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Towards Sustainable Web Design: Incorporating Eco-Friendly Guidelines in UX

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List of Abbreviations

3DUX	Data-Driven UX Design
AI	Artificial Intelligence
AWS	Amazon Web Services
CD	Continuous deployment
CI	Continuous integration
CO ₂	Carbon Dioxide
CO2.js	Open Source JavaScript library for carbon accounting
CPU	Central Processing Unit
CSS	Cascading Style Sheet
DSRM	Design Science Research Methodology
ESG	Environmental, Social- and Governance
GHG	Greenhouse Gas
GPU	Graphics Processing Unit
GRI	Global Reporting Initiative
HCD	Human Centered Design
HCD+	Humanity Centered Design
HCI	Human-Computer Interaction
HIPPO	Highest Paid Person's Opinion
ICT	Information and Communication Technology
IPCC	Intergovernmental Panel on Climate Change
ISO 14001	International Standard for Environmental Management Systems
ISO 9241-11:2018	International Standard for Ergonomics (Usability)
ISO 9241-210:2019	International Standard for Human-Centered Design Processes
KI	Künstliche Intelligenz
KPI	Key Performance Indicators
RACI	Responsible, Accountable, Consulted, Informed
RAM	Random Access Memory
ROI	Return on Investment
SDG	Sustainable Development Goals
SEO	Search Engine Optimization
SWDM	Sustainable Web Design Model
SWM	Sustainable Web Manifesto
UCD	User Centered Design
UI	User Interface

UX	User Experience
W3C	World Wide Web Consortium
WCAG	Web Content Accessibility Guidelines
WSG	Web Sustainability Guidelines

1. Introduction

The growing presence of websites and digital platforms has sparked critical questions regarding their impact on our planet and society. Designers, who traditionally focus on user satisfaction, increasingly face the challenge of reconciling user needs with environmental responsibility and ethical considerations. Indeed, the idea that design can inadvertently cause ecological harm resonates with a cautionary observation made by Don Norman:

“Why are designers designing stuff that destroys the environment in its making...”¹

This remark underscores the tension between conventional design practices and the urgent need to adopt more eco-friendly approaches.

The potential for small technical changes to yield disproportionately large benefits further highlights why sustainability merits a central place in user experience (UX) design. A vivid example comes from Danny van Kooten, who remarked:

“Just last week I reduced global emissions by an estimated 59.000 kg CO₂ per month by removing a 20 kB JavaScript dependency in Mailchimp for WordPress. There's no way I can have that kind of effect in other areas of my life.”²

This reflects how seemingly minor alterations—like optimizing file sizes—can have a meaningful cumulative influence on worldwide carbon output, especially when scaled across numerous digital products.

Recent studies indicate that as digital services grow rapidly, concerns over energy consumption, data-center operations, and electronic waste have intensified, reinforcing the need for sustainability in UX.³ By designing and coding with efficiency in mind—such as reducing data transfers or streamlining code—designers can mitigate the environmental impact of websites and applications.⁴ Likewise, integrating accessibility and socially inclusive features helps accommodate a wide demographic, thereby reducing resource-heavy rework cycles and ensuring that digital offerings remain both user-friendly and eco-responsible.

Adopting a more holistic approach to design demands that professionals and stakeholders address technical, aesthetic, and moral considerations at every stage of the process. These

¹ Interaction Design Foundation – UX Design Courses 2021: Sustainable Design - Design for the 21st Century with Don Norman

² Danny van Kooten 2020: CO₂ emissions on the web

³ see Freitag et al. 2021: The real climate and transformative impact of ICT, pp. 2–4

⁴ see Olson-Royal 2023: Web Performance Optimization and Sustainability

include choosing energy-efficient hosting solutions, employing data-light design elements, and rethinking performance metrics to accommodate environmental criteria. As part of this integrative perspective, it is crucial to involve all relevant teams—management, developers, marketers, and designers—in early discussions of sustainability goals.⁵ By doing so, organizations can reconcile profitability and convenience with a commitment to preserving ecological systems.

1.1 Primary Objective

The primary objective of this study is to investigate how sustainability guidelines can be integrated into the UX design process to create environmentally friendly and sustainable websites. The study aims to explore how incorporating these guidelines can contribute to reducing the environmental footprint of web-based platforms and identify practical strategies for UX designers to adopt more sustainable practices. By analyzing current methodologies and identifying best practices, the research intends to offer concrete recommendations for embedding sustainability considerations into UX workflows. This leads to the central research question of this thesis:

How can sustainability guidelines be effectively integrated into the UX design process to develop more sustainable websites?

1.2 Secondary Objectives:

Three secondary questions support the main research question:

- What existing sustainability guidelines are currently utilized in web design, and how effective are they within the UX design process?
- What gaps or opportunities exist within current sustainability guidelines for web design, and how can new or enhanced guidelines address these areas?
- What are the key components of a practical implementation framework that enables designers to incorporate sustainability guidelines throughout the website design lifecycle?

⁵ see Norman 2025: Interview with Don Norman

2 Methodology

This thesis follows a modified IMRAD (Introduction, Method, Results, and Discussion) structure, tailored to the Design Science Research Methodology (DSRM) and adapted to meet its specific requirements. The structure includes an Introduction, Method, Literature Review, Problem and Requirements, Artefact, Discussion, and Conclusion.⁶

2.1 Design Science Research

DSRM was chosen for its problem-solution focus, which supports the development of a practical framework. It emphasizes creating testable artefacts, iterative refinement, and bridging theory with practice, ensuring the framework is both applicable and academically grounded. The methodology also supports measurability, aiding in validating its impact on digital sustainability. While evaluation typically forms a component of DSRM studies, it has been omitted from this thesis due to time and length constraints.

Design science research represents "the scientific study and creation of artefacts as they are developed and used by people with the goal of solving problems of general interest".⁷ This methodology is fundamentally concerned with addressing practical problems, defined as "a gap between the current state and a desirable state". Within this paradigm, an artefact serves as a supportive mechanism for individuals when they encounter challenges in various practices.⁸

2.2 Design Science Research Method Framework

DSRM comprises five core activities forming an iterative, non-sequential process. These activities are characterized by input-output relationships rather than following a strict temporal order. A critical feature of this framework is that all activities and outcomes must be connected to an existing knowledge base of theories, models, and prior artefacts.⁹

Its five activities are explicate problem, define requirement, design and develop, demonstrate and evaluate.

The first activity focuses on investigating and analyzing a practical problem to establish its significance and general.¹⁰ This process involves several key sub-activities.

A clear and narrowly interpreted problem definition must be formulated to ensure a common understanding among all stakeholders. This definition process should involve multiple

⁶ see Johannesson/Perjons 2014: An Introduction to Design Science, pp. 153–154

⁷ Johannesson/Perjons 2014: An Introduction to Design Science, p. 7

⁸ see Johannesson/Perjons 2014: An Introduction to Design Science, pp. 2–3

⁹ see Johannesson/Perjons 2014: An Introduction to Design Science, pp. 76–79

¹⁰ see Johannesson/Perjons 2014: An Introduction to Design Science, p. 76

stakeholder groups such as managers, employees, and customers to deepen and complete the problem analysis. The problem must be contextualized by describing its practice environment, stakeholders, and activities. Additionally, researchers must justify why the problem is important and challenging.¹¹ A root cause analysis should be performed to uncover underlying issues beyond mere symptoms. These underlying issues might include information deficiencies, inadequate incentives, or unclear responsibilities.¹²

Guidelines for this activity include clearly positioning and precisely formulating the problem, justifying its importance, ensuring it is of general interest and solvable, specifying literature and stakeholder sources, and documenting the explication process.¹³

The second activity involves outlining the artefact and defining its requirements.

Researchers must choose the appropriate artefact type—construct, model, method, or instantiation and provide an overview description.¹⁴

Detailed functional and non-functional requirements must be collected from stakeholders. These requirements should address specific root causes identified in the first activity and manage potential conflicts, such as tensions between free communication and privacy restrictions.¹⁵

Requirement definitions should be based on existing research, prior artefacts, and stakeholders' opinions gathered through methods such as interviews.¹⁶

Guidelines for this activity include specifying what artefact to build, formulating and justifying each requirement clearly, ensuring feasibility while striving for originality, and documenting the literature and stakeholder inputs involved.¹⁷

The third activity is to create an artefact that addresses the explicated problem while fulfilling the defined requirements. This process yields both prescriptive knowledge (what to do) and descriptive knowledge (design rationale).¹⁸ This phase is structured into four sub activities.

Imagine and Brainstorm involves generating diverse, innovative ideas through divergent thinking using techniques like empathetic design, lateral thinking, and structured methods such as "six thinking hats". Brainstormed ideas must be evaluated with convergent thinking, using decision-making models (rational, bounded rationality, garbage can) while being mindful of biases such

¹¹ see Johannesson/Perjons 2014: An Introduction to Design Science, pp. 93–95

¹² see Johannesson/Perjons 2014: An Introduction to Design Science, pp. 94–95

¹³ see Johannesson/Perjons 2014: An Introduction to Design Science, p. 98

¹⁴ see Johannesson/Perjons 2014: An Introduction to Design Science, p. 106

¹⁵ see Johannesson/Perjons 2014: An Introduction to Design Science, p. 105

¹⁶ see Johannesson/Perjons 2014: An Introduction to Design Science, pp. 106–107

¹⁷ see Johannesson/Perjons 2014: An Introduction to Design Science, p. 106

¹⁸ see Johannesson/Perjons 2014: An Introduction to Design Science, p. 117

as anchor, confirmation, and sunk cost biases.¹⁹ Researchers develop sketches and prototypes that detail both the artefact's core functions (e.g., interface, user interactions) and its overall structure (e.g., modules, components). Instruments like use case diagrams, user stories, and storyboards facilitate communication and further development.²⁰

The fourth activity is to validate artefact feasibility by demonstrating its application in a selected case—illustrative, fictitious, or real. This demonstration reveals both operational and explanatory knowledge about the artefact's functionality. Researchers must choose or design a case that is representative and challenging enough to test the artefact adequately. The artefact is applied to the chosen case, and the outcome is documented to illustrate how it addresses the problem.²¹ Guidelines for this activity include justifying why the chosen case is appropriate and explicitly describing which parts of the artefact are tested.²²

The final activity assesses how effectively the artefact solves the problem and meets defined requirements, providing both descriptive and explanatory insights. Researchers test the artifact's utility, evaluate both its functional and non-functional aspects, compare it with existing solutions, identify possible side effects, and determine its position within the underlying design theory.²³ DSR differentiates between *ex ante* (evaluation before full deployment) and *ex post* (evaluation after deployment) strategies, as well as between artificial (lab-based) and naturalistic (real-world) evaluations, each with inherent advantages and limitations.²⁴

The evaluation involves three sub-activities that work together to ensure comprehensive artefact assessment. First, in analyzing the evaluation context, researchers carefully examine available resources, constraints, and conditions including time, budget, and access limitations that shape the evaluation environment.²⁵ Next, researchers select evaluation goals and strategies by deciding what specific aspects to evaluate—such as requirements fulfillment, contextual influences, comparisons with existing solutions, potential side effects, and whether the evaluation should be formative or summative—while choosing appropriate research strategies and methods, including informed argument approaches for *ex ante* evaluations.²⁶ Finally, researchers design and carry out the evaluation by detailing the study design through setting up

¹⁹ see Johannesson/Perjons 2014: *An Introduction to Design Science*, pp. 118–119

²⁰ see Johannesson/Perjons 2014: *An Introduction to Design Science*, p. 124

²¹ see Johannesson/Perjons 2014: *An Introduction to Design Science*, pp. 133–134

²² see Johannesson/Perjons 2014: *An Introduction to Design Science*, p. 134

²³ see Johannesson/Perjons 2014: *An Introduction to Design Science*, p. 137

²⁴ see Johannesson/Perjons 2014: *An Introduction to Design Science*, pp. 138–139

²⁵ see Johannesson/Perjons 2014: *An Introduction to Design Science*, p. 139

²⁶ see Johannesson/Perjons 2014: *An Introduction to Design Science*, pp. 141–142

necessary environments, creating interview guides, establishing data collection protocols, selecting analysis methods, and then executing the evaluation according to this design.²⁷

Guidelines for this final activity emphasize the importance of evaluating every requirement and the problem-solving capability of the artefact, along with thoroughly describing how the evaluation was conducted to inform future iterations or final assessments.²⁸

2.3 Literature Review

The literature review was conducted to establish a comprehensive understanding of the current state of research and practice in sustainable UX design.

It aims to clarify the aspects of UX, sustainability, and sustainable web design guidelines pertinent to this research. Boundaries were established regarding the time frame of sources, with preference given to literature published within the last five years, except in cases where relevant recent sources were unavailable.

The literature review began with searches in the University of Applied Sciences Neu-Ulm library, supplemented by web searches to gather relevant books, papers, articles, and websites.

Findings from were organized according to thematic categories that correspond to the chapters in the Literature Review.

2.4 Semi-structured Qualitative Interviews

To complement the literature review and gain practical insights into sustainable UX design, semi-structured qualitative interviews were conducted with professionals in the field. This method was chosen to explore in-depth perspectives on challenges, practices, and opportunities that are not always captured in published literature.

The interviews followed a semi-structured format, balancing consistency with flexibility, and covered topics such as participants' understanding of sustainability in digital contexts, current practices, implementation barriers, and suggestions for improvement. This interview format was chosen to give the experts the freedom to present their experiences and assessments in detail without being restricted by predetermined answer options. The semi-structured approach allowed interviewees to fully present their individual perspectives and specific challenges in the field of sustainable UX design, while at the same time ensuring a certain degree of comparability

²⁷ see Johannesson/Perjons 2014: An Introduction to Design Science, pp. 142–143

²⁸ see Johannesson/Perjons 2014: An Introduction to Design Science, p. 145

and structure. This flexibility also made it possible to address unforeseen topics that arose during the interview, allowing for deeper and more varied insights.

A grounded theory approach was used for data analysis. Initial coding involved line-by-line analysis to identify themes such as sustainability dimensions (environmental, social, economic, longevity), constraints (budget, time, technology, internal politics), collaboration (cross-functional teamwork, executive support), and strategies (audits, training, interventions). In focused coding, these were grouped into broader categories: multidimensional sustainability, practical constraints, collaborative integration, and strategic interventions. Theoretical coding then connected these categories into a conceptual framework, revealing sustainable UX as a holistic process that balances ideal practices with real-world limitations. This framework forms the analytical foundation for the chapter Problem and Requirements.

3 Literature Review

This chapter examines the literature on UX design and sustainability in digital contexts. It establishes UX theoretical foundations through definitions, usability relationships, and design processes. The chapter explores sustainability's role in digital design, addressing environmental impacts through circular economy principles and humanity-centered approaches. It evaluates digital carbon footprints across hardware, data transfer, and data centers, and reviews tools for measuring environmental impact. Finally, it examines guidelines on sustainable web design.

3.1 User Experience Design

UX is a fundamental concept in digital product design. Allanwood and Beare describe it as “a realistic approach to the process of designing digital products that require some sort of Human Interaction.”²⁹

The ISO 9241-11:2018 standard defines UX as the “user’s perceptions and responses that result from the use and/or anticipated use of a system, product or service”, emphasizing both actual and expected use.³⁰ UX includes user-centric factors like preferences, emotions, trust, and privacy, all of which shape how users perceive and interact with a product.³¹

The term UX gained popularity through Don Norman, a pioneer in Human-Computer Interaction (HCI), who was the first to hold “User Experience” in a job title when he worked at Apple.³² Norman emphasizes the importance of applying human-centered design principles to create products that enhance lives and bring joy to users. However, he critiques the misuse of UX, warning against limiting it to interface design and overlooking the broader system. He notes many confuse UX with UI (User Interface), ignoring the full scope of interaction.³³

UX design is inherently subjective. While usability can be optimized objectively, UX depends on individual preferences and reactions. Designers don’t create the experience directly but influence it through the system or product design.³⁴

²⁹ Allanwood/Beare 2019: User experience design: A Practical Introduction, p. 2

³⁰ International Organization for Standardization 2018: ISO 9241-11:2018 (en), Ergonomics of human-system interaction — Part 11: Usability: Definitions and concepts

³¹ see Kauer-Franz/Franz 2023: Usability und User Experience Design, p. 44

³² Interaction Design Foundation (IxDF) 2024: What is Don Norman?

³³ Nielsen Norman Group (NNgroup) - Youtube 2016: Don Norman: The Term “UX”

³⁴ see Kauer-Franz/Franz 2023: Usability und User Experience Design, p. 44

As a holistic construct, UX spans six dimensions—functional, physical, perceptual, cognitive, social, and psychological—with meta-levels like sense-making and aesthetics adding coherence. Users bring their own moods, attitudes, and motivations to interactions, which shape emotional and aesthetic responses and accumulate into an overall experience over time.³⁵

Given UX's multidimensional and subjective nature, flexible and adaptive design strategies are crucial. Iterative processes help designers respond to diverse user contexts and emotions.

Hassenzahl highlights that positive UX arises when core human needs such as autonomy, competence, and relatedness are met. These needs influence emotional states, linking UX not only to function but to psychological fulfillment. For example, autonomy correlates with feelings of inspiration, alertness, and determination, while competence relates to satisfaction and challenge.³⁶

UX design and sustainability are increasingly intertwined. As digital platforms grow, so does their environmental impact. Sustainable UX ensures positive experiences while promoting energy efficiency, reduced emission, and mindful digital use.³⁷

Many UX teams now align their work with the United Nations Sustainable Development Goals (SDGs), such as Climate Action (SDG 13) and Responsible Consumption and Production (SDG 12), broadening the focus to include social and economic sustainability. Tools like the Sustainable UX Design Toolkit support these efforts.³⁸

UX is a holistic practice addressing both function and emotional satisfaction. It considers the full scope of user interactions, shaped by subjective experience and broader systemic factors. Today, integrating sustainability into UX is vital for creating meaningful, responsible digital experiences.

3.1.1 Definition Usability

Usability is a key aspect of product, system, or service design, focusing on how well users can achieve their goals. The ISO 9241-11:2018 standard defines usability as the *“extent to which a system, product or service can be used by specified users to achieve specified goals with*

³⁵ see Robert/Lesage 2011: Designing and Evaluating User Experience, p. 3

³⁶ see Hassenzahl 2008: User experience (UX)

³⁷ see Blevis 2007: Sustainable interaction design, p. 503; see Verma 2024: How to Practice Sustainable UX or Green UX Design; see Jonas 2024: The 11 principles of Sustainable UX

³⁸ see United Nations: The 17 Sustainable Development Goals; see Markmann: The Sustainable UX Design Toolkit, pp. 6–8

effectiveness, efficiency and satisfaction in a specified context of use“.³⁹ This definition highlights three core components: effectiveness, efficiency, and satisfaction.

Effectiveness is the *“accuracy and completeness with which users achieve specified goals”*⁴⁰ while efficiency concerns the *“resources used in relation to the results achieved”* such as time and effort.⁴¹ Satisfaction, in contrast, involves how well users’ physical, cognitive, and emotional responses match their expectations, making it more subjective and harder to quantify.⁴²

Usability also depends heavily on the context of use, defined as the *“combination of users, goals and tasks, resources, and environment”*.⁴³ Since usability can vary with changes in these factors, it must be evaluated within a specific context.⁴⁴

Improving usability can also promote sustainability. Intuitive interfaces reduce unnecessary user actions and data use, lowering energy consumption.⁴⁵ Efficient user flows and streamlined content can enhance satisfaction while minimizing environmental impact.

In summary, usability involves designing for effective, efficient, and satisfying goal achievement within a defined context which benefits both UX and sustainability.

3.1.2 Design Processes

UX design processes are systematic approaches aimed at creating meaningful and relevant experiences for users. They typically involve research, ideation, prototyping, testing, and implementation. The goal is to ensure that the final product is both user-centric and functional.⁴⁶

The purpose of any strategy is to create a plan that assesses the current position and then guides the journey toward the desired future state.⁴⁷ This strategic planning is crucial in UX design to bridge the gap between current product offerings and user expectations.

³⁹ International Organization for Standardization 2018: ISO 9241-11:2018 (en), Ergonomics of human-system interaction — Part 11: Usability: Definitions and concepts, chap. 3.2.3

⁴⁰ International Organization for Standardization 2018: ISO 9241-11:2018 (en), Ergonomics of human-system interaction — Part 11: Usability: Definitions and concepts, chap. 3.1.12

⁴¹ International Organization for Standardization 2018: ISO 9241-11:2018 (en), Ergonomics of human-system interaction — Part 11: Usability: Definitions and concepts, chap. 3.1.13

⁴² International Organization for Standardization 2018: ISO 9241-11:2018 (en), Ergonomics of human-system interaction — Part 11: Usability: Definitions and concepts, chap. 3.1.14

⁴³ International Organization for Standardization 2018: ISO 9241-11:2018 (en), Ergonomics of human-system interaction — Part 11: Usability: Definitions and concepts, chap. 3.1.15

⁴⁴ see Kauer-Franz/Franz 2023: Usability und User Experience Design, p. 51

⁴⁵ see Verma 2024: How to Practice Sustainable UX or Green UX Design

⁴⁶ see Interaction Design Foundation (IxDF): What are UX Design Processes?

⁴⁷ see Levy 2015: UX strategy, p. 7

A successful UX design process fosters strong collaboration among various teams, including design, development, and marketing. Early involvement of cross-functional teams enhances the overall effectiveness of the design process.⁴⁸

3.1.2.1 Roles involved into the UX design process

In UX design projects, specific roles ensure the effective application of UX principles. Allanwood notes that each team includes someone responsible for facilitating UX activities. In larger teams, titles like UX Design Director, UX Strategist, User Evangelist, and UX Analyst distinguish these roles from production tasks.⁴⁹

Given the collaborative nature of agile development, a flexible RACI matrix is useful for planning responsibilities. This matrix outlines how different roles contribute to phases, activities, and deliverables.

In a RACI matrix, each person or role has its own column, and each task has an individual row. Each cell specifies the involvement of the corresponding party with the task, designated by one of four letters:

- **R:** Responsible
- **A:** Accountable (for each task, there should be only one accountable person)
- **C:** Consulted
- **I:** Informed

⁴⁸ see Interaction Design Foundation (IxDF): What are UX Design Processes?

⁴⁹ Allanwood/Beare 2019: User experience design: A Practical Introduction

Product or Initiative Name: RACI

High-level objectives and key results

Owner: Team Name
 Last updated: 00-00-00
[Link to Product Roadmap](#)

Product Development Task	Responsible (R) The team member who does the work (Can be more than one person)	Accountable (A) The person who provides final review and deems completion (Only one)	Consulted (C) People who provide input and expertise (Can be more than one person)	Informed (I) People kept in the loop on progress (Can be more than one person)		
	Product Manager / Owner	UX / Product Design	Engineering	UX Manager	Stakeholders / Leadership	Add Roles as Needed
Strategic Context	R/A	C	C	I	I	
Setting product vision	R/A	R	R	X	X	
Defining objectives & key results	R/A	C	C	X	X	
Product strategy & roadmap	R/A	C	C	X	X	
Discovery						
Writing research goals & objectives						
Planning & running a workshop						
Conducting Research						
Stakeholder interviews						
User interviews						
Analysis & synthesis						

NN/g

Figure 1: RACI Matrix by NNGroup⁵⁰

RACI models can be adapted to fit a team's needs. UX roles often included are Product Designers, UX Researchers, UX Designers, Content and Copywriters, Information Architects, Customer Experience roles, and UX Managers.⁵¹

3.1.2.2 Overview of relevant processes

There are several popular UX design processes, including Human-Centered Design, User-Centered Design, Design Thinking, the Double Diamond model, the Waterfall model, Agile UX, and Lean UX. Each is examined for its core principles, key stages, and practical relevance, with insights from authoritative sources highlighting their value to the UX field.

⁵⁰ Anna Kaley 2022: Setting UX Roles and Responsibilities in Product Development

⁵¹ Nielsen Norman Group (NNgroup): Setting UX Roles and Responsibilities in Product Development

Human Centered Design

Human-Centered Design (HCD) prioritizes the needs, contexts, and experiences of people throughout the design process. The ISO 9241-210:2019(E) defines it as an „*approach to systems design and development that aims to make interactive systems more usable by focusing on the use of the system and applying human factors/ergonomics and usability knowledge and techniques*“.⁵² Key principles include understanding users, involving them throughout development, using user centered evaluation, and iterating the design.⁵³ HCD also addresses the whole user experience and relies on multidisciplinary teams.⁵⁴ Through ongoing prototyping, testing, and refinement, HCD ensures solutions align with real user needs in complex, systems.⁵⁵

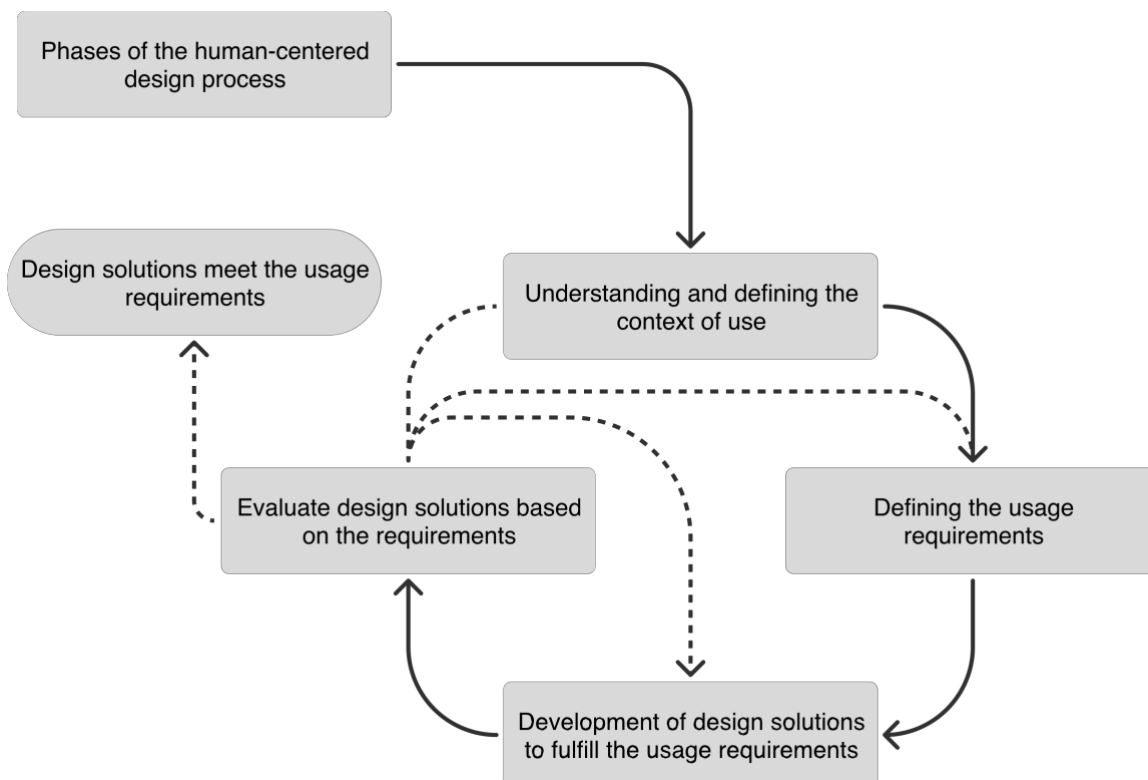


Figure 2: Human-Centered Design Process⁵⁶

User-Centered Design

User-Centered Design (UCD) is a UX framework that prioritizes users' needs, preferences, and behaviors to create intuitive, efficient, and enjoyable products.⁵⁷ Usability is central, aiming for

⁵² International Organization for Standardization 2019: ISO 9241-210:2019 (en), Ergonomics of human-system interaction — Part 210: Human-centred design for interactive systems, chap. 3.7

⁵³ see NIST 2021: Human Centered Design (HCD)

⁵⁴ see NIST 2021: Human Centered Design (HCD)

⁵⁵ see Interaction Design Foundation (IxDF): What is Human-Centered Design (HCD)?

⁵⁶ NIST 2021: Human Centered Design (HCD)

⁵⁷ see UXPin 2024: UX Design Frameworks – What Are The Most Useful Ones?

easy-to-use designs with clear navigation and structure.⁵⁸ Early prototyping and user testing help identify issues before final development. UCD supports continuous improvement through ongoing feedback and iteration.⁵⁹ This approach not only supports business goals but also enhances the overall user experience.

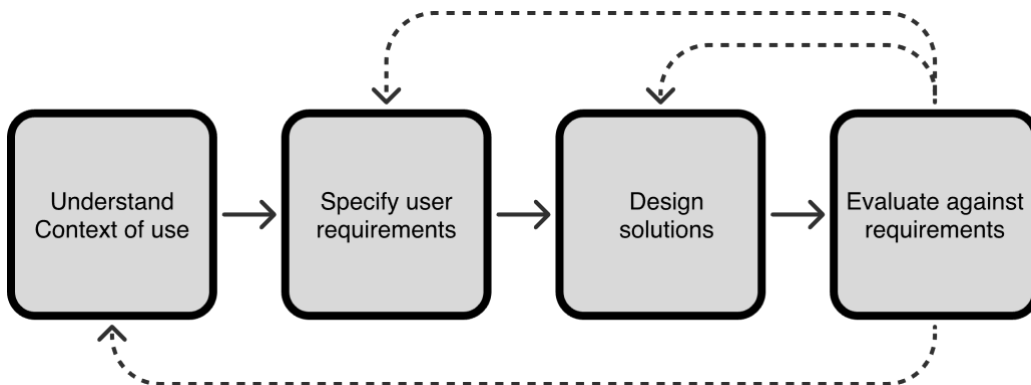


Figure 3: User centered Design Process⁶⁰

Design Thinking

Design Thinking is an iterative, user-centered framework central to many UX processes.⁶¹ It emerged in the 1950s-60s as professionals from fields like engineering, architecture, industrial design, and cognitive science collaborated to solve complex post-industrial and post-war challenges by combining human, technological, and strategic perspectives.⁶²

The process is comprised of five stages: Empathize, Define, Ideate, Prototype, and Test. Designers begin by understanding user needs, define the core problem, brainstorm solutions, build prototypes, and test them with users. The cycle repeats based on feedback, fostering user insight, creativity, and practical, user-centered solutions.⁶³

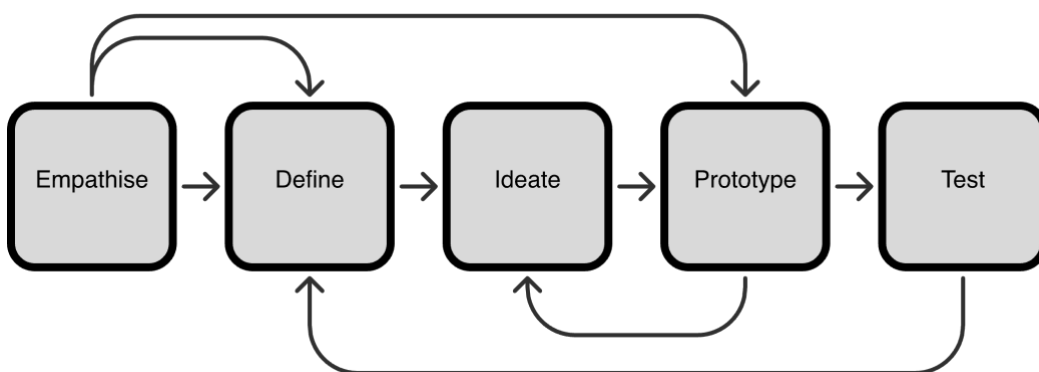


Figure 4: Design Thinking Process

⁵⁸ see UXPin 2024: UX Design Frameworks – What Are The Most Useful Ones?

⁵⁹ see UXPin 2024: UX Design Frameworks – What Are The Most Useful Ones?

⁶⁰ Interaction Design Foundation (IxDF): What is User Centered Design (UCD)?

⁶¹ see UXPin 2024: UX Design Frameworks – What Are The Most Useful Ones?

⁶² see Dam/Siang 2022: The History of Design Thinking

⁶³ see UXPin 2024: UX Design Frameworks – What Are The Most Useful Ones?

Double Diamond

The Double Diamond model, developed by the Design Council, offers a clear visual of the design process for both designers and non-designers. It consists of two phases—each with divergent and convergent thinking—comprising Discover, Define, Develop, and Deliver. In Discover, designers explore the problem broadly by engaging affected users. In Define, they synthesize insights to frame the challenge. Develop focuses on generating and co-designing ideas, while Deliver involves testing and refining solutions.⁶⁴ The process is non-linear, with continuous feedback and iteration essential in today’s evolving digital landscape.

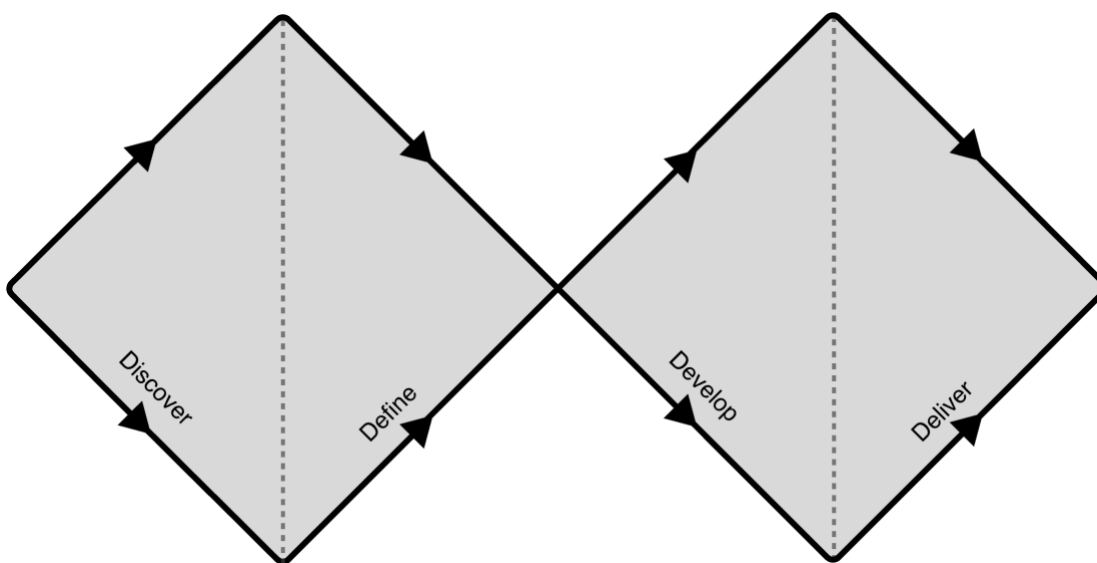


Figure 5: Double Diamond Process⁶⁵

Data-Driven UX Design

Data-Driven UX Design (3DUX) focuses on using real user data to guide design decisions, improving usability and overall experience. Inspired by ISO 9241-210 and incorporating risk evaluation from IEC 62366-1, 3DUX offers a structured approach to UX.⁶⁶ Benefits include shortened discussions, stronger justification, more reliable outcomes, and defensible design choices.⁶⁷ By relying on empirical data, 3DUX avoids last-minute changes driven by the “Highest Paid Person’s Opinion” (HIPPO Effect). Most projects begin with existing products and not from scratch.⁶⁸ The process starts with a context-of-use analysis, including risk assessment, followed

⁶⁴ see Design Council 2024: The Double Diamond

⁶⁵ Design Council 2024: The Double Diamond

⁶⁶ see Kauer-Franz/Franz 2023: Usability und User Experience Design, p. 127

⁶⁷ see Kauer-Franz/Franz 2023: Usability und User Experience Design, p. 128

⁶⁸ see Kauer-Franz/Franz 2023: Usability und User Experience Design, p. 129

by defining usage requirements. Design solutions are developed and prioritized based on risk and usage frequency, then evaluated and refined in iterative cycles.⁶⁹ Depending on the evaluation outcomes, the process may cycle back to previous steps or advance to technical development and product release.⁷⁰ The scope varies by situation, but always centers on human needs, requiring stakeholder involvement in quality evaluation.⁷¹

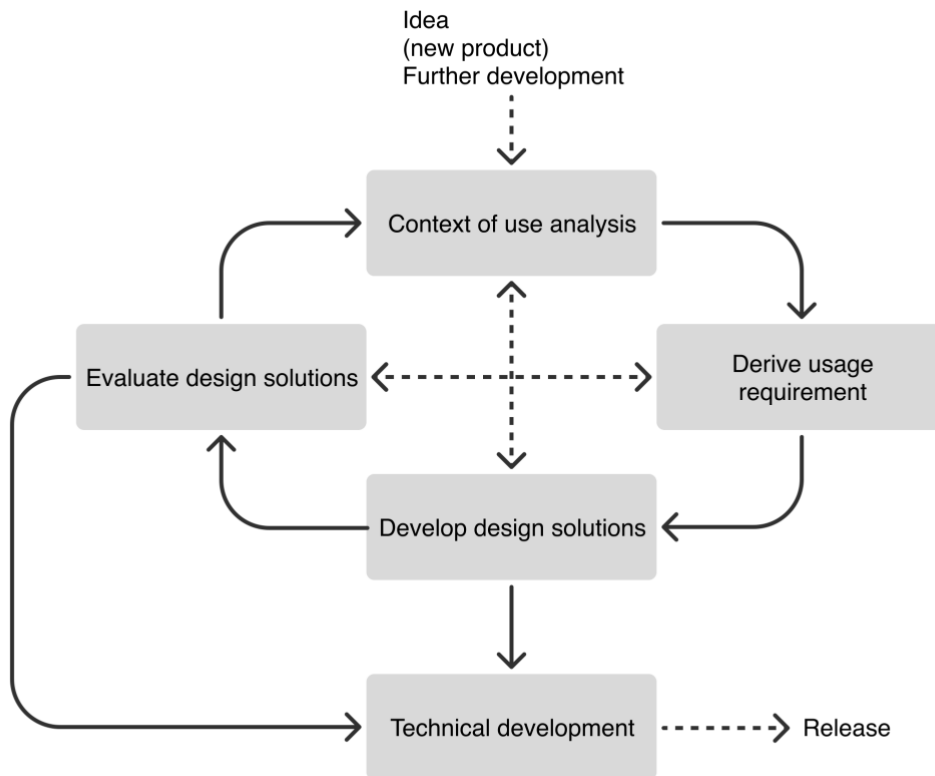


Figure 6: Data-Driven UX Design process⁷²

Waterfall model

The Waterfall model is a linear UX design method with distinct phases like user research, wireframing, and testing each completed before the next begins. Progress flows in one direction, relying on prior outputs and emphasizing detailed planning and documentation. However, its rigidity poses challenges in evolving environments. Discovered issues late can require restarting the process, causing increased costs and delays. Due to its inflexibility, Waterfall is often unsuitable for projects needing adaptability or iterative user feedback.⁷³

⁶⁹ see Kauer-Franz/Franz 2023: Usability und User Experience Design, p. 133

⁷⁰ see Kauer-Franz/Franz 2023: Usability und User Experience Design, p. 133

⁷¹ see Kauer-Franz/Franz 2023: Usability und User Experience Design, pp. 130–131

⁷² Kauer-Franz/Franz 2023: Usability und User Experience Design, p. 134

⁷³ see Design Studio 2023: What is Agile UX?

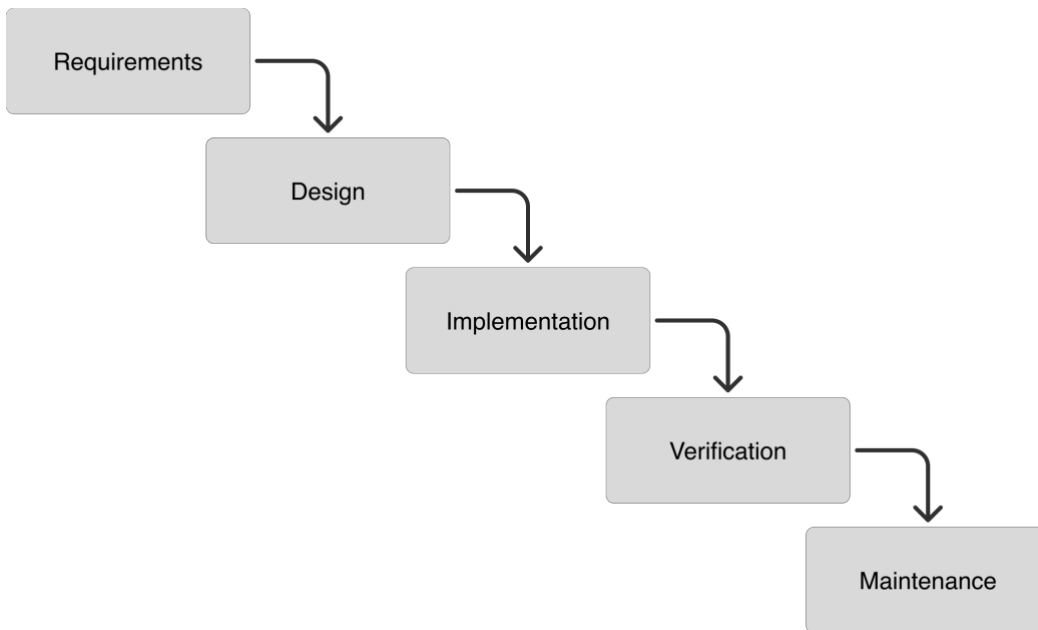


Figure 7: Waterfall process

Agile UX

Agile UX merges UX design with Agile development to overcome the rigidity of linear models. It uses short sprints (3-14 days), to focus on specific tasks, allowing for rapid development and adaptation.⁷⁴ Prioritizing cross-functional collaboration and flexibility, it embraces change over strict planning.⁷⁵ Continuous user feedback and iterative refinement allow designs to evolve with user needs, resulting in more responsive, user-aligned products.

⁷⁴ see Design Studio 2023: What is Agile UX?

⁷⁵ see Nielsen Norman Group (NNgroup) 2023: Lean UX & Agile

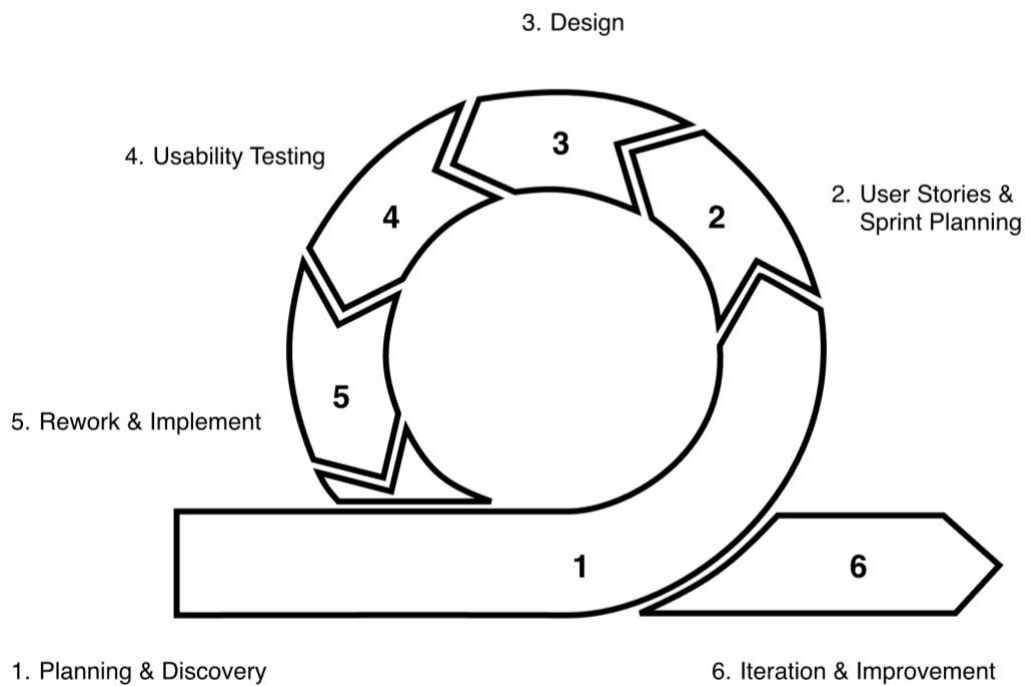


Figure 8: Agile UX Process

Lean UX

Lean UX aims to deliver user value through constant experimentation and waste reduction.⁷⁶ It prioritizes designing experiences over extensive documentation and relies on tight team collaboration. Feedback is gathered early and often to guide rapid decisions and iterations. Instead of strict requirements, it uses problem statements to form assumptions, which are tested via hypotheses. These outline beliefs, relevance, expected outcomes, and required evidence, driving data-based decisions and reducing subjective conflict.⁷⁷ This continuous testing fosters quick improvements and a user-focused design culture.

All UX design processes, except Waterfall, prioritize the end-user through iteration and evaluation, but differ in their approaches. Human-Centered and User-Centered Design focus on empathy and early prototyping. Design Thinking follows a structured cycle of empathy, definition, ideation, prototyping, and testing. Data-Driven UX relies on empirical evidence, while Agile UX and Lean UX emphasize rapid iterations and validation. These complementary approaches address various project needs and organizational goals by integrating user insights and multidisciplinary collaboration.

⁷⁶ see Nielsen Norman Group (NNgroup) 2023: Lean UX & Agile

⁷⁷ see Interaction Design Foundation (IxDF) 2021: A Simple Introduction to Lean UX

3.2 Sustainability in Digital Design

Sustainability has become a pressing issue in digital design, driven by the need to reduce the environmental impact of technology while addressing user needs now and in the future. This section explores the definitions of sustainability, the urgency of integrating sustainable practices into digital design, the principles of the circular economy, the evolution from human-centered to humanity-centered design, and the digital carbon footprint.

3.2.1 Defining Sustainability

Sustainability is fundamental for integrating eco-friendly practices into digital design. The Brundtland Commission defines it as development that *“meets the needs of the present without compromising the ability of future generations to meet their own needs”*⁷⁸

Don Norman expands on this, framing sustainability as the capacity to maintain a stable state indefinitely. He stresses the need to halt harmful activities and reversing existing damage.⁷⁹ Noting it's *“too late to stop the ecological damage, but not too late to slow it down and reverse its progress”*⁸⁰

3.2.2 Urgency of Sustainable Practices

The Intergovernmental Panel on Climate Change (IPCC) has highlighted that human activities have driven global warming since the mid-20th century, with surface temperatures rising ~0.85°C between 1880 and 2012. This has led to severe changes in natural and human systems, including extreme weather, rising seas, and biodiversity loss, disproportionately affecting vulnerable populations.⁸¹

To limit warming to 1.5°C, the IPCC calls for deep emissions cuts and systemic change across sectors.⁸² Recent findings emphasize the Information and Communication Technology's (ICT) sector's role, with emissions accounting for 2.1%–3.9% of all greenhouse gas (GHG) emissions. In 2023, global emissions reached nearly 53 gigatonnes of CO₂-equivalent, according to the GHG Emissions of All World Countries 2024 Report.⁸³

Based on this, the Sustainable Web Manifesto concluded:

⁷⁸ Brundtland, G.H. 1987: Our Common Future, pt. From One Earth to One World. I. The Global Challenge 3. Sustainable Development §27

⁷⁹ see Norman 2023: Design for a better world, p. 125

⁸⁰ Norman 2023: Design for a better world, p. 125

⁸¹ see Allen et al. 2018: Framing and Context, p. 53

⁸² see Allen et al. 2018: Framing and Context, p. 53

⁸³ see Freitag et al. 2021: The real climate and transformative impact of ICT, pp. 2–4; see European Commission. Joint Research Centre./IEA. 2024: GHG emissions of all world countries.

“If the internet were a country, it would be the fourth largest polluter.”⁸⁴

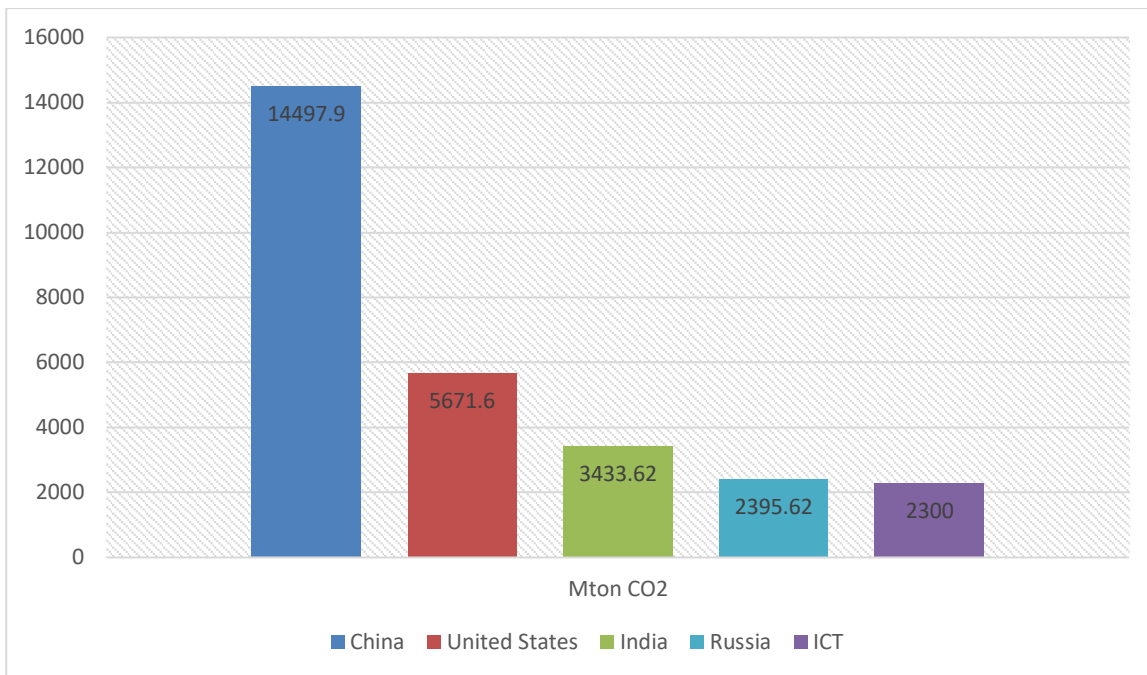


Figure 9: Annual CO₂e Emissions in Mt by Country in 2020⁸⁵

This alarming comparison highlights the need to reduce digital emissions alongside those from traditional industries. It reinforces the IPCC’s push for transformative changes in how we power, build, and manage digital products.

Recognizing the material impact of digital technologies motivates designers and developers to adopt sustainable practices—from green hosting and efficient design to durable hardware and clean energy—aligned with broader climate goals.

3.2.3 Circular Economy and Design Principles

Integrating sustainability into UX design become essential, ensuring digital products remain functional while meeting environmental responsibility. Central to this is the circular economy which opposes the linear “take-make-dispose” model. It promotes eliminating waste reusing resources and regenerating natural systems.⁸⁶ This decouples growth from finite resource use and addresses climate change, pollution, and biodiversity loss.

⁸⁴ see Freitag et al. 2021: The real climate and transformative impact of ICT, pp. 2–4; see European Commission. Joint Research Centre./IEA. 2024: GHG emissions of all world countries., p. 52

⁸⁵ see Freitag et al. 2021: The real climate and transformative impact of ICT, pp. 2–4; see European Commission. Joint Research Centre./IEA. 2024: GHG emissions of all world countries., p. 52

⁸⁶ see Ellen MacArthur Foundation: Circular economy introduction

In digital design, several key aspects reflect this approach. Longevity encourages building products that last, with structures allowing updates and maintenance, reducing overhauls thus minimizing resource consumption.⁸⁷ Efficiency, on minimizing resource use—such as energy, data, and computational power—through clean code and lightweight assets, improving UX and reducing environmental impact.⁸⁸

Modularity and reusability promote using interchangeable components via design systems, component libraries, reducing redundancy and digital waste.⁸⁹ Repairability ensures digital systems are easy to update or troubleshoot through clean, modular code. End-of-life planning advocates for recycling or repurposing hardware and software rather than disposal.⁹⁰

A lifecycle approach—supported by cradle-to-cradle thinking—ensures sustainability is considered across all product stages, from development to decommissioning. Designers can integrate reuse, enable sharing via open-source tools, and plan for responsible retirement of assets.⁹¹

In practice, trends like modular design and code reuse cut down on resources while enhancing the overall user experience. Many websites today repurpose components from open-source frameworks to build efficient systems.⁹² Designing for device longevity also helps, as websites optimized for older hardware reduce the need for constant device upgrades. A standout example is LOW←TECH MAGAZINE’s solarpowered website, proving low-bandwidth can operate sustainably under constrained energy conditions.⁹³

By adopting circular economy principles—reusability, modularity, and planned end-of-life—paired with lifecycle thinking, designers create more efficient, lasting, and eco-conscious digital experiences.

⁸⁷ see Erik Fiala 2024: Designing for the Circular Economy

⁸⁸ see Erik Fiala 2024: Designing for the Circular Economy

⁸⁹ see Jason Bodell 2023: Building A Greener Online Future With Sustainable Web Design

⁹⁰ see Erik Fiala 2024: Designing for the Circular Economy

⁹¹ see Ben Linders 2023: Sustainable Software Systems Using Circular Economy Principles

⁹² see Jason Bodell 2023: Building A Greener Online Future With Sustainable Web Design

⁹³ see Decker: About the Solar Powered Website

3.2.4 From Human-Centered to Humanity-Centered Design

UX design has traditionally followed a human-centered approach, prioritizing individual users' needs and usability and clarity.⁹⁴ However, critics argue that this narrow focus overlook systemic issues like bias, marginalization, and environmental impact.⁹⁵ In response, humanity-centered design has emerged (HCD+), urging designers to maintain HCD's core values while expanding their scope to include the well-being of all living things the planet.⁹⁶

HCD is grounded in four principles: solving root problems, focusing on people, taking a systems point of view and refining through iteration.⁹⁷ While this framework improves user experience, it often neglects long-term sustainability and equity.⁹⁸

Humanity-centered design (HCD+) builds on these foundations but shifts in five key ways:

1. Tackling systemic causes, not just symptoms.
2. Expanding focus from individual users to entire ecosystems.
3. Considering long-term ripple effects of design.
4. Maintaining iteration but including societal and environmental needs.
5. Emphasizing co-design with communities.⁹⁹

The following figure visually compares the four HCD and five HCD+ principles, showing how the expanded model integrates ecosystems, long-term thinking, and collaborative design.

⁹⁴ see Norman 2023: Design for a better world, p. 181

⁹⁵ see Norman 2023: Design for a better world, pp. 181–182

⁹⁶ see Norman 2023: Design for a better world, p. 182

⁹⁷ see Norman 2023: Design for a better world, p. 182

⁹⁸ see Norman 2023: Design for a better world, p. 183

⁹⁹ see Norman 2023: Design for a better world, p. 183

Human-Centered Design vs. Humanity-Centered Design

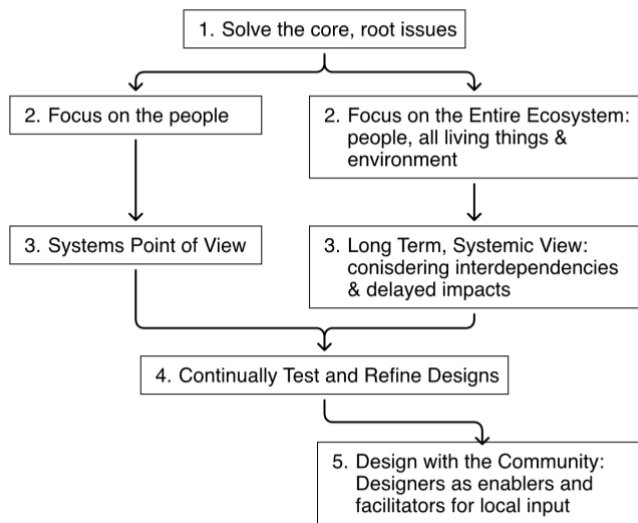


Figure 10: Comparing the four human-centered with the five humanity-centered design principles proposed.

The shift is grounded in theory. Some argue that traditional HCD, while effective for adoption, is “the wrong lens for a sustainable world”. Grotzer and Cao suggest a more earth-centered approach that links human well-being with environmental health.¹⁰⁰

A core element of HCD+ is systems thinking. While HCD uses tools like the “5 Whys” to find root causes, HCD+ considers broader social, technological, and environmental interconnections. It also calls for cultural sensitivity and awareness of design bias, urging respect for diverse perspectives and local knowledge.

In summary, humanity-centered design advances UX by broadening its scope beyond individuals to include ecological, societal and ethical dimensions. This evolution fills critical gaps in sustainability, equity, and long-term impact that HCD alone cannot address.

3.3 Digital Carbon Footprint

As digital technologies become more central to everyday life, their environmental impact has come under increased scrutiny. The digital carbon footprint refers to the greenhouse gas emissions generated throughout the lifecycle of digital devices and services.¹⁰¹ From browsing

¹⁰⁰ see Grotzer/Cao 2023: EarthXDesign for a Sustainable World: Moving from Human-Centered to Earth-Centered Design

¹⁰¹ see Nutanix: What is a Digital Carbon Footprint & How To Reduce It

social media to streaming, daily online activities require vast energy resources, contributing to carbon emissions and environmental strain.¹⁰²

3.3.1 Understanding the Digital Carbon Footprint

The digital carbon footprint stems from several key sources:

- **Hardware Production and Disposal:**

Making smartphones, computers, and network equipment demands electricity and rare earth materials. Short lifespans lead to rising e-waste and environmental damage from extraction and disposal.¹⁰³

- **Energy Consumption During Use:**

Charging devices and powering modems, routers, and other equipment requires electricity.¹⁰⁴

- **Data Transfer:**

Transmitting data via LTE, 5G, or cable consumes energy through the supporting network infrastructure.¹⁰⁵

- **Data Storage in Data Centers:**

Servers storing and processing data need continuous electricity, especially for cooling—making data centers major contributors to emissions.¹⁰⁶

3.3.2 The Impact of Data Centers on Energy Consumption

Data centers are essential to internet infrastructure but are major consumers of energy and water. They contribute an estimated 2–3% of global greenhouse gas emissions, a number expected to rise with increasing data demands.¹⁰⁷ In the United States alone, they consume 2% of the nation’s electricity.¹⁰⁸

Their energy comes from both powering servers and operating energy-intensive cooling systems.¹⁰⁹ High-performance data centers often rely on geo-redundant setups for reliability, which increases electricity consumption despite efforts to use renewable energy sources.¹¹⁰

¹⁰² see Kasia 2022: What is the digital carbon footprint?

¹⁰³ see Kasia 2022: What is the digital carbon footprint?

¹⁰⁴ see Kasia 2022: What is the digital carbon footprint?

¹⁰⁵ see Kasia 2022: What is the digital carbon footprint?

¹⁰⁶ see Kasia 2022: What is the digital carbon footprint?

¹⁰⁷ see UNEP 2021: With new pact, tech companies take on climate change

¹⁰⁸ see Osaka 2023: A new front in the water wars

¹⁰⁹ see Kasia 2022: What is the digital carbon footprint?

¹¹⁰ see United Internet AG: Sustainability Report 2020

3.3.3 Water Consumption in Data Centers

While carbon emissions from data centers receives much attention, their water usage is an equally urgent issue. Cooling systems rely heavily on water to manage server heat.¹¹¹

A single hyperscale data center may use 3.8 and 19 million liters of water daily— comparable to a small city’s consumption. In 2022, global data centers used about 1.1 billion liters per day projected to rise to 1.7 billion liters per day by 2030.¹¹² In Virginia’s “Data Center Alley” usage grew nearly 64% since 2019, reaching over 7 billion liters in 2023.¹¹³

Though often located in areas with cheap, low-carbon energy, many centers are also in water-stressed regions.¹¹⁴ This includes drought-prone states like Arizona and California, worsening local shortages.¹¹⁵ Cooling methods like evaporative cooling are efficient but cause high water loss. Many centers still rely on potable municipal water, and the use of reclaimed water remains limited.¹¹⁶

The sector’s water footprint reveals a sustainability paradox: lowering carbon emissions may unintentionally strain water resources, calling for a more balanced environmental strategy.

3.3.4 Industry Responses to Water Consumption

Major tech companies have acknowledged the environmental implications of their water usage and have committed to initiatives aimed at mitigating these impacts.

- **Amazon Web Services (AWS):** Aims to be water-positive by 2030 by improving, efficiency, using sustainable sources, and supporting water replenishment projects.¹¹⁷
- **Microsoft:** Also targets water positivity by 2030, focusing on reducing intensity and replenishing water in water-stressed regions where it operates.¹¹⁸

¹¹¹ see Zhang 2024: Data Center Water Usage

¹¹² see Friedmann 2024: Data Center Water use

¹¹³ see Solomon Klappholz 2024: Data center water consumption is spiraling out of control

¹¹⁴ see Siddik/Shehabi/Marston 2021: The environmental footprint of data centers in the United States, pp. 3–4

¹¹⁵ see Osaka 2023: A new front in the water wars

¹¹⁶ see Zhang 2024: Data Center Water Usage

¹¹⁷ see Amazon Sustainability: Water stewardship

¹¹⁸ see Smith 2020: Microsoft will replenish more water than it consumes by 2030

- **Google:** Plans to replenish 120% of its water use by 2030 through community investments and water management.¹¹⁹
- **Meta:** Pledges to restore more water than it consumes by 2030 via efficient cooling, reclaimed water systems, and local restoration projects.¹²⁰

While these initiatives are notable, water usage remains substantial. For example, Google's data centers averaged 550,000 gallons per day—around 200 million gallons annually.¹²¹ Continued innovation in water efficiency is critical.

3.4 Measuring Tools

Quantifying energy use and emissions is essential for developing sustainable web solutions. Several tools and frameworks assess both operational and embodied impacts—factoring in data transfer, hosting, and device energy use. The following overview highlights key tools, their features, and applications.

3.4.1 The Sustainable Web Design Model (SWDM)

The Sustainable Web Design Model (SWDM) is an open-source method for estimating GHG emissions from digital products and services. It is collaboratively developed by Wholegrain Digital, Mightybytes, Footprint, EcoPing, and the Green Web Foundation, and aims to be approachable for practitioners getting started with digital carbon accounting. It calculates both operational and embodied emissions across data centers, networks, and user devices.¹²²

SWDM uses global average data for energy and grid intensity but allows users to input more specific figures when available. It leans toward overestimation to avoid underreporting and builds on research from sources like the International Energy Agency and Malmödin.¹²³

3.4.2 Website Carbon Calculator

The Website Carbon Calculator is one of the longest standing tools for estimating a web page's carbon footprint.¹²⁴ It measures data-transfer size for a single URL, applies an energy-intensity

¹¹⁹ see Tara Varghese 2024: How we're supporting our commitment to water stewardship

¹²⁰ see Meta Sustainability: Water

¹²¹ see Zhang 2024: Data Center Water Usage

¹²² see Sustainable Web Design: Estimating Digital Emissions

¹²³ see Sustainable Web Design: Estimating Digital Emissions

¹²⁴ see Website Carbon Calculator: Website Carbon Calculator v3 | What's your site's carbon footprint?

factor, and converts this to estimated emissions using a global average grid intensity. If a hosting provider uses renewable energy per the Green Web Foundation’s dataset emissions from data center are adjusted.¹²⁵

While focused only on operational emissions from data transfer, the tool is popular for its simplicity and accessible interface. Users can also display a badge showing their site’s footprint to promote transparency. However, it offers only quick, page-level snapshots limiting its use for detailed or ongoing assessments.¹²⁶

Its reliance on a global averages may overlook regional energy differences, and it excludes embodied emissions like those from hardware production and full infrastructure lifecycles.¹²⁷

3.4.3 Ecograder

Ecograder, developed by Mightybytes is a free tool that estimates a website’s environmental impact using Google Lighthouse performance metrics and The Green Web Foundation’s CO2.js library. The tool generates an “eco-score” (on a 1–100 scale) by analyzing page performance, user experience, and green hosting attributes, with suggestions for reducing digital carbon emissions.¹²⁸

However, it only measures CO₂ from the initial page load. Features like lazy loading —where more content loads as users scroll—aren’t captured, possibly underestimating emissions. It also doesn’t account for client-side resource use (CPU, GPU, RAM), which can increase energy demand despite lightweight appearances. Ecograder does not account for this subsequent data, potentially underestimating the overall page weight.

Ecograder overlooks broader infrastructure impacts like device usage, full server operations, or the hosting provider’s energy sources. It offers just a snapshot view based on one page load; while users can input monthly traffic for projections, it doesn’t reflect variations from interactions like scrolling or dynamic content.

Still, Ecograder stands out as a free tool offering actionable insights. It’s a solid starting point for assessing sustainability but should be paired with deeper audits for a complete picture.

¹²⁵ see Website Carbon Calculator: How does it work?

¹²⁶ see Website Carbon Calculator: FAQ

¹²⁷ see Website Carbon Calculator: How does it work?

¹²⁸ see Ecograder: How it Works

3.4.4 CO2.js

CO2.js is an open-source JavaScript library from the Green Web Foundation that combines leading carbon-accounting models and datasets.¹²⁹ It defaults to the Sustainable Web Design Model but also includes the older “OneByte” model for comparison, along with grid-intensity data and hosting information from the Green Web dataset.

Built for easy integration, CO2.js works with automated workflows, enabling real-time carbon estimates in analytics or monitoring tools. Its JavaScript base supports both client- and server-side use, giving teams flexible options for embedding emissions tracking.¹³⁰

3.4.5 Other Key Considerations

Measuring tools continue to evolve—some now use direct machine-level power data for greater accuracy, while others offer faster, top-down estimates. Though useful, these tools depend on assumptions about average device efficiency and user behavior, so refining data inputs is advised.¹³¹

No single tool fits all needs. Services relying on cloud compute may benefit from cloud-carbon-footprint software that factors in CPU use and data center location.¹³² Simpler tools like Website Carbon Calculator and Ecograder are helpful for raising awareness and kickstarting sustainability efforts.

3.5 User Behavior and Perceptions Related to Sustainability

User behavior plays a key role in digital sustainability, influencing how well eco-friendly design interventions perform over time. Optimized performance and minimalist design appeal to users who value speed and efficiency. Even slight delays in load times can hurt engagement, highlighting the need for performance-focused sustainable web design.¹³³

¹²⁹ see Irani 2023: Curious about driving the transition to a fossil-free internet?

¹³⁰ see Irani 2023: Curious about driving the transition to a fossil-free internet?

¹³¹ see Sustainable Web Design: Estimating Digital Emissions

¹³² see Irani 2023: Curious about driving the transition to a fossil-free internet?

¹³³ see Connective 2025: Sustainable Web Design

Minimalist visuals not only improve usability but also cut data use and energy consumption. Features like dark mode, which saves energy on OLED displays, reflect growing interest in designs that combine aesthetics with sustainability.¹³⁴

Nudging users toward eco-friendly choices—such as setting sustainable options as defaults—leverages cognitive biases to promote responsible behavior.¹³⁵

Persuasive elements like real-time environmental feedback and storytelling further reinforce sustainable habits.¹³⁶ These techniques are grounded in behavioral science principles, including heuristics, framing, and social norms.¹³⁷

Despite positive reception, user awareness of these features varies, making clear communication crucial.¹³⁸ When sustainable choices also improve usability—like faster load times or better navigation—users respond even more positively.¹³⁹

Ethical nudging should preserve autonomy. Transparent, non-intrusive feedback can foster intrinsic motivation while respecting user control.¹⁴⁰

Overall, aligning performance, aesthetics, and ethical persuasion helps embed sustainability into digital design while enhancing user experience.

3.6 Existing Sustainability Guidelines

Numerous sustainability guidelines have emerged to offer practical recommendations, measurable criteria, and aspirational principles for reducing the environmental impact of digital products and services.

One key framework is the Web Sustainability Guidelines (WSG) 1.0, developed by the W3C Sustainable Web Interest Group. It includes 93 guidelines and 232 success criteria across four

¹³⁴ see Connective 2025: Sustainable Web Design; see Hulleberg et al. 2023: The Awareness and Practices of Web Developers Toward Sustainable Web Design

¹³⁵ see The Geekettez: Enhancing User Experience for Sustainability

¹³⁶ see Gary McGovern: Sustainable Website Design; see Strikingly: User-Friendly and Sustainable Business Websites Design

¹³⁷ see Rabab Ali Abumalloh et al. 2024: Nudging Techniques

¹³⁸ see Hulleberg et al. 2023: The Awareness and Practices of Web Developers Toward Sustainable Web Design

¹³⁹ see Connective 2025: Sustainable Web Design

¹⁴⁰ see Rabab Ali Abumalloh et al. 2024: Nudging Techniques

areas: UX Design, Web Development, Infrastructure, and Business Strategy.¹⁴¹ Built on prior work and shaped by collaboration, the WSG sets measurable targets for web sustainability.¹⁴²

It uses an “impact and effort” scale to identify quick wins and longer-term improvements, similar to WCAG to embed sustainability alongside accessibility.¹⁴³

Colas raises concern that many criteria are overly vague or low-impact, approximately 60 out of 238 criteria were considered too broad.¹⁴⁴ Similarly, Blum argues that the benefits are too abstract, lacking validation of their real-world impact. Extensive documentation further complicates adoption (93 guidelines with over 40,000 words at a high reading level) complicates the adoption process, particularly due to the absence of a prioritized and no “top 10” action plan.¹⁴⁵ Jut-so Digital criticizes the “one-size-fits-all” approach and that they may be difficult to adopt, especially for smaller teams.¹⁴⁶ Lastly, Datson and Arora present findings that some practices endorsed by the WSG do not consistently lead to energy savings. In their experiment with an LCD device, display brightness had little impact on power use between light and dark mode—but 80% of participants significantly increased screen brightness when using dark mode.¹⁴⁷

The Sustainable Web Manifesto complements the WSG by outlining six core principles—Clean, Efficient, Open, Honest, Regenerative, and Resilient—that shape technical standards.¹⁴⁸

The Ethical Web Principles also from W3C, expand the focus to include accessibility, privacy, and social inclusion, positioning sustainability within broader digital responsibility.¹⁴⁹

These principles provide high-level direction but don’t include specific carbon-reduction methods.¹⁵⁰

In parallel, organizations are adopting broader standards such as ISO 14001 and the Global Reporting Initiative (GRI) align digital practices with (ESG) goals.¹⁵¹ The W3C guidelines reference these frameworks, like the GRI, to enhance transparency and accountability.¹⁵²

¹⁴¹ see Alexander Dawson (Editor) 2025: Web Sustainability Guidelines (WSG)

¹⁴² see Tzviya Siegman 2023: Introducing Web Sustainability Guidelines

¹⁴³ see 2025: Web Sustainability Guidelines (WSG)

¹⁴⁴ see Colas 2023: My rating of web sustainability guidelines

¹⁴⁵ see Andy Blum: Web Sustainability Guidelines | andy-blum.com

¹⁴⁶ see jut-so Digital Agency 2023: Introducing Web Sustainability Guidelines 1.0

¹⁴⁷ see Zak Datson/Mohit Arora: Does what you scroll burn coal? Mythbusting energy consumption on the web; see Datson: The Dark Side of Dark Mode

¹⁴⁸ see Wholegrain Digital: Sustainable Web Manifesto

¹⁴⁹ see Daniel Appelquist/Hadley Beeman/Amy Guy: Ethical Web Principles

¹⁵⁰ see W3C 2024: Ethical Web Principles is a W3C Statement

¹⁵¹ see Scott Lane: Harnessing the Power of ISO 14001

¹⁵² see Alexander Dawson (Editor) 2025: Web Sustainability Guidelines (WSG)

Tools from the Green Web Foundation such as CO2.js and green hosting databases, support real-time tracking and reduction of website emissions.¹⁵³ Community-driven resources like ClimateAction.tech and Branch Magazine offer practical checklists and best practices.¹⁵⁴

Across frameworks, common strategies include minimizing data transfer, using efficient code, and choosing green hosting—measures that improve both sustainability and user experience. Many guidelines now recommend continuous optimization through audits and refinements. These approaches show industry-wide alignment around reducing digital waste, improving performance, and designing environmentally responsible, user-friendly products.

Sustainability integration also drives business value: faster load times lower energy use and boost engagement, SEO, and conversion rates.¹⁵⁵ Companies benefit from improved reputation and regulatory compliance.¹⁵⁶

Finally, these guidelines promote not just environmental but also social and economic resilience. By encouraging inclusive design and ethical practices, they help digital products reach wider audiences and adapt to change.¹⁵⁷

In summary, frameworks like the WSG, the Sustainable Web Manifesto, and the Ethical Web Principles, provide a roadmap for building digital products that are sustainable, ethical, and high-performing—benefiting users, businesses, and the planet alike.

3.6.1 Evaluation

Although the WSG and the SWM both seek to address the significant environmental and social impacts of digital technologies, several gaps emerge when viewed through the lens of UX design integration.

The WSG includes 93 guidelines with 232 success criteria.¹⁵⁸ While comprehensive, the sheer volume can overwhelm teams who lack dedicated sustainability specialists. An early review of the WSG notes that approximately 60 of these criteria are “too broad,” risking confusion or

¹⁵³ see Green Web Foundation: The Green Web Directory

¹⁵⁴ see ClimateAction.Tech: Community; see Branch: Branch Magazine Issue 8

¹⁵⁵ see Olson-Royal 2023: Web Performance Optimization and Sustainability

¹⁵⁶ see Retail Insider 2025: How Sustainable Web Design Benefits Businesses and the Planet

¹⁵⁷ see Alexander Dawson (Editor) 2025: Web Sustainability Guidelines (WSG)

¹⁵⁸ see Alexander Dawson (Editor) 2025: Web Sustainability Guidelines (WSG)

paralysis for practitioners.¹⁵⁹ This density makes it hard for UX teams to quickly identify which recommendations to prioritize and in what order.

Although the guidelines emphasize iterative design and user research, they do not consistently map sustainability considerations onto UX frameworks. As a result, practitioners may struggle to see how or when to integrate environmental goals into typical user flows, wireframing sessions, or usability testing cycles. A significant part of the guidelines focuses on back-end optimization, hosting solutions, and coding efficiency. While these measures are vital, they often lie outside the direct purview of UX designers, whose focus is on information architecture, interaction design, and user research. Hence, the guidelines risk being dismissed as “too technical” if UX and development teams lack a shared framework or clear channels of collaboration.

The SWM underscores broad principles like “Clean,” “Efficient,” “Open,” “Honest,” “Regenerative,” and “Resilient”.¹⁶⁰ However, it offers limited operational guidance on how to translate these ideals into the granular tasks of a UX design sprint, such as drafting user stories, prototyping features, or running stakeholder workshops. While inspiring, these principles often require further elaboration before they can be actioned in practice.

Although both the WSG and the SWM encourage carbon tracking, reduced data transfer, and renewable energy usage, they do not always provide robust measurement protocols or standardized metrics to validate sustainability claims. Without more precise methods, organizations risk deploying superficial “green” labels for marketing without substantially reducing resource consumption or emissions.

Beyond telling organizations to “reduce data loads,” the guidelines devote comparatively little attention to nudging or incentivizing end-users to adopt more eco-friendly behaviors, like using “low-data modes” or adjusting content consumption. Research on behavioral design suggests that bridging the “intention–action gap” requires strategic feedback loops and user involvement, which remain underdeveloped in the current guidelines.¹⁶¹

While certain WSG sections address organizational strategy, the guidelines may be challenging to implement for teams operating within tight budgets, rigorous release cycles, or limited buy-in

¹⁵⁹ see Colas 2023: My rating of web sustainability guidelines

¹⁶⁰ see Wholegrain Digital: Sustainable Web Manifesto

¹⁶¹ see Rabab Ali Abumalloh et al. 2024: Nudging Techniques

from executive stakeholders. Tying sustainability to business value may require clearer, evidence-based justifications than are presently outlined.

From a UX standpoint, the WSG and the SWM provide an important foundation but would benefit from clearer mapping to recognized UX workflows, prioritization frameworks, and behavioral design strategies. Although they articulate a broad vision of a greener, more equitable digital future, practical concerns—such as short design sprints, multiteam collaboration, and budget constraints—can impede real-world adoption.

4 Interview analysis

This chapter presents the consolidated results from a series of seven in-depth interviews with experts in the field of sustainable web design and UX. Building on the methodological framework outlined earlier, the analysis focuses on specific challenges, practical barriers, and design-relevant insights that inform the definition of problems and requirements in sustainable UX.

4.1 Selection of interviewees

Experts were selected based on their extensive experience and expertise in the field of sustainable web design and UX. The selection criteria included many years of practice in UX design, specific knowledge in the integration of sustainability principles or active involvement in relevant projects. The participants represent different roles and perspectives within the UX community, including UX designers, sustainable web design experts and a pioneer in the field of UX who also takes sustainability aspects into account.

In total, seven experts participated:

- Erik Berkheimer, UX Designer at Team23
- Verena Hubing, UX Designer at SAP
- Noah Knauss, UX Architect at 21TORR
- Peter Post, UX- and Servicedesign Consultant
- Sandy Dähnert, UX Freelancer GreenTheWeb
- Sebastian Flock, Founder acb Studio
- Don Norman, UX Pioneer & Co-founder of the Nielsen Norman Group

The interviews were transcribed and then subjected to a thematic analysis. Central themes and patterns were identified, which served as the basis for the problem definition and the requirement definitions of this thesis. This analysis made it possible to gain deeper insights into the practical challenges and solutions that arise in the context of sustainable UX design.

4.2 Interview findings

The analysis highlighted four main categories, each underpinned by illustrative excerpts from the interviews. These categories collectively shape the “problem space” for sustainable web design and inform the subsequent requirements.

Multiple experts stressed that sustainability is not limited to environmental measures but extends to social and economic dimensions.

“Nachhaltigkeit ist... soziale als auch ökologische... ökonomische Bereiche.”¹⁶²

“Nachhaltigkeit kann man im Sinne von Langlebigkeit sehen im digitalen Kontext.”¹⁶³

Participants see sustainability not only as an environmental concept but as a system that includes user inclusion (accessibility, mental well-being), budget viability, and resource management.

All participants acknowledged that while sustainability is desirable, projects are subject to budgetary, time, and technological constraints. Several interviewees described real-world tensions that can arise when trying to integrate eco-friendly considerations into standard workflows. Among them, Erik Berkheimer emphasized that organizations typically need *motivation* in order to prioritize sustainability:

“...Weil du kannst nicht von einer große Masse an Menschen einfach erwarten, dass sie das machen. Also es funktioniert meiner Meinung nach bei ganz vielen Themen nicht. Und du brauchst Motivationsfaktoren und dann musst du über Förderungen ... gehen.”¹⁶⁴

He also noted that frameworks like human-centered design must often be adapted based on a project’s scope and budget. Instead of applying the full process, his team selectively uses methods—particularly in prototyping and implementation—to fit constraints.

Other interviewees (e.g., Sandy Dähnert) also cited limited time or finances as reasons sustainability measures are scaled back. Nevertheless, as Noah Knauss observed, once teams invest the necessary startup effort, a more eco-friendly approach can become self-sustaining:

“Also für uns im Arbeitsalltag hat das nur einen Initialaufwand, den das mit sich bringt. Wir müssen jetzt am Anfang einmal rein starten in das Thema und das wirklich etablieren. Ab dem Zeitpunkt wird das quasi eine Selbstverständlichkeit, ein Selbstläufer.”

A major recurring theme was the importance of collaboration across organizational silos: marketing, design, engineering, management, and even external stakeholders like clients and end-users.

“...and by getting everybody together, let's forget what system, what division we're in, let's see what's best for the company. You start to realize where all these issues are, and then you try to figure out how to work around them.”¹⁶⁵

¹⁶² Sandy Dähnert 2025: Interview with Sandy Dähnert

¹⁶³ Noah Knauss 2024: Interview with Noah Knauss

¹⁶⁴ Erik Berkheimer 2024: Interview with Erik Berkheimer

¹⁶⁵ Norman 2025: Interview with Don Norman

Participants agreed that integrative collaboration fosters mutual responsibility and stronger decisions, while siloed thinking limits sustainable outcomes. From a UX perspective, Berkheimer described how his agency navigates “*super viele unterschiedliche Projekte*” and “*sehr unterschiedliche Rollen*”, requiring close coordination to uphold consistent standards.¹⁶⁶ Sebastian Flock underlined how diverse, cross-functional teamwork can support sustainability outcomes:

“Je diverser die Teams ... umso nachhaltiger kann ein Produkt werden.”¹⁶⁷

Involving developers, designers, strategists, and stakeholders early helps spot inefficiencies—like heavy images or code—before they’re locked into final products.

Participants noted that while sustainability is the goal, it often conflicts with tight deadlines, profit targets, or internal politics. Don Norman stressed the importance of presenting executives with solutions instead of problems:

“You can’t go and tell the executives that they’re doing things wrong because that doesn’t do any good... It’s not that I didn’t want to know, good executives need to know what’s wrong, but what they really want is what’s the answer... So what you have to do is figure out an alternative strategy for the company that is good for the world, but also is good for the company.”¹⁶⁸

Interviewees mentioned various eco-friendly tools and practices—from dynamic image optimization (e.g., Cloudinary) to carbon audits via Ecograder or Website Carbon Calculator. Accessibility checks and progressive enhancements also arose as common practices, highlighting that social inclusion is key to truly “green” solutions.

Noah Knauss, however, raised concerns about AI conflicting with sustainable goals:

“KI ist halt eigentlich das Gegenteil von Sustainable. Das, was da im Hintergrund alles passiert, ist absolut nicht das, was eigentlich von Sustainable UX benötigt wird, sondern eigentlich der Feind davon...”¹⁶⁹

Many participants noted tensions between business goals and “ideal” sustainability. Peter Post emphasized that service design and user-centered approaches can encourage more resource-

¹⁶⁶ Erik Berkheimer 2024: Interview with Erik Berkheimer

¹⁶⁷ Sebastian Flock 2025: Interview with Sebastian Flock

¹⁶⁸ Norman 2025: Interview with Don Norman

¹⁶⁹ Noah Knauss 2024: Interview with Noah Knauss

efficient models—especially in the context of circular economy solutions. This often means guiding behavior at key touchpoints:

“Da geht es um Manipulation. Wie kann man Leute beeinflussen bei Nudging-Techniken, Behavioral-Design-Techniken ... man macht es ihnen leicht und bietet ihnen einen attraktiven Einstieg.”

Post argued that UX and service design can reduce friction, promote reuse or sharing, and help shift business models toward circular, longer-term revenue streams. Still, limited budgets and client-side demands like reporting often hinder progress.

A common theme across interviews was the clash between sustainability goals and business constraints. Eco-friendly guidelines requires ongoing support despite cost, time, and knowledge limitations. Interviewees also underlined the need to move beyond “green checklists” toward adaptive frameworks that prioritize resource awareness and social equity from the start. Most advocated for inclusive, iterative processes that bridge departmental silos.¹⁷⁰ This kind of collaboration improves alignment, reveals constraints, and supports realistic sustainability trade-offs.

Based on these insights, key strategies include: conducting sustainability audits throughout the project lifecycle; launching cross-disciplinary workshops early on; and providing training on lightweight design, inclusive language, mental health, and accessibility. These efforts foster dialogue around balancing environmental, social, and economic goals. Finally, promoting internal policies aligned with accessibility legislation could help normalize sustainable UX practices. Embedding these steps into routine workflows reduces friction and aligns business outcomes with planetary well-being.

¹⁷⁰ see Norman 2025: Interview with Don Norman; see Peter Post 2025: Interview with Peter Post

5 Problem and Requirements

This chapter brings together insights from the literature review and expert interviews to support the development of an artefact that embeds sustainability into UX design. It balances practical methodologies with long-term ecological and business objectives, emphasizing quality user experiences alongside environmental, social, and economic sustainability.

5.1 Findings from the Literature Review

Key themes from the literature review reveal both foundational theory and actionable guidance for sustainable UX. The review tracks how UX has evolved to prioritize not just usability but also ethical, measurable, and systemic approaches.

5.1.1 Evolving Perspectives on UX and Sustainability

UX thinking has shifted from focusing solely on usability and emotional engagement to a more holistic view. Recent studies, including those by Don Norman, push for a humanity-centered approach that addresses broader environmental and societal responsibilities.¹⁷¹ This shift, calls on designers to address systemic interdependencies and ethical responsibilities beyond the individual user.¹⁷²

5.1.2 Sustainability as a Core Design Imperative

Sustainability has emerged as a critical concern within digital design. The literature highlights that ICT contributes 2.1%–3.9% of global emissions, with the internet ranking as the fourth largest emitter if treated as a country.¹⁷³

Data center water use and e-waste from short product lifecycles highlight the need for more sustainable digital practices.¹⁷⁴

Practices like efficient coding, reduced data transfer, and renewable hosting improve both site performance and environmental impact.

¹⁷¹ see Kauer-Franz/Franz 2023: Usability und User Experience Design, p. 44; see Norman 2023: Design for a better world, p. 125

¹⁷² see Norman 2023: Design for a better world, pp. 181–183

¹⁷³ see Freitag et al. 2021: The real climate and transformative impact of ICT, pp. 2–4; see European Commission. Joint Research Centre./IEA. 2024: GHG emissions of all world countries., p. 52

¹⁷⁴ see Zhang 2024: Data Center Water Usage

5.1.3 Circular Economy and Resource Efficiency

Literature promotes circular economy principles as essential for sustainable web design.

Key guidelines include:

Designing for durability and easy updates lowers resource use.¹⁷⁵

Reusing components and design systems reduces digital waste¹⁷⁶

Clean, modular code helps counteract planned obsolescence.¹⁷⁷

5.1.4 Measurement and Quantification of Sustainability

Tools for assessing environmental impact include:

The SWDM, an open-source method for calculating emissions across infrastructure, allowing local data input to improve accuracy.¹⁷⁸

The Website Carbon Calculator, it estimates emissions from URL data transfers using global averages; offers general advice but no tailored recommendations.¹⁷⁹

Ecograder, which combines performance and carbon metrics into an “eco-score,” but may miss incremental content loads.¹⁸⁰

And CO2.js, a real-time carbon tracking library with integrated hosting and grid data, suitable for automated workflows.¹⁸¹

These tools raise awareness and offer guidance, but their reliance on averages and snapshots shows a need for more nuanced, ongoing measurements.

5.1.5 Existing Sustainability Guidelines and Frameworks

The literature identifies several key frameworks guiding sustainable web design. These aim to reduce digital waste, optimize performance, and align digital products with environmental, social, and economic sustainability objectives, though critical evaluations reveal gaps in implementation.

¹⁷⁵ see Erik Fiala 2024: Designing for the Circular Economy

¹⁷⁶ see Jason Bodell 2023: Building A Greener Online Future With Sustainable Web Design

¹⁷⁷ see Erik Fiala 2024: Designing for the Circular Economy; see Decker: About the Solar Powered Website

¹⁷⁸ see Sustainable Web Design: Estimating Digital Emissions

¹⁷⁹ see Website Carbon Calculator: Website Carbon Calculator v3 | What's your site's carbon footprint?

¹⁸⁰ see Ecograder: How it Works

¹⁸¹ see Green Web Foundation: CO2.js

5.1.5.1 Web Sustainability Guidelines (WSG) 1.0:

Created by the W3C Sustainable Web Interest Group, WSG 1.0 includes 93 guidelines and 232 criteria across UX, development, hosting, and strategy. Developed through a collaborative, standards-based process, it positions sustainability as a core design concern.¹⁸²

However, critics argue many criteria are too vague or impractical. Colas found ~60 of 238 criteria overly broad or questionable.¹⁸³ Blum noted a lack of validation and case studies.¹⁸⁴ Jut-so Digital called out the “one-size-fits-all” approach, which may not suit smaller teams.¹⁸⁵ Datson and Arora showed some practices, like dark mode, don’t always yield real savings, e.g., users increasing screen brightness.¹⁸⁶

5.1.5.2 Sustainable Web Manifesto:

This non-technical, ethical declaration outlines six principles: Clean, Efficient, Open, Honest, Regenerative, and Resilient. While abstract, it has influenced cultural attitudes and helped shape formal standards.¹⁸⁷

5.1.5.3 Ethical Web Principles:

Published by the W3C, these high-level principles address broader concerns—accessibility, privacy, and sustainability—without prescribing technical steps. They complement other frameworks by establishing ethical intent.¹⁸⁸

Collectively, these guidelines aim to align digital products with environmental, social, and economic sustainability objectives.

Critical Evaluation of Existing Guidelines

Critical insights from the literature reveal several gaps in current sustainability guidelines:

Too many criteria can overwhelm teams. Few connect clearly to UX workflows like Agile or Design Thinking. Many focus on back-end practices, offering little for UX designers. These often lack actionable direction, risking superficial efforts. Few strategies address user behavior or intention–action gaps. Time, budget, and skills often limit real-world application.

¹⁸² see Alexander Dawson (Editor) 2025: Web Sustainability Guidelines (WSG)

¹⁸³ see Colas 2023: My rating of web sustainability guidelines

¹⁸⁴ see Andy Blum: Web Sustainability Guidelines | andy-blum.com

¹⁸⁵ see jut-so Digital Agency 2023: Introducing Web Sustainability Guidelines 1.0

¹⁸⁶ see Zak Datson/Mohit Arora: Does what you scroll burn coal? Mythbusting energy consumption on the web

¹⁸⁷ see Wholegrain Digital: Sustainable Web Manifesto

¹⁸⁸ see Daniel Appelquist/Hadley Beeman/Amy Guy: Ethical Web Principles

These critiques call for a more user-centered, context-sensitive approach that ties sustainability to UX realities and business needs.

5.1.6 User Behavior and Perceptions

Empirical evidence shows that user behavior and perceptions are central to the success of sustainable design. Streamlined designs enhance usability while lowering data use and energy consumption. Real-time feedback and nudges can guide users toward greener choices without limiting autonomy. Users generally accept design compromises—like dark mode or reduced media quality—when they improve speed and navigation.

5.1.7 Integration into UX Design Processes

Sustainability aligns well with established UX design processes such as Design Thinking, Agile UX, Lean UX, and Human-Centered Design. Iterative design approaches with ongoing feedback and testing support embedding sustainability throughout the design lifecycle.

5.1.8 Conclusion

The literature confirms that integrating sustainability into UX design improves both environmental impact and user experience. It also offers business benefits like better performance and engagement. These findings lay the groundwork for creating a practical framework that equips designers to integrate eco-conscious practices across all design phases, supporting the next stages of this study's problem analysis and solution development.

5.2 Problem Context

The digital sector's carbon footprint, driven by energy and water demand of websites, apps, and data centers, underscores the need for sustainable UX practices. Even small design improvements can have large-scale ecological benefits. This shift reflects a broader move from human-centered to planet-centered design, prioritizing long-term societal and environmental well-being.

Yet, many organizations face barriers to adopting sustainable practices. Business priorities often favor short-term gains, while standard UX methods focus on usability and aesthetics. Existing guidelines, such as the W3C's Web Sustainability Guidelines, are too broad for daily use, and

ethical declarations like the Sustainable Web Manifesto lack actionable detail. This gap highlights the need for realistic, context-sensitive solutions that designers can easily adopt. Organizational support is also critical. While leaders increasingly value sustainability, they want proof that eco-conscious practices can drive both impact and profit. UX professionals must therefore show how reduced data loads, efficient design, and energy-aware interactions can align with business goals.

5.2.1 Key Tension and Challenges

The interviewees noted that tight schedules and limited budgets often deprioritize sustainability. Design teams must deliver quickly, leaving little room to experiment with greener approaches. Without clear metrics or leadership support, sustainability efforts risk becoming shallow. Superficial changes can erode user trust and dilute environmental goals. Interviewees emphasized the need for genuine commitment and transparent benchmarks.

Successful implementation requires cross-team collaboration. However, many teams work in isolation—designers may optimize layouts, but without developer or infrastructure alignment, the final product may not reflect these gains.

Existing frameworks often don't map well to UX tools like personas or wireframes. Designers lack a clear process for embedding sustainability into everyday practice. Ethical guidelines like the Sustainable Web Manifesto provide ideals but not practical steps.

While many companies express support for sustainability, turning that vision into actionable project goals remains difficult. Interviewees noted that leadership is open to initiatives that demonstrate both environmental and financial return. Designers must therefore quantify and clearly communicate the benefits of sustainable features.

5.2.2 Requirements Framework

The requirements are grouped thematically, each directly linked to issues from the literature and expert interviews. In summary:

- **Requirement 1: Efficient Integration** — focuses on low-overhead design practices and smart resource use.
- **Requirement 2: Measurable Sustainability Metrics** — calls for clear indicators of environmental and social impact.
- **Requirement 3: Cross-Functional Collaboration** — addresses siloed teams through shared roles and documentation.

- **Requirement 4: Alignment with UX Processes** — integrates sustainability into standard UX methods.
- **Requirement 5: Balanced Environmental and Social Focus** — promotes both technical efficiency and inclusive, ethical design.
- **Requirement 6: Iterative Audit Checkpoints** — ensures ongoing evaluation throughout the design lifecycle.

To manage budget and time constraints, the framework must provide templates and workflows easily embedded in fast-paced projects. Step-by-step guidance throughout the UX process ensures that sustainability doesn't add excessive overhead.

To avoid greenwashing, the framework must include concrete sustainability metrics that track environmental and social performance. These metrics, like data usage, energy load, and inclusivity, will promote accountability and move beyond symbolic gestures.

To tackle siloed collaboration, cross-functional checkpoints and shared tools must be integrated into common development processes. Clear roles, documentation, and alignment with sprints and retrospectives ensure all stakeholders contribute to sustainability efforts.

Alignment with standard UX processes is key. The framework should provide guidelines on how to adapt common methods, like personas, wireframes, journey maps, to reflect sustainability. For example, personas can include ecological habits, wireframes can flag bandwidth-heavy elements, and journey maps can spotlight eco-touchpoints.

To ensure that environmental and social dimensions receive balanced attention, a dual-focused requirement is needed. On the environmental side, the framework must propose tactics for minimizing data loads, server calls, and overall energy consumption. On the social side, it must incorporate guidelines that uphold inclusive design principles, such as accommodating assistive technologies, recognizing diverse cultural contexts, and supporting lower-end devices. Moreover, it must highlight ethical considerations pertinent to persuasive design techniques, ensuring that nudges meant to reduce resource usage do not inadvertently violate user autonomy or well-being.

Finally, iterative audit checkpoints should span the entire design lifecycle. This requirement envisions systematically scheduled evaluations—during user research, design prototyping, code implementation, and post-launch analytics—that enable teams to identify and rectify environmentally inefficient practices in a timely manner. The inclusion of checklists and

recommended tools for auditing metrics ensures that even under tight project constraints, these evaluations remain practical and achievable

6 Artefact development process

The process follows design science research methodology, structured into three main phases: Explicate Problem, Define Requirements, and Design & Development. The framework developed represents a first draft, providing the foundation for future stakeholder testing and refinement.

6.1 Explicate Problem Phase

The first phase involved clarifying the problem context, defining the problem precisely, positioning and justifying it, and identifying root causes.

The research began by identifying the practice domain as UX design for web-based platforms with a specific focus on sustainability integration. This domain sits at the intersection of user experience design and environmental sustainability concerns, representing an emerging area of professional practice.

Key stakeholders were identified across the digital product lifecycle based on literature review as well as interview analysis.

The initial concern about sustainability in digital design was formulated as: "Sustainability is not sufficiently integrated into standard UX practices leading to missed opportunities for reducing the digital carbon footprint and ensuring socially responsible design."

This formulation narrowed the focus to specific challenges:

- Lack of clear, actionable sustainability guidelines within UX design processes
- Inadequate measurement systems for eco-friendly design practices, raising concerns about potential greenwashing
- Organizational barriers including budget constraints, time limitations, and siloed team structures

This helped limit the scope of the research while maintaining focus on the core issues.

The problem was positioned within two contexts.

First, the organizational and technological context of contemporary UX practice, characterized by:

- Short project cycles and tight deadlines
- Traditional UX frameworks prioritizing user satisfaction over sustainability
- Siloed team structures inhibiting cross-functional collaboration

Second, the broader sustainability challenges, including:

- Rising ICT emissions and their contribution to climate change
- Resource inefficiencies in digital product development
- Social impacts of digital products

The problem justification addressed both environmental and business concerns. The research demonstrated that sustainable UX design leads to practical benefits including faster load times, reduced data transfer, lower energy consumption, and improved user experience, aligning environmental goals with business objectives.

Root cause analysis identified four fundamental issues:

1. Insufficient integration of sustainability into established UX processes and methods (wireframes, prototypes, user journeys)
2. Limited cross-functional collaboration leading to misalignment between design, development, and business strategies
3. Absence of practical, measurable metrics (e.g., real-time data on energy usage, CO₂ emissions) to validate sustainability efforts
4. Resource constraints (time, budget, expertise) forcing sustainability considerations to be deprioritized in early project phases

These root causes provided direction for the requirement definition phase, ensuring that the developed artefact would address fundamental issues rather than merely treating symptoms.

6.2 Define Requirements Phase

The second phase focused on outlining the artefact and eliciting specific requirements for its development. The artefact type was selected as a framework (model/method) designed to integrate sustainability into UX design processes. The "Sustainable UX Integration Framework" was conceptualized as a set of tools, templates, and workflows that would embed eco-friendly guidelines throughout the design lifecycle. This choice of artefact type was determined by the nature of the explicated problem, which indicated the need for systematic guidance rather than a single tool or isolated technique. The framework was described at an overview level as an adaptable, modular model designed to be integrated within standard UX processes, from user research to post-launch audits.

Requirements were elicited from two primary sources: literature review and interview analysis using grounded theory.

From the literature review, requirements emerged around:

- Efficiency considerations (minimalist designs, low data overhead)
- Measurable outcomes (integrated KPIs for energy/data use and accessibility)
- Alignment with established sustainability principles from the Sustainable Web Manifesto, W3C Web Sustainability Guidelines, and Ethical Web Principles

The interview analysis using grounded theory revealed requirements addressing real-world implementation challenges:

- Clear accountability mechanisms
- Embedded sustainability checks at key design and development stages
- Balanced technical and social considerations, ensuring that eco-design does not sacrifice accessibility or cultural inclusiveness

Requirements were organized into six categories:

1. **Efficient Integration:** The artefact must be low-overhead and easily insertable into existing UX workflows, minimizing disruption to established processes.
2. **Measurable Sustainability Metrics:** The framework must incorporate clear, quantitative parameters including carbon emissions, data transfer efficiency, and accessibility compliance.
3. **Cross-Functional Collaboration:** Roles and responsibilities must be clearly defined across design, development, and business units to prevent siloed sustainability efforts.
4. **Alignment with UX Processes:** Traditional UX methods (personas, journey maps, wireframes) must be adapted to include sustainability dimensions.
5. **Balanced Environmental and Social Focus:** Both ecological efficiency and ethical design considerations must be addressed.
6. **Iterative Audit Checkpoints:** Mandatory evaluation points must be defined throughout the design lifecycle.

6.3 Design and Development Phase

The third phase involved creating the artefact through four sub-activities: imagining and brainstorming, assessing and selecting, sketching and building, and justifying and reflecting.

Empathetic design principles were applied to ensure the framework would address the needs of all stakeholders. This involved attempting to understand the world through others' experiences

and emotions. Particular attention was paid to ensuring the framework would be adaptable to various organizational sizes and resource levels, acknowledging that sustainability implementation capabilities vary significantly across organizations.

Convergent thinking was applied to systematically assess the viability of each generated idea against the defined requirements. This evaluation process followed Simon's view of design as a process of narrowing the solution space through systematic exploration.¹⁸⁹

Various design ideas were developed, evaluated and prioritized. The evaluation was based on the previously defined requirements.

Ideas were prioritized based on:

- Potential to deliver measurable sustainability outcomes
- Minimal additional overhead to existing processes
- Feasibility given typical budgetary and time constraints

Trade-offs were identified, particularly between environmental benefits and potential impacts on user experience, ensuring that energy-saving features would not compromise accessibility or usability.

From the evaluation, core elements were selected for inclusion in the framework:

- Integration of sustainable audit checklists
- Modified design templates and agile workflows with embedded sustainability checkpoints
- Measurement tools for calculating digital carbon footprint
- Cross-functional accountability mechanisms

A sketch was developed mapping how the framework would operate throughout the UX lifecycle, from initial user research (incorporating sustainability questions) through ideation, wireframing, prototyping, development (with integrated performance metrics), and post-launch audits.

The structural blueprint included:

- A flowchart illustrating the step-by-step integration of sustainability tasks
- Key interfaces including audit checklist integration, KPI dashboards, and RACI charts
- Three primary modules:
 1. Templates and Checklists for each stage
 2. Measurement Tools integrating carbon calculators and performance tracking
 3. Collaboration Workflows defining cross-functional protocols

¹⁸⁹ see Johannesson/Perjons 2014: An Introduction to Design Science, p. 122

Each component of the framework was linked back to specific requirements:

- The audit checklists were designed to minimize overhead while ensuring measurable outcomes
- Cross-functional RACI charts addressed interview-identified needs for collaborative work
- Integrated performance metrics countered concerns about potential greenwashing

This justification process ensured alignment between the explicated problem, defined requirements, and developed artefact.

Following design science's iterative nature, next steps were outlined:

- Stakeholder demonstrations and pilot testing
- Periodic reviews to integrate user feedback
- Performance data collection from real-world application
- Re-assessment of organizational and technical constraints

The development process concluded development of a first prototype of the Sustainable UX Integration Framework. While representing a first draft, it establishes a foundation for further refinement through testing and validation.

7 Artefact

The Sustainable UX Integration Framework is grounded in the identified challenges, namely budgets constraints, tight deadlines, the threat of greenwashing, and a need for cross-functional collaboration. It also builds on the requirements laid out in the Problem and Requirements, including measurable sustainability metrics, alignment with established UX processes, balance between environmental and social goals, and regular audits at key project milestones.

7.1 Core Objectives

Efficiency: Embed sustainability with minimal impact on time and resources.

Measurability: Track quantifiable results to counter greenwashing.

Cross-Functional Alignment: Ensure organization-wide adoption.

Inclusivity: Address accessibility, cultural sensitivity, and autonomy.

Iterative Auditing: Embed sustainability checks at each project milestone, allowing teams to refine and adjust their approach in real time.

7.1.1 Guiding Principles

Minimalism: Reduce energy-intensive components, consistent with the Web Sustainability Guidelines' emphasis on streamlined layouts and code.

User-Centric Transparency: Communicate any eco-friendly features or limitations clearly to end-users.

Context-Specific Adaptation: Recognize that no single approach will fit every organization. Provide adaptable templates and modular workflows that can scale up or down based on budget, timeline, and technical infrastructure.

Measurable Outcomes: Track metrics for both environmental impact and user experience.

7.2 Artefact Design and Components

The Sustainable UX Integration Framework is organized into five main components: Tools, Workflows, and Templates; Integration with UX Processes; Measurement and Metrics; Iterative Audit Points; and Ethical and Social Considerations.

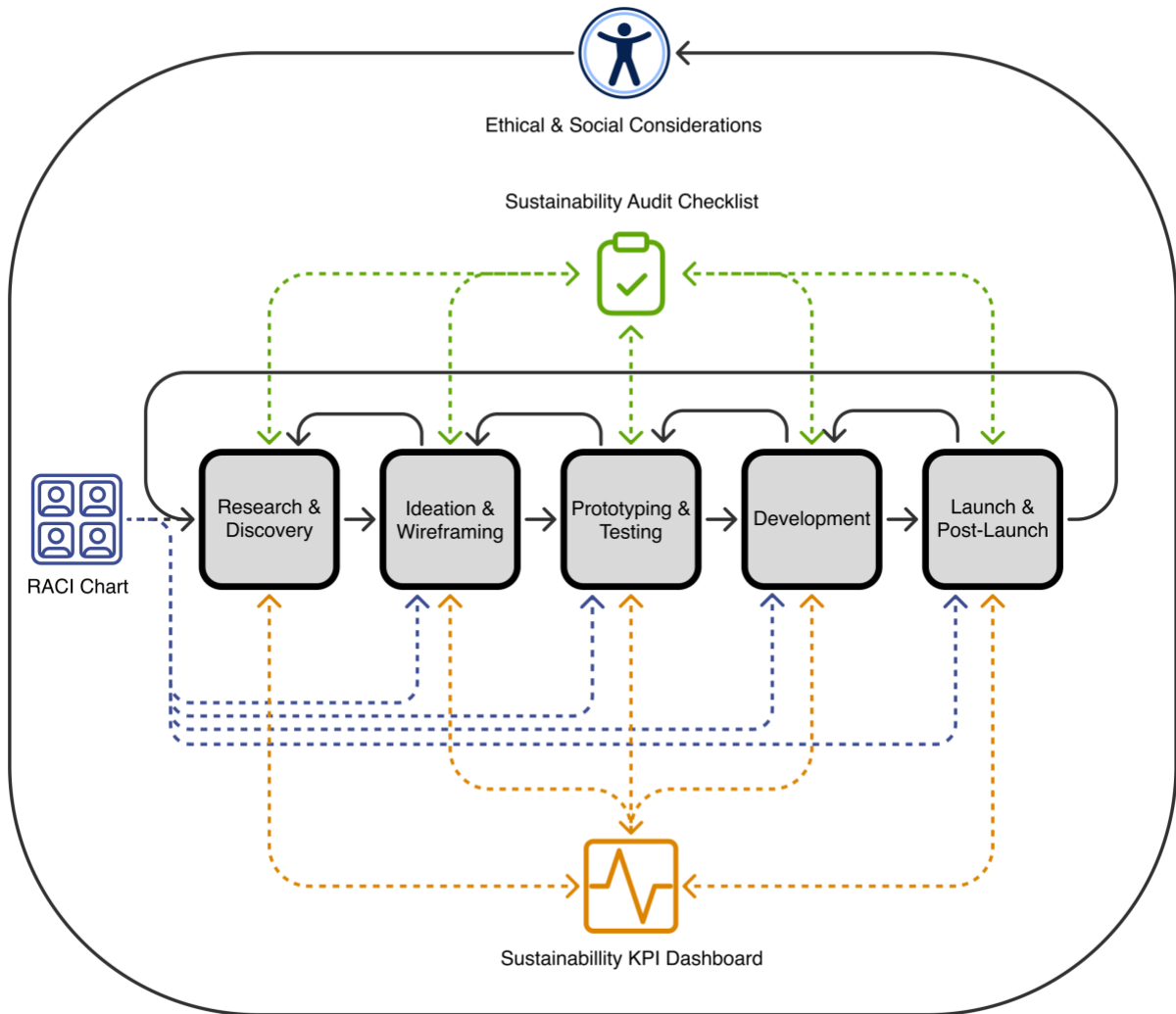


Figure 11: Sustainable UX Integration Framework

7.2.1 Tools, Workflows and Templates

Budget and time constraints often hinder the integration of sustainability measures. Therefore requirement 1 Efficient Integration states that the framework should provide efficient, low-overhead ways to embed eco-friendly design. To meet this, the framework proposes a lightweight audit checklist that helps teams quickly evaluate a design’s sustainability—for example, by checking if high-bandwidth media is minimized or images are optimized.

Sustainability Audit Checklist

1. Preliminary Planning & Integration

- Sustainability Briefing at project kickoff
- Define sustainability roles
- Update personas and journey maps with sustainability criteria

2. Environmental Efficiency

- Ensure media optimization through and minimize high-bandwidth assets
- Remove unused code and streamline dependencies
- Use green hosting solutions

3. Performance & Measurable Metrics

- Use tools to measure load times, data transfer and emissions
- Set and monitor limits for data transfer and energy use

4. Ethical & Social Considerations

- Clearly communicate eco-features with opt-out options to avoid dark patterns
- Ensure sustainability measures align with WCAG and inclusive standards

5. Iterative Improvement & Future Proofing

- Plan audits throughout each process phase
- Gather ongoing user and team feedback on sustainability features
- Organize regular cross-team sustainability workshops

Figure 12: Sustainability Audit Checklist

Also, a sustainability-adapted RACI matrix can clarify team roles, assigning responsibilities like aligning wireframes to minimalistic patterns or optimizing code, thereby fostering cross-functional collaboration. The framework also suggests eco-focused adaptations to existing design sprint templates, such as starting each sprint with a brief on W3C or Web Sustainability Guidelines. These tools address common time and budget constraints by integrating sustainable practices into standard workflows rather than treating them as separate tasks.

A Sustainability KPI Dashboard is a core monitoring tool in the Framework. The dashboard measures carbon emissions, data efficiency, load times, accessibility compliance, and eco-feature engagement. the dashboard helps teams make data-driven decisions aligned with sustainability goals. It integrates seamlessly with existing development workflows and CI/CD pipelines to provide insights without adding unnecessary overhead.

7.2.2 Integration with UX Processes

A key critique of current sustainability guidelines is their insufficient fit with day-to-day UX practice. In the user research phase, sustainability is integrated by asking users about preferences like “low-data mode” and annotating personas with data sensitivity or device limitations. This helps ensure sustainable features meet user needs and creates early metrics.

During ideation and wireframing, teams can assess feature necessity using Web Sustainability Guidelines and rough data estimates. This minimizes “feature creep” and supports minimalistic, fast-loading designs—meeting Requirement 5 by balancing environmental and social aspects.

In prototyping and usability testing, tools like Lighthouse and CO2.js can be built into test scripts to measure performance. This supports measurable sustainability.

In development, continuous integration practices track resource use at every commit. Techniques like lazy loading, tree-shaking, and minimal CSS frameworks, as recommended by the WSG, turn sustainable intentions into efficient code and addressing Requirements 4 and 5.

In the launch and post-launch phase, transparency is key. Sharing performance and sustainability metrics in release notes builds trust, drives adoption of eco features and minimizes the risk of greenwashing. This fulfills Requirement 6 by aligning user feedback and business outcomes with sustainability.

Overall, embedding eco tasks into UX workflows addresses the challenge of integrating sustainability into fast-paced, ROI-driven processes.

7.2.3 Iterative Audit Points

Sustainability audits span the full design lifecycle. Early audits evaluate whether a product is needed at all, based on WSG guidelines. The aim during this phase is to avoid pursuing resource-intensive projects that do not have a clear value proposition, with the audit being conducted once at project inception.

In design reviews, checklists should assess visuals and interactivity to catch high-impact design choices early. During sprints, carbon and performance scans ensure each new feature meets efficiency standards.

A pre-launch audit summarizes metrics and any trade-offs made, while post-launch audits use live data to fine-tune product performance. These recurring checkpoints ensure accountability and long-term eco integration.

7.2.4 Ethical and Social Considerations

Sustainability includes environmental and social responsibility. The framework promotes transparent nudging, such as default energy-saving modes with clear opt-out options—avoiding dark patterns and preserving user autonomy.

It also prioritizes accessibility by default, ensuring efficiency measures don't harm users who need high-contrast, enlarged text, or alt-inputs. Image compression, for example, must retain critical detail.

Lastly, inclusive collaboration is encouraged through cross-team workshops, helping break silos and surface hidden biases. These practices ensure sustainability efforts are ethical, inclusive, and user centered.

7.3 Implementation Approach

Implementation begins with phased adoption. A pilot project or sprint collects baseline data on load times, data use, and user feedback on eco-features. If results are positive, the framework can be scaled to other product lines.

To address time and budget constraints, the framework provides modular templates, including simple audit checklists and prebuilt RACI charts. These integrate seamlessly into existing workflows.

To avoid greenwashing, performance metrics, carbon estimates, and eco-feature adoption rates should be shared internally and externally. Each milestone should include a sustainability review to track measurable progress.

Cross-functional collaboration is essential. “Eco-huddles” or sustainability sprints involving design, development, marketing, and business teams ensure shared responsibility. RACI charts clarify roles, and aggregated metrics should be reported to executives to demonstrate the business value of eco-friendly design.

Finally, to navigate technological constraints, audits should prioritize efficiency—e.g., removing outdated libraries or compressing assets—over major infrastructure overhauls. For cloud-based systems, region-specific carbon data should be integrated; for on-premises systems, transitions to green data centers are recommended where feasible.

8 Discussion

8.1 Interpretation of Key Findings

The Sustainable UX Integration Framework demonstrates that sustainability and user-centered design can coexist when approached systematically. Integrating tools like checklists, templates, and RACI charts into UX workflows supports measurable performance improvements without compromising user experience.

Making sustainability a core design principle—rather than an add-on—allows environmental and usability goals to be addressed in tandem. Cross-functional collaboration is essential: clearly defined roles and shared responsibilities among teams foster more thorough implementation and break down organizational silos.

Incorporating sustainability into standard UX not only reduces energy consumption but may also streamline development through minimalism. This aligns with circular economy principles—favoring longevity, efficiency, and modularity—and can improve accessibility and performance. Iterative audits throughout the design lifecycle ensure sustainability remains a continuous focus, enabling teams to course correct as needed.

The research also highlights a key gap: existing sustainability guidelines, such as Web Sustainability Guidelines 1.0, are often too technical or abstract for UX practitioners. The framework fills this void by translating broad principles into actionable UX practices.

8.2 Implications for Theory and Practice

This framework advances the discourse on digital sustainability by translating abstract principles into actionable UX methods. With the ICT sector responsible for 2.1%–3.9% of global emissions and the internet ranking among the top polluters, a structured approach to sustainable UX design is increasingly urgent.

The findings show that eco-friendly design can improve load times and reduce energy use, aligning sustainability with performance optimization. This challenges the notion that ecological responsibility requires trade-offs and highlights potential benefits for user engagement and business outcomes.

By introducing measurable sustainability metrics into UX workflows, the framework promotes evidence-based practices and greater accountability. Transparency through published metrics helps mitigate greenwashing and reinforces ethical standards.

Cross-functional collaboration—across design, development, and business—supports a more holistic, inclusive approach to digital product development. The framework’s emphasis on accessibility, inclusivity, and ethical design further strengthens its applicability.

Successful implementation may inspire further research and case studies on scaling sustainability from pilot projects into routine digital design practice, potentially accelerating industry-wide adoption of eco-friendly digital practices.

8.3 Limitations

This research presents an initial framework that has not yet been tested or validated in real-world settings, limiting confidence in its practical effectiveness. As the design science process concluded at the development stage, the framework’s long-term impact remains theoretical.

Expert interviews and literature informed the framework, but the qualitative nature and limited sample may introduce bias, reducing generalizability across regions and organizational contexts.

Adaptation may be required for organizations with legacy systems or limited resources. While incremental implementation is proposed, this may weaken its impact in complex environments. Risks of greenwashing remain if sustainability metrics are applied superficially. Though the framework emphasizes transparency, full integration of eco-features cannot be guaranteed.

Limited quantitative data and reliance on snapshot metrics hinder the assessment of long-term environmental effects. Existing tools, such as Website Carbon Calculator and Ecograder, offer only partial insights. Finally, time and budget constraints may restrict broader adoption, limiting short-term scalability.

8.4 Recommendations for Future Research and Application

Based on the findings and limitations identified, several recommendations emerge:

1. Conduct pilot testing and stakeholder demonstrations to validate and refine the framework in real-world settings, starting with a single project or sprint as recommended in the implementation approach.
2. Enhance the framework by incorporating automated sustainability measurement tools, such as integration with CI/CD pipelines for real-time energy and data usage tracking.
3. Expand quantitative research to complement qualitative findings, using controlled experiments or performance data collection to measure the actual impact of eco-friendly design decisions over time.

4. Further investigate trade-offs between energy savings and user experience to optimize design decisions without compromising accessibility or usability, acknowledging that minimizing resource usage shouldn't come at the expense of accessibility features.
5. Develop training programs and cross-department workshops to foster interdisciplinary collaboration required for effective sustainable design, building on the recommended "eco-huddles" or sustainability sprints.
6. Explore potential policy advocacy or integration with industry standards to ensure sustainability metrics become standardized and endorsed by regulatory bodies.
7. Conduct longitudinal studies to assess long-term benefits and possible unintended consequences of integrating sustainability into UX processes.
8. Establish iterative audits as an ongoing process within design cycles, with regular updates based on user feedback and performance monitoring, expanding on the comprehensive audit process outlined in the artefact.

8.5 Conclusion

The Sustainable UX Integration Framework offers a promising approach to embedding environmental responsibility within digital design practices. By translating abstract sustainability principles into actionable UX methods, it provides a pathway toward eco-friendly digital products without sacrificing user experience or business goals.

Current sustainability guidelines, while valuable, often lack practical implementation guidance for UX practitioners. The framework addresses this through structured tools, measurable metrics, and iterative audits, fostering accountability and collaboration.

Its dual focus on environmental and social factors reflects a shift toward humanity-centered design. While further validation is needed, the framework lays a foundation for integrating sustainability into digital product development amid growing ecological concerns.

References

- Alexander Dawson (Editor) (2025): Web Sustainability Guidelines (WSG). URL: <https://w3c.github.io/sustainableweb-wsg/> (25.12.2024).
- Allanwood, Gavin/Beare, Peter (2019): User experience design: A Practical Introduction. Second edition. London: Bloomsbury Visual Arts.
- Allen, Myles R. et al. (2018): Framing and Context. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. Cambridge: Cambridge University Press, pp. 49–92. DOI: 10.1017/9781009157940.003.
- Amazon Sustainability: Water stewardship. URL: <https://sustainability.aboutamazon.com/natural-resources/water.html> (12.03.2025).
- Andy Blum: Web Sustainability Guidelines | andy-blum.com. URL: <https://andy-blum.com/articles/web-sustainability-guidelines/> (15.03.2025).
- Anna Kaley (2022): Setting UX Roles and Responsibilities in Product Development: The RACI Template. URL: <https://www.nngroup.com/articles/ux-roles-responsibilities/> (12.04.2025).
- Ben Linders (2023): Sustainable Software Systems Using Circular Economy Principles. URL: <https://www.infoq.com/news/2023/07/circular-economy-principles/> (26.02.2025).
- Blevis, Eli (2007): Sustainable interaction design: Invention & disposal, renewal & reuse. DOI: 10.1145/1240624.1240705.
- Branch: Branch Magazine: A Just and Sustainable Internet for All. URL: <https://branch.climateaction.tech/> (13.03.2025).
- Brundtland, G.H. (1987): Our Common Future: Report of the World Commission on Environment and Development. Geneva. URL: <http://www.un-documents.net/ocf-ov.htm>.
- ClimateAction.Tech: Community. URL: <https://climateaction.tech/community/> (13.03.2025).
- Colas, Thibaud (2023): My rating of web sustainability guidelines. URL: <https://thib.me/my-rating-of-web-sustainability-guidelines> (15.03.2025).
- Connective (2025): Sustainable Web Design: Building a Greener Digital Future. URL: <https://connectivewebdesign.com/blog/sustainable-web-design> (14.03.2025).
- Dam, Rikke Friis/Siang, Teo Yu (2022): The History of Design Thinking. URL: <https://www.interaction-design.org/literature/article/design-thinking-get-a-quick-overview-of-the-history> (15.12.2024).
- Daniel Appelquist/Hadley Beeman/Amy Guy: Ethical Web Principles. URL: <https://www.w3.org/TR/ethical-web-principles/> (13.03.2025).
- Danny van Kooten (2020): CO2 emissions on the web. URL: <https://www.dannyvankooten.com/blog/2020/website-carbon-emissions/> (16.12.2024).
- Datson, Zachary: The Dark Side of Dark Mode. In: BBC Research & Development,.

- Decker, Kris De: About the Solar Powered Website. URL: <https://solar.lowtechmagazine.com/about/the-solar-website/> (26.02.2025).
- Design Council (2024): The Double Diamond. URL: <https://www.designcouncil.org.uk/our-resources/the-double-diamond/> (15.12.2024).
- Design Studio (2023): What is Agile UX? Process & Methodology of Agile UX. URL: <https://www.designstudiouiux.com/blog/what-is-agile-ux/> (15.12.2024).
- Ecograder: How it Works. URL: <https://ecograder.com/how-it-works> (23.12.2024).
- Ellen MacArthur Foundation: Circular economy introduction. URL: <https://www.ellenmacarthurfoundation.org/topics/circular-economy-introduction/overview> (26.02.2025).
- Erik Berkheimer (2024): Interview with Erik Berkheimer on Sustainable UX in Web Design and Guideline Creation.
- Erik Fiala (2024): Designing for the Circular Economy: Sustainable Digital Products. URL: <https://erikfiala.com/blog/designing-for-circular-economy-sustainable-digital-products/> (26.02.2025).
- European Commission. Joint Research Centre./IEA. (2024): GHG emissions of all world countries. LU: Publications Office. URL: <https://data.europa.eu/doi/10.2760/4002897> (30.12.2024).
- Freitag, Charlotte et al. (2021): The real climate and transformative impact of ICT: A critique of estimates, trends, and regulations. In: Patterns, Vol. 2 (9), p. 100340. DOI: 10.1016/j.patter.2021.100340.
- Friedmann, Julio (2024): Data Center Water use. Vol. Artificial Intelligence for climate change mitigation roadmap.
- Gary McGovern: Sustainable Website Design: Does Your Website Hurt the Planet? URL: <https://www.cmswire.com/digital-experience/sustainable-website-design-is-your-website-hurting-the-planet/> (14.03.2025).
- Green Web Foundation: The Green Web Directory. URL: <https://www.thegreenwebfoundation.org/tools/directory/> (24.11.2024).
- Green Web Foundation: CO2.js. URL: <https://www.thegreenwebfoundation.org/co2-js/> (15.03.2025).
- Grotzer, Tina/Cao, Lydia (2023): EarthXDesign for a Sustainable World: Moving from Human-Centered to Earth-Centered Design.
- Hassenzahl, Marc (2008): User experience (UX): Towards an experiential perspective on product quality. DOI: 10.1145/1512714.1512717.
- Hulleberg, Ola et al. (2023): The Awareness and Practices of Web Developers Toward Sustainable Web Design. pp. 134–145. DOI: 10.1007/978-3-031-35699-5_11.
- Interaction Design Foundation – UX Design Courses (2021): Sustainable Design - Design for the 21st Century with Don Norman. URL: <https://www.youtube.com/watch?v=ej5FhFFMu8M> (31.10.2024).

- Interaction Design Foundation (IxDF) (2021): A Simple Introduction to Lean UX. URL: <https://www.interaction-design.org/literature/article/a-simple-introduction-to-lean-ux> (09.11.2024).
- Interaction Design Foundation (IxDF): What are UX Design Processes? — updated 2024. URL: <https://www.interaction-design.org/literature/topics/ux-design-processes> (01.11.2024).
- Interaction Design Foundation (IxDF) (2024): What is Don Norman? URL: <https://www.interaction-design.org/literature/topics/don-norman> (31.10.2024).
- Interaction Design Foundation (IxDF): What is Human-Centered Design (HCD)? — updated 2024. URL: <https://www.interaction-design.org/literature/topics/human-centered-design> (10.11.2024).
- Interaction Design Foundation (IxDF): What is User Centered Design (UCD)? — updated 2025. URL: <https://www.interaction-design.org/literature/topics/user-centered-design> (12.04.2025).
- International Organization for Standardization (2018): ISO 9241-11:2018 (en), Ergonomics of human-system interaction — Part 11: Usability: Definitions and concepts. URL: <https://www.iso.org/obp/ui/en/#iso:std:iso:9241:-11:ed-2:v1:en> (10.11.2024).
- International Organization for Standardization (2019): ISO 9241-210:2019 (en), Ergonomics of human-system interaction — Part 210: Human-centred design for interactive systems.
- Irani, Fershad (2023): Curious about driving the transition to a fossil-free internet? Here's how CO2.js can help. URL: <https://www.thegreenwebfoundation.org/news/curious-about-driving-the-transition-to-a-fossil-free-internet-heres-how-co2-js-can-help/> (23.12.2024).
- Jason Bodell (2023): Building A Greener Online Future With Sustainable Web Design. URL: <https://www.ronins.co.uk/hub/sustainable-web-design/> (26.02.2025).
- Johannesson, Paul/Perjons, Erik (2014): An Introduction to Design Science. [Cham]: Springer.
- Jonas, Thorsten (2024): The 11 principles of Sustainable UX. URL: <https://sustainableuxnetwork.com/the-11-principles-of-sustainable-ux> (16.12.2024).
- jut-so Digital Agency (2023): Introducing Web Sustainability Guidelines 1.0. URL: <https://jut-so.de/en/introducing-web-sustainability-guidelines-1-0/> (15.03.2025).
- Kasia (2022): What is the digital carbon footprint? URL: <https://planbe.eco/en/blog/what-is-the-digital-carbon-footprint/> (21.11.2024).
- Kauer-Franz, Michaela/Franz, Benjamin (2023): Usability und User Experience Design. 1. Auflage 2022, 1. korrigierter Nachdruck 2023. edition. Bonn: Rheinwerk Verlag.
- Levy, Jaime (2015): UX strategy. 1. ed. edition. Sebastopol: O'Reilly.
- Markmann, Alice Tomomi Un-Ji: The Sustainable UX Design Toolkit.
- Meta Sustainability: Water. URL: <https://sustainability.atmeta.com/water/> (12.03.2025).
- Nielsen Norman Group (NNgroup) (2023): Lean UX & Agile: Study Guide. URL: <https://www.nngroup.com/articles/lean-ux-agile-study-guide/> (09.11.2024).

- Nielsen Norman Group (NNgroup): Setting UX Roles and Responsibilities in Product Development: The RACI Template. URL: <https://www.nngroup.com/articles/ux-roles-responsibilities/> (31.10.2024).
- Nielsen Norman Group (NNgroup) - Youtube (2016): Don Norman: The term "UX." URL: <https://www.youtube.com/watch?v=9BdtGjoIN4E> (31.10.2024).
- NIST (2021): Human Centered Design (HCD). In: NIST,. URL: <https://www.nist.gov/itl/iad/visualization-and-usability-group/human-factors-human-centered-design> (09.11.2024).
- Noah Knauss (2024): Interview with Noah Knauss on Sustainable UX in Web Design and Guideline Creation.
- Norman, Don (2025): Interview with Don Norman on Sustainable UX in Web Design and Guideline Creation.
- Norman, Donald A. (2023): Design for a better world. Cambridge, Massachusetts; London, England: The MIT Press.
- Nutanix: What is a Digital Carbon Footprint & How To Reduce It. URL: <https://www.nutanix.com/info/digital-carbon-footprint> (21.11.2024).
- Olson-Royal, Joana (2023): Web Performance Optimization and Sustainability. URL: <https://www.mightybytes.com/blog/web-performance-optimization-and-sustainability/> (13.03.2025).
- Osaka, Shannon (2023): A new front in the water wars: Your internet use. In: Washington Post,. URL: <https://www.washingtonpost.com/climate-environment/2023/04/25/data-centers-drought-water-use/> (21.11.2024).
- Peter Post (2025): Interview with Peter Post on Sustainable UX in Web Design and Guideline Creation.
- Rabab Ali Abumalloh et al. (2024): Nudging Techniques: Design, Theoretical Grounds, and Ethical View. In: Journal of the Knowledge Economy,. DOI: 10.1007/s13132-024-02219-x.
- Retail Insider (2025): How Sustainable Web Design Benefits Businesses and the Planet. URL: <https://retail-insider.com/articles/2025/02/how-sustainable-web-design-benefits-businesses-and-the-planet/> (13.03.2025).
- Robert, Jean-Marc/Lesage, Annemarie (2011): Designing and Evaluating User Experience. In: The Handbook of Human-Machine Interaction: A Human-Centered Design Approach,.
- Sandy Dähnert (2025): Interview with Sandy Dähnert on Sustainable UX in Web Design and Guideline Creation.
- Scott Lane: Harnessing the Power of ISO 14001: A Cornerstone for ESG and Regulatory Compliance. URL: <https://www.speeki.com/en-US/blog/iso-14001-for-esg-and-regulatory-compliance> (13.03.2025).
- Sebastian Flock (2025): Interview with Sebastian Flock on Sustainable UX in Web Design and Guideline Creation.

Siddik, Md Abu Bakar/Shehabi, Arman/Marston, Landon (2021): The environmental footprint of data centers in the United States. In: Environmental Research Letters, Vol. 16 (6), p. 064017. DOI: 10.1088/1748-9326/abfba1.

Smith, Brad (2020): Microsoft will replenish more water than it consumes by 2030. URL: <https://blogs.microsoft.com/blog/2020/09/21/microsoft-will-replenish-more-water-than-it-consumes-by-2030/> (12.03.2025).

Solomon Klappholz (2024): Data center water consumption is spiraling out of control. URL: <https://www.itpro.com/infrastructure/data-centres/data-center-water-consumption-is-spiraling-out-of-control> (21.11.2024).

Strikingly: User-Friendly and Sustainable Business Websites Design: Reducing Bounce Rates and Energy Consumption. URL: <https://www.strikingly.com/blog/posts/user-friendly-sustainable-business-websites-design-reducing-bounce-rates-energy-consumption> (14.03.2025).

Sustainable Web Design: Estimating Digital Emissions. URL: <https://sustainablewebdesign.org/estimating-digital-emissions/> (23.12.2024).

Tara Varghese (2024): How we're supporting our commitment to water stewardship. URL: <https://blog.google/outreach-initiatives/sustainability/how-were-supporting-our-commitment-to-water-stewardship/> (12.03.2025).

The Geekettez: Enhancing User Experience for Sustainability: A Case Study. URL: <https://www.thegeekettez.com/en/sustainable-ux/> (14.03.2025).

Tzviya Siegman (2023): Introducing Web Sustainability Guidelines. URL: <https://www.w3.org/blog/2023/introducing-web-sustainability-guidelines/> (18.10.2024).

UNEP (2021): With new pact, tech companies take on climate change. URL: <https://www.unep.org/news-and-stories/story/new-pact-tech-companies-take-climate-change> (21.11.2024).

United Internet AG: Sustainability Report 2020. URL: <https://report.united-internet.de/sustainability/2020/climate-and-environmental-protection/energy-consumption.html> (21.11.2024).

United Nations: The 17 Sustainable Development Goals. URL: <https://sdgs.un.org/goals> (14.03.2025).

UXPin (2024): UX Design Frameworks – What Are The Most Useful Ones? URL: <https://www.uxpin.com/studio/blog/design-frameworks/> (09.11.2024).

Verma, Gaurav (2024): How to Practice Sustainable UX or Green UX Design. URL: <https://thesustainableux.com/how-to-practice-sustainable-ux-or-green-ux-design/> (16.12.2024).

W3C (2024): Ethical Web Principles is a W3C Statement. URL: <https://www.w3.org/news/2024/ethical-web-principles-is-a-w3c-statement/> (14.03.2025).

Website Carbon Calculator: FAQ. URL: <https://www.websitecarbon.com/faq/> (23.12.2024).

Website Carbon Calculator: How does it work? URL: <https://www.websitecarbon.com/how-does-it-work/> (23.12.2024).

Website Carbon Calculator: Website Carbon Calculator v3 | What's your site's carbon footprint? URL: <https://www.websitecarbon.com/> (23.12.2024).

Wholegrain Digital: Sustainable Web Manifesto. URL: <https://www.sustainablewebmanifesto.com/> (16.11.2024).

Zak Datson/Mohit Arora: Does what you scroll burn coal? Mythbusting energy consumption on the web. URL: <https://www.bbc.co.uk/rd/articles/2025-01-sustainability-web-energy-consumption> (15.03.2025).

Zhang, Mary (2024): Data Center Water Usage: A Comprehensive Guide. URL: <https://dgtlinfra.com/data-center-water-usage/> (20.11.2024).

Appendices

A1: Interview Transcripts

A2: Interview Question Protocol

A3: Scan for plagiarism

A4: Sustainability Audit Checklist

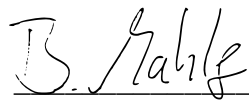
Statutory Declaration

I herewith declare that I have composed the present thesis myself and without use of any other than the cited sources and aids. Sentences or parts of sentences quoted literally are marked as such; other references with regard to the statement and scope are indicated by full details of the publications concerned.

The thesis in the same or similar form has not been submitted to any examination body and has not been published. This thesis was not yet, even in part, used in another examination or as a course performance.

Ulm, 14.04.25

Place, Date

A handwritten signature in black ink, appearing to read 'B. Nahl', written over a horizontal line.

Signature