensation like a dinosaur game when the Internet is unavailable. Lovely low-tech fun.” (p06)

“It would be nice to know how much energy I saved while using the energy-saving option” (p10)
Reflections:

This is the most “extreme” example of platforms going completely offline when renewable energy is simply not available at the location. The comments differ. Some testers were excited about the possibility of having a “clear cut” with social media apps that are being over-consumed by them. The idea of not having an internet connection in the evenings was speculated to contribute positively to mental well-being. Positive reconnection with the environment and its cycles was also raised as a consequence of aligning with renewable energy.

On the other hand, lack of availability of certain services at times could lead to a lot of frustration, and fear - especially in the context of being “on the go”, travelling where connection was valued. Unlike, the home environment, where potential disruptions could have been dealt with more coping mechanisms were available.

User’s feedback:

“Aligning online activities with renewable energy helps me understand the local environment and how it's connected to the energy system. It builds an emotional and perhaps more meaningful connection to nature” (p07)

“I would feel frustrated but that's a good thing - we are used to super fast, always available resources - and that's an exploitative mindset. In the end, it contributes positively to curbing carbon emissions, I would just move to another thing that I'm interested in.” (p09)

“I would feel peaceful if I'm unable to access certain services after dusk - it would give me more mental space.” (p08)

“We are comfortable creatures, therefore I might feel resentful of nature. Nature is, once again, ruler and an inhibitor.” (p10)

“I would hate it if I couldn't watch Netflix on a rainy day - but if I can prepare for it - I can see myself living this lifestyle.” (p08)
Learnings:

1. **Willingness to reschedule**: People are willing to reschedule entertainment for another time (perhaps to the time with clean energy). Entertainment was considered as a luxury experience that can be negotiated.

2. **Heavy data available on demand**: Environmental impact of computing should not be ignored, nevertheless these heavy topics should have its time and space, and be on demand, as one of the users mentioned: “heavy data is a party pooper, in a world where we are bombarded with dramatic news, it can bring even more anxiety and be ineffective”.

3. **Internet should be treated like a garden**: The paradigm of always-available, always-reliable Internet is possible due to fossil fuel energy used to power it. What if this paradigm changes, and we treat it like a garden, with more acceptance and care to its imperfections and quirikness? That might be one of the ways to deal with energy transition at a scale, not only in the context of Internet.

4. **Giving a point of action**: Users considered points of action as essential to not only change behaviours, but to paint a picture of hope that an action is possible, and can be performed to contribute to greener Internet.

5. **Show the collective impact**: Again (as the same pattern emerged from the initial research), users are interested in learning more about their collective contribution to greener Internet, and what kind of impact their change brings. Intuitively, I presume that it can be a tricky and complex area to deal with.

6. **Together = Energy-saving**: The intriguing idea of a shared broadcast culture emerged - it is a signal for me that there are activities that can be done together, collectively, both in the spirit of togetherness and in order to lower the usage of resources and bringing communities together.

7. **Lack of lived experience**: Users wondered how would it feel to bring these experiences into a multitude of their lived, nuanced experiences and how would it influence them in a long run.

8. **Try me at home**: There was a clear indication that people are more willing to challenge their Internet consumption at home, hence its considered a more predictable, safe place in comparison to being outside, “on the go”.

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**Digital Vegan**: it’s a feature that supports users in limiting their digital consumption. They need to choose their carbon footprint limit and drag the social media app of their choice to the bowl. Based on that Digital Vegan calculates how long the services can be used based on how carbon-heavy they are. Users can influence the priority of services and negotiate. Note: Not tested.
6.3. Mapping out the Sacrificial Concepts

I grouped the concepts based on values explored to further analyse this content based on categories such as "knowing", "acting", and "caring". I was inspired by A Baltic Sea Lab [35](Lohmann, 2020) that mapped out three pillars of ocean literacy:

1. **Acting**: refers to active participation and agency. It's about feeling empowered, being able to participate and be a part of the network, having the capacity and daring to engage.
Caring: refers to the act of empathy and emotional and embodied connection. It activates mechanisms of care, and love for the world with words, or actions.

Knowing: involves concepts that touch upon the more analytical side. It brings awareness of ecological and social issues, and seeks to understand complexity.

Ideally, the final concept should include all three elements, but some may be prioritised over others, like rungs on a ladder.

I analysed the material from various perspectives - I have noticed that concepts worked on varied levels of engagement - some of them only built awareness without giving a point of how to act upon them, and some of them presented a new norm that required or nudged towards a behavioural change. Part of them engaged individuals, and some of them were activating communities. Based on that, I was able to crystallise three different concepts. Since they take up a very different place in this mapping, they are indeed, spread out in their scope - I aimed to have diverse concepts.
6.4. Concept Directions

Three main concepts were created based on sacrificial concepts.

Concept 1: **Green Low**

is an eco-friendly operating system that adjusts its functions according to the type of energy available on the grid. It tells the user what kind of energy is being used and predicts when the connection may be weaker due to the use of non-renewable energy sources. The system offers a slower and more thoughtful version of current digital experiences without sacrificing the overall experience.
Concept 2: Caretakerist

is an activist guerilla project the purpose is to hijack electronic parcels and leave a QR code on the packaging, if interacted with, leads people to a mobile app, that infiltrates the components of the device and gives an estimate of how “livable” and durable the parts are and how to take action to take care of them to extend their lifespan. It recommends where to repair phones locally, action against companies that value profit over humanity's well-being, giving tools to individuals that want to go against consumerism on a grassroots level, and accelerating systemic change within companies.

Concept 3: Green Hacktivism

is an initiative bringing together tech creatives, environmental activists, and concerned citizens worldwide to address the Internet's environmental impact.

By fostering an open and inclusive community where participants can share their ideas and experiences, Green Hacktivism seeks to raise awareness of the urgent need to act more sustainably on the web and to promote a more environmentally conscious approach to digital technology. In addition to education, Green Hacktivism also promotes a range of proactive strategies for addressing the problem. These include advocating for legal changes that support more sustainable practices, supporting companies that prioritize environmental concerns, and boycotting or even hacking platforms that fail to take their environmental responsibilities seriously. By harnessing the collective power of its members, Green Hacktivism enforces real change and make a meaningful contribution to the fight against climate change.

Why Green Low?

The first concept provides a solid foundation for further exploration but remains open about its functional features which makes it, from a personal point of view, the most thrilling.

It stands out from other concepts in several ways. Firstly, it offers a relatively passive engagement with a low threshold to enter. As it comes as a default to the end-user, it is not an external app but an inherent part of the system.

Secondly, it showcases how bold companies can be in their pro-environmental strategies and user engagement makes a strong argument for companies to be encouraged in their decisions.

The only aspect missing from the initial formulation of the concept was community engagement. Insights from both phases highlighted the use and importance of the community, rather than just an individual making changes alone. In this situation, an individual with a mobile phone is essentially acting alone. I aimed to shift the concept in this direction and explore better ways to involve the community.

7. Concept Development

7.1. Finding joy in scarcity

Right after the concept presentation, I had a conversation with a designer, who suggested using joy as a design quality, as a result influencing the process significantly.

"What if sustainability is the foundation, but joy and playfulness are the driving force? What if people engage with it because it's fun and improves their lives, not just because it's the right thing to do from an environmental standpoint?" - feedback from Matteo

How can people align their online activities with renewable energy in a spirit of joy?

Enacting large-scale and sustainable change involves various strategies that can be rooted in both fear and love. After reading more about fear-based strategies, I realised how I have unconsciously repeated these patterns in my own concepts, eliciting anxiety and guilt. Since this is a widely applied practice on a societal level, as I will prove below, it comes naturally to mind. This is based on work done by Daniel's Parnitzke as a part of a Master Thesis “Finding Pleasure in Scarcity” from 2020[36], which can be found on his solar-powered website.
From this point of the project, the objective is to explore ways in which people can perceive the experience of alignment with renewable energy, with its temporal disruption, not as a problem but as an opportunity that can potentially bring joy - a step forward, not backward.

7.2. Survey - finding joy at home
I conducted a survey with twenty users, asking what brings them joy on a daily basis in the context of their homes. I received many endearing responses.

I had two objectives:

1. finding activities that can be a meaningful alternative to digital consumption;
2. reflecting on how the experience of alignment with green energy can elicit the same joy as one of the participants mentioned: “sitting on a terrace and listening to the birds chirping”.

Sustainable change action can be rooted both in fear and love.

How to elicit joy in this context of change and find joy in scarcity?
I invited three student designers from school to attend a co-creation workshop on creating “joyful user journeys” to widen up the various context in which the experience of alignment with green energy can reside.

I had two objectives:

1. to create joyful strategies recipe through a shared discussion;
2. to generate a best-case user journeys in a context of Internet disruption;

I used a "cleaning a messy room" analogy to the action of alignment with green energy on the grid, assuming that users can perceive the alignment itself as a chore or an act of activism that requires negotiation. I believed this negotiation could elicit, in this particular case - joy instead of being an unpleasant duty, and I wanted to explore how it could be expressed.

I asked participants to reflect on how someone would have to behave in order to convince them to clean their messy room. Based on their responses, we constructed joyful strategies to be used later for creating user journeys.

**Reflection:**

As I reflect on the workshop, I realise how cognitively demanding it was and how much imagination it required from participants to engage with it in a meaningful way, hence it was based on thinking about the joy, not necessarily experiencing it and actively reacting to it.
7.4. Co-creation workshop: tangible artefacts

I invited three designers from school to attend a co-creation workshop focused on sketching tangible interactions. The aim was to generate various concepts that would elicit joy as a consequence of use, or encounter, which can later be translated into a digital format as a functionality within the operating system.

Outcome of the workshop: 5 speculative artefacts.

- **Expressive Forecaster**
  The collection of objects that light up, move, and make a sound when green energy comes to the grid notifying a person in an ambient, unobtrusive way.

- **Wheel of Fortune**
  The wheel of fortune is an interactive board with tokens, and each token represents a different offline activity - but what would that be...
is a surprise eliciting joy.

- **Portable Energy Harvester**
  Is a device that is backup for moments of no energy, enhancing a feeling of safety. It is powered by the activity of a human body.

- **Solar Slider**
  Slider is a part of the mobile device's cover and can be used to adjust the quality of the consumed content to save energy giving a sense of agency.

- **Energy-exchange wand**
  Enables users to negotiate energy usage around the house, for example, exchanging one hour of the light source for the usage of a music speaker, giving a sense of agency.

### 8. Result - Glow OS

#### 8.1. The list of functional features

The outcome of this project is **Glow OS**, a part of an operating system that enables users to align online activities with a local energy grid. This way, they can schedule their digital consumption during times with abundant renewable energy and minimise it when fossil fuel energy is present.

**Glow OS** offers three main functionalities, which cover the most typical online activities: connect (video calls, chats), entertainment (social media, streaming services), and other basic functionalities, all designed in an energy-efficient version. Additionally, it offers a preparation experience that allows users to download desired content before the forecasted change in energy source supply.

Eight different feature touchpoints have been designed:

*Feature 1: Dynamic alignment*
Dynamic alignment is a feature that allows people to synchronise their networks with the available energy on the grid. This results in an adaptive, transformable interface that makes use of natural cycles of abundance and scarcity.

By default, the experience is unrestricted, but consumption is not encouraged by design. The functionalities are still present, but they are network-adaptive, meaning that they change their format without altering the content.

The alignment is the core of the concept and every feature is a result of it.

*Feature 2: Green forecast*
This feature informs the user about the current status of the energy grid and provides estimated predictions of future conditions if fossil fuel energy exceeds a certain threshold in the energy mix. It serves two functions:

1. educating the user and fostering a deeper understanding and relationship with energy, and
2. building resilience for potential scenarios where reliance on renewable sources may be a necessity.
Feature 2: cards showcasing what powers the Internet at the moment and forecasting the future.

Feature 3: Community connect

This feature enables users to connect with the community of local “aligners” in short messages that use peer-to-peer protocols and bluetooth connection for sending messages. This feature is only available in fossil fuel time as an added value and a form of a “treat” for this time but also for building resilient communities of care.

Feature 3: a messaging experience utilising short distance connections working without wifi.

Feature 4: Low-energy presence

In the fossil fuel time, the video-calling experience transforms into an audio-call with an interactive expression of presence, where both parties can draw shapes with their fingers.

Feature 4: a video-call transforming into an audio-call with a glowing sense of presence.
Feature 5: **Smart Prepare**
This feature allows users to prepare content when they have access to solar power, and enjoy it later when fossil fuel energy is present again. It is available only when solar energy is on the grid.

Feature 6: **Offline Wheel of Fortune**
Used in the time with fossil fuel to inspire the user to perform a meaningful activity offline.

Feature 7: **A meadow**
A digital garden grows, with one new flower blooming every day using Glow OS.

Feature 8: **Solar Slider**

Feature 5: allow users to download feed, articles, shows, posts, and videos to be consumed later.

Feature 6: user spins the wheel to get a suggestion of offline activity of their choice.

Feature 7: gamification element appearing every morning to greet a user and express gratitude for their positive actions.
This feature allows the user to temporarily use non-renewable energy in an emergency situation without exiting the mode. To use “dirty energy”, slide down, and to return to the “green” energy-efficient mode, slide up.

9. Reflections

Top down bottom up: focus group in a highly systemic problem area

The positioning of the focus group for this project was an ongoing discussion. From the start of the project, I was internally conflicted about choosing end-users as a focus group. On one hand, I strongly believe that digital experiences should be environmentally friendly by default, and it is the product maker’s responsibility to ensure this. In this scenario, users would engage with digital experiences without requiring any effort, thereby decoupling awareness from actions. Consequently, users would consume effortlessly, but inherently more sustainably. However, I have learned about Jevons paradox, which suggests that energy efficiency should be accompanied by changes in behaviour, or else it becomes a never-ending cycle.

I addressed the issue through an operating system that, in my opinion, occupies a unique position of being “in between”. On one hand, it is imagined to be developed by a big tech company that prioritises the planet and people over profit. On the other hand, the system is user-facing, the user decide whether to engage with it, but if they do - it serves as a solid argument for companies to continue those better, more sustainable practices. Asking people to change in a system that is designed to encourage certain behaviours can be difficult. However, I see working on an operating system level as an optimal leverage point, which does not mean that product companies should not act on their own, within their own design space.
Grey energy → green energy: renewable energy comes with an environmental cost

It is worth noting that I did not address the environmental costs of transitioning to renewable sources of energy in this project. Although it is important to acknowledge that the long-term benefits of renewable energy sources significantly outweigh the costs. Furthermore, renewable energy sources can reduce our dependence on finite resources, such as fossil fuels, which are becoming increasingly scarce and expensive to extract. To ensure a just transition to renewables is out of scope for this project - nevertheless, I hope, it is clearly communicated, that the just transition must be done through decreased consumption of those who consume without limits.

Using humour as a way to cope with a difficult subject

Reflecting on the starting point of this project, I recognize how emotionally charged the topic of sustainability can be for myself and others. It is understandable to feel alarmed when deepening one's knowledge on the climate crisis. However, I quickly realised that as a designer, my most powerful tool (especially in this short-term, individual project) is to materialise a positive and optimistic vision to collectively look forward to. By keeping it light-hearted and stepping away from a grim, data-driven attitude, solutionist approach, and listening carefully to how users feel, I trust that I have explored this topic from an angle that leads to more actionable results, and humour potentially encouraged participants and mentors to stay within the process.

Expanding energy-aware digital experiences to the energy-aware household

While the scope of this project remained limited to digital sustainability, there is potential to expand the same principles to the entire household and its (many) electronic devices and enhance the positive impact of the act of alignment. I believe that the research areas of energy-efficient households and digital sustainability can benefit from one another. Not to mention, the users of electric chargers that have developed an advanced mental model of energy grid status that is incentivized by financial profit (renewable energy is cheaper).

Simplified complications: energy systems are nuanced

In order to work with energy awareness, I had to simplify the topic in some ways, although this flattens out the complexities. This was necessary to move forward in a short time span. Energy systems are complex and dynamic, often using a mix of different sources of energy at the same time (not Sweden, but UK and Germany for sure). I am presenting a system that is dynamically aligned, but it does not take into consideration situations where there is a 50-50 split of coal and wind energy on the grid. Developing the necessary assumptions and thresholds to be fair in these situations would be an interesting UX design challenge.

Joy as a design quality

I found it difficult to elicit joy and use it as a design quality. Although I believe I have successfully avoided incorporating strategies of fear into my design proposition, it does not necessarily result in a joyful experience - it is much more complex than that. There is a vast amount of untapped potential that I think is worth exploring using more experiential methods to gain a more nuanced understanding.

The question I was getting from my mentor was: how these functional features make people feel? The other feedback I received was to be explicit about the plurality of qualities that go beyond joy. I am going to be more explicit below.
Scattered, investigative and hands-on process

Using sacrificial prototypes proved effective in this process, given the vast and relatively unexplored area of digital sustainability. Through visualisation and communication of concepts with participants, I gained crucial insights early on in the process and mapped out ways in which digital sustainability can be expressed. Although speculative in nature, the user-centered approach is at the core, as it all begins and ends with people interacting with things.

Prototyping early on gave me more confidence in applying these ideas and readings in action, especially after the research phase when I realised the complexity of the Internet's infrastructure itself. However, I still feel like I have only scratched the surface.

Resilience and slower networks

This project proposes the redistribution of energy-heavy online activities to times when solar energy is abundant. When renewable energy is scarce, these activities will transform into an energy-low version. However, it is not simply a simplified version of the original experience; it has its own unique qualities and value. This approach addresses situations where the Internet is disrupted due to a lack of digital infrastructure or unforeseen events that cause the Internet to go down, such as natural disasters or war.

10. Conclusions

In this project, I propose Glow OS, an operating system designed for personal internet use that considers both planetary and user needs. The Glow OS empowers users to align their online activities with renewable energy on the grid, optimising energy consumption during periods of abundance and scarcity. By harnessing the power of natural intelligence and embracing cycles of energy availability, the Glow OS focuses on two typical internet use cases: entertainment and social connection, without compromising their functionalities.

The first priority of Glow OS is to synchronise with the availability of clean energy, ensuring that users can shift their energy consumption to the time with abundant solar energy. This system also provides valuable insights into the origin of the energy being utilized, fostering solar literacy and nurturing a deeper connection between users and the energy system. Ultimately, this enhanced awareness facilitates a more rapid and comprehensive transition toward widespread adoption of renewable energy sources on a systemic level. The second priority is minimising energy consumption by not encouraging it. Glow OS is presented as a minimal interface.
The system emphasises **joy** as a design quality by giving the user agency at all times. This allows them to switch back to non-Glow OS mode whenever necessary. In an emergency, users can also use fossil fuel energy. The goal is to make the system more usable over time by avoiding excessive strictness or rigidity. It provides a weather forecast that enables users to prepare for times when fossil fuel is on the grid, and suggests alternative offline activities during these times.

The Glow OS holds a potential for transformative impact in several key areas:

1. **Energy Resilience**: By preparing individuals for potential energy disruptions, the Glow OS enhances energy resilience while ensuring an enjoyable user experience.
2. **Incentivizing Sustainable Practices**: The Glow OS integrates sustainable practices into users’ daily lives, transforming them into lived experiences and encouraging their widespread adoption.
3. **Empowering Renewable Energy Use**: By granting users agency over their energy sources, the Glow OS incentivizes the use of renewable energy and provides an entry point into the broader energy system.
4. **Fostering Community Participation**: The Glow OS promotes community engagement and awareness, facilitating a deeper understanding of the nuances of local energy systems.
5. **Cultivating Meaningful Relationships**: Glow OS nurtures a profound connection between individuals and the energy system itself, leading to more meaningful relationships with it.

This project has explored the topic of digital sustainability from various angles. It has examined what digital consumption and digital carbon footprint mean to people and how it can be addressed. To explore this, I have infused sacrificial concepts with values such as transparency, care, or togetherness. By using user-centred and speculative methods, I defined a design space by devising different design principles. Workshops with designers helped establish various strategies to evoke joy as a design quality.

Sharing Glow OS can benefit the interaction design community by providing examples of how to incorporate digital sustainability into their practice and inspiring them to do so. I hope, this can lead to creating new tangible and digital examples of how slower, more mindful and energy-minimal designs and interactions can emerge, expanding the understanding of how to **design within limits**.

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Thank you to all the angry blog writers using their frustration to write beautifully about digital sustainability and degrowth, these inspirational pieces made me move forward, and a bit less lonely in this research area that deeply questions our current practices.

To my fellow students at UID who may read this report, I have one piece of advice that others have given and that has worked for me like a charm when presenting or just doing design: **don't forget to have fun**.

**References**


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**Appendix**

- **Create energy minimal digital experiences**
  - Opportunities
    - Creating low-energy version without compromising the experience
    - Adaptable and transformable to the type of energy on the grid
    - Challenging environmental dark patterns such as endless feed and autoplay videos with slower and mindful alternatives

- **Create transparency about the ecological impact of digital experiences**
  - Opportunities
    - Visualizing the relation of consumption of digital and energy usage, exhaustion of natural resources
    - Enabling interaction about the impact of digital energies in sustainably, meaningfully, preferably “non-carbon” format

- **Encourage to conserve rather than to consume**
  - Opportunities
    - Helping people think in terms of what they consume rather than what they get
    - Reduce people’s desire for the information they don’t need
    - Help people see that it is not a matter of using more

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