The Journey from Consumer to Investor: Designing a Financial AI Companion for Young Adults to Help With Sustainable Shopping, Saving, and Investing

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從消費者到投資者的旅程：為年輕成人設計一個財務人工智慧夥伴，幫助他們進行可持續購物、儲蓄和投資

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Abstract

Taiwanese college students are concerned with environmental issues, yet they are hindered by lack of simple tools to affect systemic change. Meanwhile, on the other side of the Planet, strengthening environmental policy from the European Union includes the concept of *digital product passports*, which aims to help distinguish *eco-designed* products made by *circular economy* companies striving to be zero-waste from companies that simply engage in *greenwashing*. Tracking product data from the source materials until the consumer purchase and finally post-purchase recycling, combined with *data-driven interaction design* facilitates building transparency into opaque global supply chains by using *large-language models* and *artificial intelligence assistants* to translate complex environmental data into human-comprehensible language.

The emerging field of *planetary health* recognizes profound interconnections between our economic behaviors, ecosystem services such as clean water, air, soil, the climate crisis, and human health. As of 2024, Earth's natural environment is being heavily degraded by the extractive business practices of companies that make many of the products and services we buy every day. The way we use our money to interact with companies - through shopping as consumers and saving / investing as investors - has an effect on the life-supporting biosphere we rely on to keep our planet inhabitable. In essence, from an ecological perspective, every financial action is either an investment decision to support more environmentally-friendly companies - or to support polluters.

My research addresses the need for tools to make sustainable financial action more convenient, focusing in particular on college students. I leverage *design research* to find design concepts for *simple AI-based user interfaces* also known as *generative UIs* to help young adults participate in *sustainable financial activism*. A survey of 700 students across 10 universities in Taiwan was conducted, enhanced by 5 expert interviews providing industry insights. The major contribution of the study is an interactive AI-assistant prototype.

ADD: Democratization of Financial Markets

Keywords: Climate Anxiety, Planetary Health, Human-AI Interaction, Digital Sustainability, Financial Activism, Transparency

摘要

大學生關注環境問題，但因學業繁忙及缺乏簡便工具來影響體制改變而受阻。歐盟更強化環保政策，引入了「數位產品護照」的概念，此舉有望幫助區分由循環經濟公司製造的、努力實現零廢棄的「生態設計」產品，與僅聲稱自己環保的公司。從原材料到消費者的產品數據追踪，結合「數據驅動的互動設計」，有助於為不透明系統建立透明度。同樣地，「大型語言模型」的發展使得「人工智能助理」能夠成為複雜環境數據與人類可理解語言之間的翻譯層。

新興的「地球健康」領域認識到我們的經濟行為、生態系統服務（如淨水、空氣、土壤）、氣候危機與人類健康之間存在深刻的相互聯繫。截至 2024 年，地球的自然環境正被開採性企業的商業行為嚴重破壞，這些企業生產我們每天購買的許多產品和服務。我們通過消費和儲蓄/投資與公司的互動方式，對我們賴以生存的、支持地球可居住生物圈產生影響。從生態學的角度看，每一個財務行動都是支持更環保公司的投資決策，或是支持污染者。

我的研究應對了為大學生提供便於實行可持續財務行動的工具需求。我專注於利用「設計研究」來尋找「簡易 AI 用戶介面」的設計概念，也稱為「生成 UI」，以幫助大學生參與「可持續財務行動主義」。在台灣 10 所大學進行了一項涵蓋 700 名學生的調查，並增加了 5 位專家訪談以提供行業見解。研究的主要貢獻是一個互動 AI 助理原型。

關鍵詞：氣候焦慮、人工智能互動、數位可持續性、財務行動主義、透明度、地球健康。

The abstract was translated on May 22, 2024 using the Claude 3 Opus model. Translation quality was checked with OpenAI GPT4, Google Gemini, Mistral Large, Meta LLama as well as human reviewers. In case of any discrepancies, please refer to the English text.

Introduction

How can college students find sustainable companies? Furthermore, if given appropriate tools, could college students leverage their purchasing power to reward sustainable companies?

My research describes the process of designing an AI companion for college students to help with sustainable shopping, saving, and investing.

Money spent shopping, saving, and investing in sustainable companies serves as an incentive to adopt more sustainable practices. If used wisely, money can reward companies for becoming more sustainable.

Encourage the least sustainable companies to improve their performance, raising the overall baseline.

Facilitate the formation of communities centered around environmental stewardship.

Build closer relationships with sustainability.

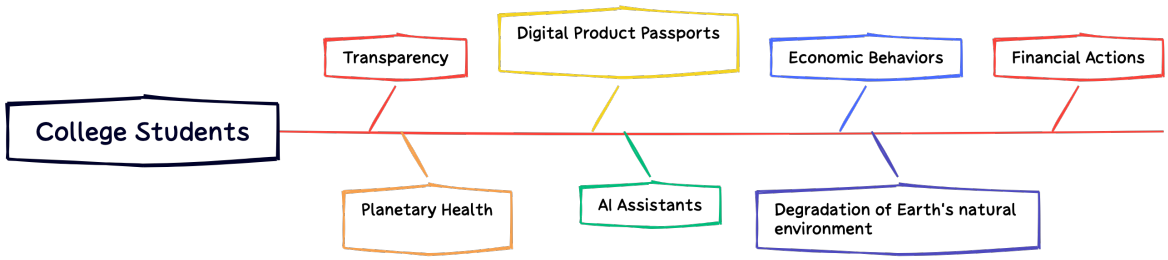


Figure 1: College Students

Relevance

The research addresses the ***"attitude-behavior gap"*** among Taiwanese college students in taking sustainable financial action.

Convergence of the following 5 trends makes my research timely in 2024.

Table 1: Trending narratives.

Trend	Direction
Environmental degradation	Worsening
Interest in sustainability among young people	?
Intergenerational money transfer; in some countries relatively young people have money	?

Trend	Direction
Availability of sustainability tools such as ESG, B Corporations, Green Bonds, etc, among metrics and instruments	Increasing
Availability of generative AI-based user interfaces (UIs)	Increasing
Democratization of Financial Markets	Increasing

Background

I grew up as an avid science fiction reader, which influenced my outlook towards future possibilities. In particular, the Star Trek universe had an imaginary portable device called a ***tricorder*** (fig. 1) enabling scientists to scan anything for insights. Be it precious minerals inside a cave or scanning the human bodies for medical data, its sensors would show up with some useful data. In daily life, I would love to have such a device for consumer choices and financial decisions - to know what to buy and which businesses to support with my money and approval.

Figure 2: Captain Sulu using a Tricorder (Star Trek) - Photo copyright by Paramount Pictures

While a *tricorder* is still science fiction, technological advancements are getting closer and closer to producing something similar. AIs are already integral to many parts of our lives, with computer models producing increasingly useful outputs. The proposal for this thesis was first written using Google's and Apple's voice recognition software in 2020, and later switching to OpenAI's *Whisper* model, allowing me to transcribe notes with the help of an AI assistant. As a foreigner living in Taiwan since 2019, I relied on AI-based tools for many aspects of my life: speaking, moving, finding food and services. When writing in Chinese, Apple's text prediction algorithms translate pinyin to 漢字 and show the most likely character based on my previous writing, Google's maps find efficient and eco-friendly routes and recommend places to eat and ChatGPT provides statistically probable advice from the sum of human knowledge. Even when we don't realize it, AI is helping us with many mundane tasks. While it takes incredibly complex computational algorithms to achieve all this in the background, it's become so commonplace, we don't even think about it. From this point

of view, another AI assistant to help students with choosing more eco-friendly businesses - to shop, save, and invest - doesn't sound so much of a stretch.

Motivation

Environmental degradation is increasingly affecting human lives - and it's largely driven by manufacturing processes - of the products we consume daily. From resource extraction in the linear economy (mining raw materials and drilling for fossil fuels) to chemical processes (causing contamination and pollution of the air, water, and soil) to waste generation and greenhouse gas emissions, industries transform the natural world into consumer products. While industry practices have improved since the industrial revolution in the 19th century, and continue to improve, it's possible to further improve standards of production and raise the global baseline for sustainability, given enough societal pressure to do so.

Nonetheless, without easily accessible and reliable data, it's difficult to know which company is more sustainable than another. As consumers and investors (even if only through passive ownership of savings), we don't really know much about enterprise production practices, unless we spend a lot of time looking at the numbers, which may be costly to access (for example ESG reports are expensive), and mostly rely on our governments and international bodies to keep us safe. Or just look at the brands themselves - and pick the ones which we like.

Objective

The study presents design research for developing an AI companion to help college students find sustainable companies for shopping, saving and investing. The major contribution of my study is an interactive artefact (a prototype) informed by design research.

Demographics

The research focuses on young adults, specifically Taiwanese college students studying in Taiwan.

	Criteria
Location	Taiwan
Population	College Students
Count	700

Experts (finance, design, sustainability).

	Criteria
Location	Global
Population	Experts
Count	5

Research Questions

My research answers the following questions.

Table 4: RQs.

Question	Methods
What scientific knowledge in sustainability, design, and finance could an AI companion integrate to support college students?	Literature Review
How would college students use an AI companion to allocate capital to sustainable companies when shopping, saving, and investing?	Literature Review and Expert Interviews
How would college students prioritize specific AI companion features?	Survey of College Students

Literature Review

Goals

Given the goal of designing an app to integrate sustainable shopping, saving, and investing. The goal of the literature review is to find insights about the target audience (Taiwanese college students), understand what kind of sustainable actions are effective, and translate these into specific ideas for app features. In order to keep track more easily, each literature review chapter includes in-context *design implications*.

The literature review branches out to 5 main directions and maps out relationships sources and the literature map, namely Taiwanese college students, generation-z demographics, sustainability, ecology, ecosystem services, EU legislation, sustainable finance, sustainable investing, savings, circular economy, economics, AI, existing sustainability, software, sustainability–related mobile apps (Apple iOS / Google Android), and web apps related to sustainable shopping, savings, and investing; apps using algorithmic interfaces (AI-based UI), design, UX/UI, service design, sustainable design, speculative design, interaction design, behavior change, nudge.

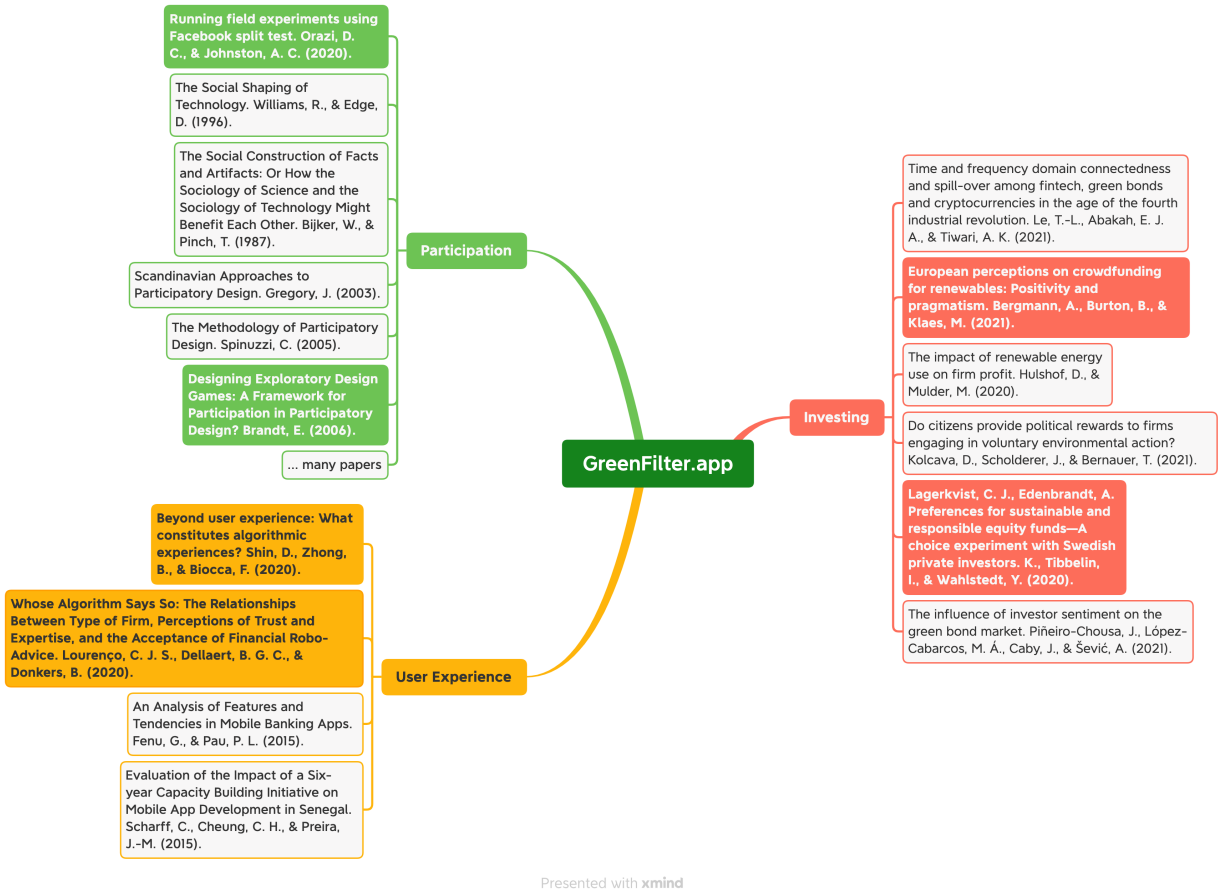


Figure 3: Example papers from the Literature Review

Sources

There is currently no single platform that hosts all scientific journals leading me to source scientific papers from

- ScienceDirect
- Nature
- the Lancet
- Oxford Academic
- Semantic Scholar
- JSTor
- Google search.

AI Usage in Research

I'm a long time AI-assistant user. AI was used for

- search
- data comparison
- data science
- chart-building

AI was *NOT* used for writing.

Research Tech Stack

The research project made use of the following software.

- Matplotlib
- NumPy
- jupyter
- seaborn
- Python
- VSCode
- GitHub
- fireflies.ai
- Google Meet
- databricks
- HuggingFace
- TypeScript
- Tally

- Zotero
- Quarto
- Apache Parquet
- Haystack
- MongoDB
- langchain
- GitHub Copilot
- Figma
- Sketch
- OpenAI ChatGPT
- Anthropic Claude
- Google Gemini
- Google Colab
- Google Sheets
- META Llama
- Mistral
- OpenAI API
- Postman
- Next.js
- fullstory
- Polygon.io
- Hotjar
- Lottie
- Docusaurus
- Google Analytics
- Google Maps
- vis.gl
- Pinecone
- Vercel
- Vercel AI SDK
- Radix UI
- highcharts

- React
- Tailwind
- Markdown

Students

Student Protests Around the World

In August 2018, Swedish high-school student Greta Thunberg skipped class to start a climate strike in front of the Swedish parliament Riksdag. Millions of people around the world joined her *Fridays for Future* protests. Time magazine named Thunberg person of the year for *creating a global attitudinal shift.* (Deutsche Welle, 2019).

Figure 4: Climate protest in Geneva on 27th September, 2019 – 1 year after the start of Fridays for Future

The protest trend is subsiding.

McKinsey says people want eco-products but aren't willing to pay more.

Willingness too pay research.

The Attitude-Behavior Gap

A large-EUPolicyscale global study by (Anthony Leiserowitz et al., 2022) on Meta's Facebook (n=108946) reported people in Spain (65%), Sweden (61%), and Taiwan (60%) believe *"climate change is mostly caused by human activities".* An even larger survey (n=1.2 million) by the United Nations across 50 countries, distributed through mobile game ads, showed the majority of people agreeing climate change is an "emergency" (UNDP, 2021). While people express eco-conscious ideas, it's non-trivial to practice sustainability in daily life. (Deyan Georgiev, 2023b) reports only 30% of people in the Gen-Z age group believe technology can solve all problems.

Table 5: 1.2 million UN survey responses to the statement *"Climate change is an emergency"* (UNDP, 2021).

Age Group	Agree	Neutral or Disagree
18-35	65%	35%
36-59	66%	34%
Over 69	58%	42%

- (Park & Lin, 2020) positive attitude towards sustainable products does not result in purchase decisions, shows research of fashion in South Korea. In one Australian study, green consumers still waste food similarly to the baseline (McCarthy & Liu, 2017).
- Munro, Kapitan & Wooliscroft (2023) shoppers trying to shop sustainably often fail to find sustainable products.
- Marc Lien (2022) Four millions British SMEs have no plan for net-zero transition.
- Ware (2024) British workers lack skills for green transition. (2024 National Environmental Services Survey)

Credit Cards

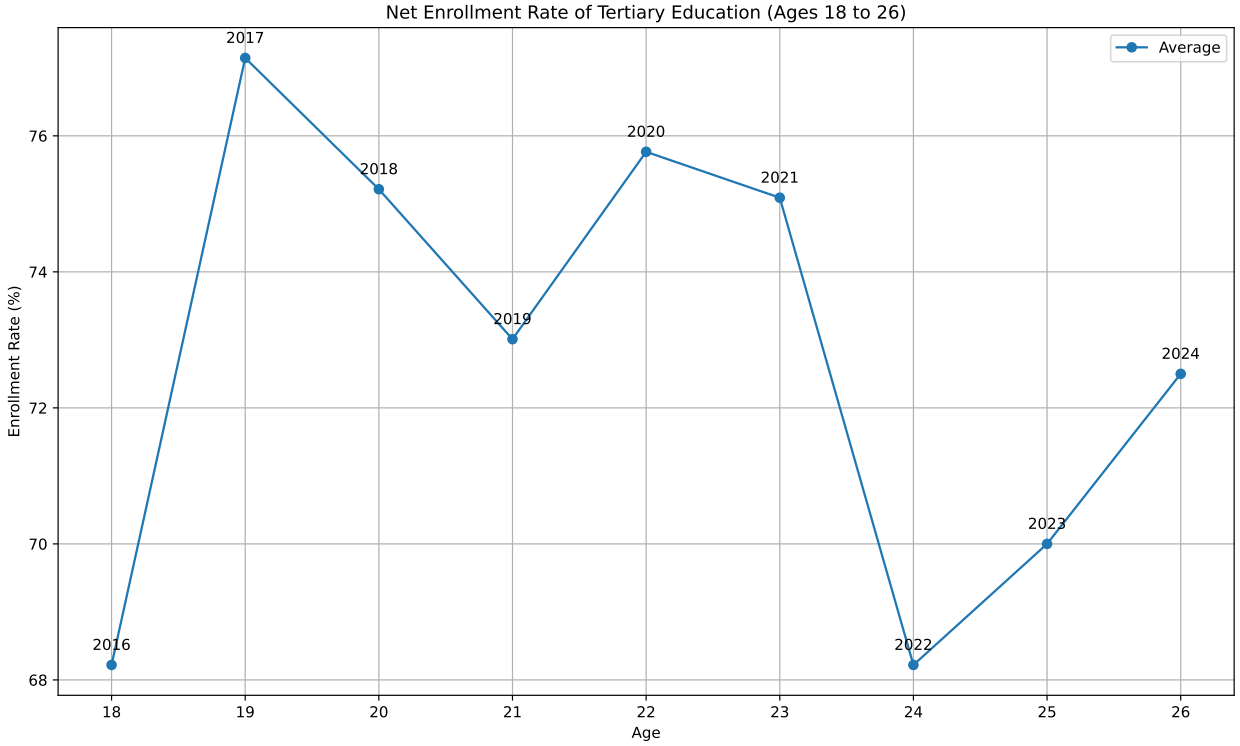
- an older study, I-Cheng Yeh (2009) provides data from credit card usage from an unnamed "important" bank in Taiwan. Because of the age of the study there's no Gen-Z data. People aged 18-26 at the time would be Millenials or Gen-X by now.

data donated (Yeh, 2016).

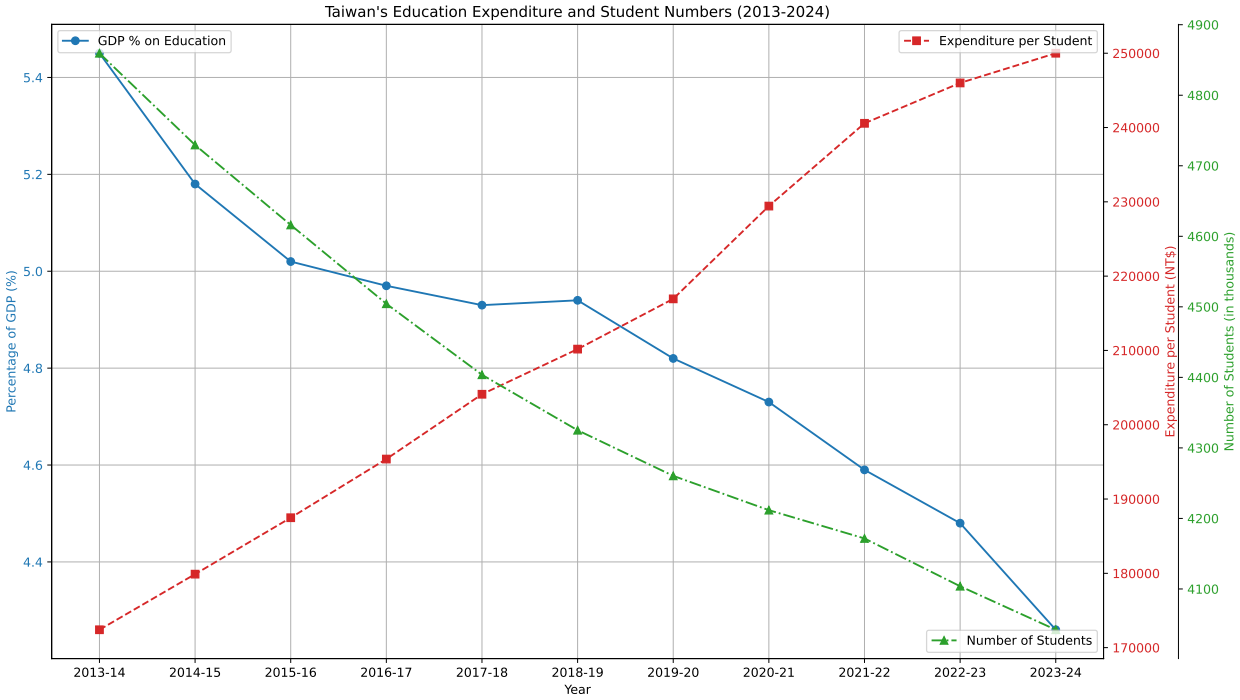
https://www.semanticscholar.org/paper/The-comparisons-of-data-mining-techniques-for-the-Yeh-Lien/1cacac4f0ea9fdff3cd88c151c94115a9fddcf33

Taiwanese Education System and Policy Environment

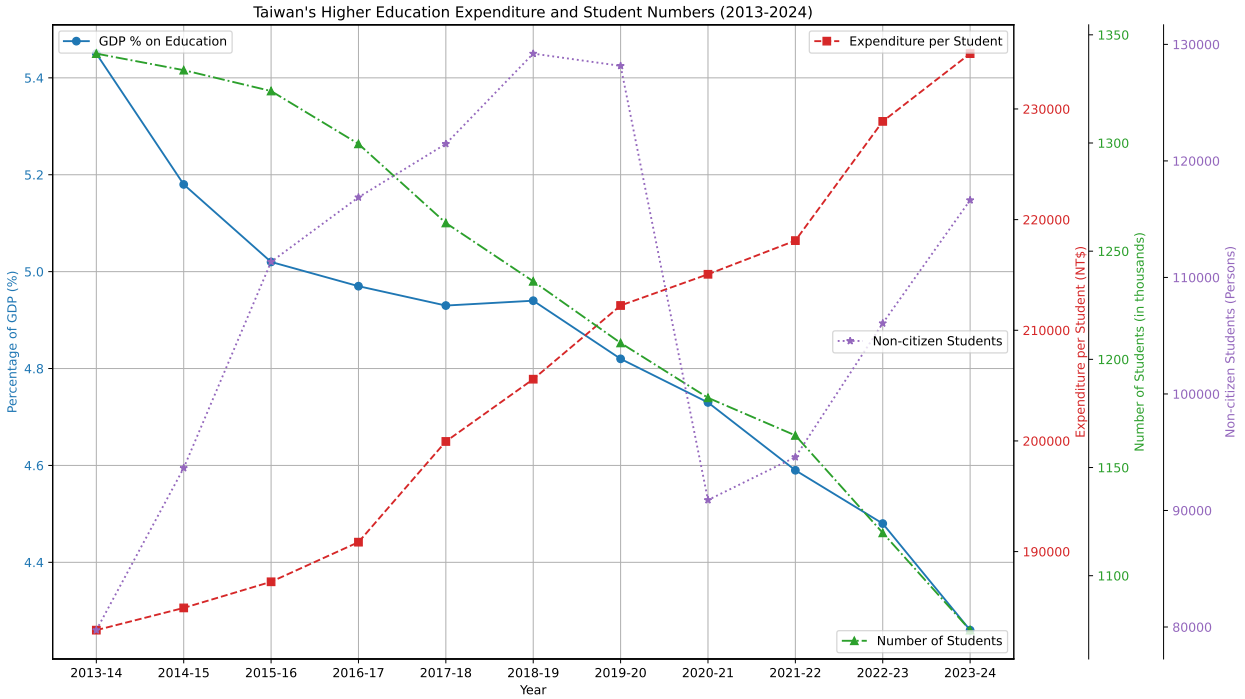
Taiwan has approximately 2 million young adults (Gen-Z, 18-26), and 73% percent of them are students attending tertiary education (Ministry of Education of Taiwan, 2024b).



As of 2024, Taiwan has a total of 148 universities, colleges, and junior colleges (Ministry of Education of Taiwan, 2024c). Education funding is 4.26% of Taiwan's GDP in 2023-24 and has been on a decline for a decade (Ministry of Education of Taiwan, 2024a). Taiwan has an aging population and declining birth rates have forced several schools to close down (Goh et al., 2023; Davidson & Chi-hui, 2024).



While the overall number of students is declining, the share of international students is increasing.



Confucianism

Taiwanese culture is deeply influenced by Confucianism, valuing academic excellence, effort, and the role of education in achieving social status (Xu, 2024). Both Confucianism and Daoism affect education to be *teacher-centered*, where traditionally the role of students is to listen and absorb knowledge; in today's society, there's space to open opportunities for revisiting *dialogue-based* education, where students would be encouraged to take a more active role and gain ownership of their education (Chang, Wegerif & Hennessy, 2023).

Sustainability Attitudes

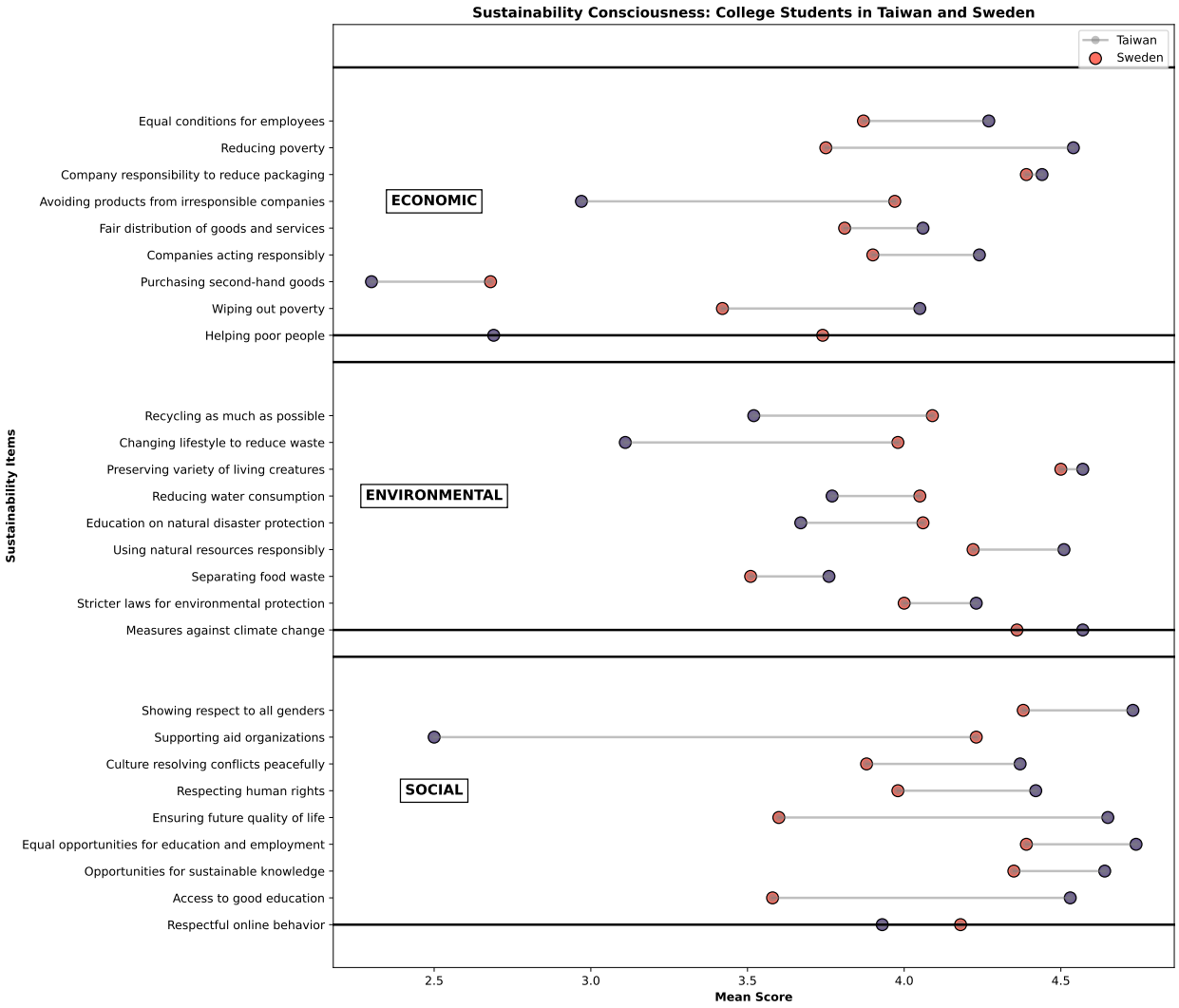
In general, Taiwanese teachers at all levels of education have a positive attitude towards sustainability.

At the pre-university level, Taiwanese government has been promoting environmental education through a green school network; however surveys at middle school and high school level suggest there is no impact on *sustainability consciousness* among students in comparison with regular schools (Olsson et al., 2019). Rather, Taiwanese students are influenced towards environmental action by *group consciousness* (Yu, Yu & Chao, 2017). In contrast,(陳珮英, 2003) reports *good knowledge of sustainable development* topics among *junior high school students* in Da-an District, Taipei City (n=596). (林, 2009) similarly reports a positive attitude and good knowledge of environmental sustainable development among senior *high school students* towards in Taipei City (n=328). Several Taiwanese studies also focus on the physical environment of school campuses, for example the sustainability of elementary school campuses (潘智謙 & Chih-Chien, 2006). Elementary-school

teachers in Taichung (n=536), have positive attitudes towards environmental education are positive, proactive and demonstrate high awareness; they have participated in many sustainability-related workshops (Liao et al., 2022).

At the university level, (Chen & Tsai, 2016) reports a *positive attitude yet moderate knowledge* about *ocean sustainability* among Taiwanese college students (n=825). (Liu et al., 2023a) studied sustainability behavior of Taiwanese University students, reporting the COVID-19 pandemic, in addition to prevalence of health issues, also spurred more attention on environmental topics. In a similar vein, the devastating nuclear disaster in Fukushima, Japan, after 2011 earthquake, had an effect on Taiwanese energy and sustainability education (姚 & 侯, 2011). Taiwanese government launched the Sustainable Council in 1997 to promote of environmental and sustainable development; a survey of university-level teachers (n=100) in central Taiwan (Taichung, Changhua, and Yunlin) shows a positive attitude toward environmental sustainability among teachers however implementation of environmental sustainability practices is from low to medium range (林 & 莊, 2015). Taiwanese government has also launched funding for University Social Responsibility (USR) programs to train college students in social innovation and local revitalization (Chen & Chou, 2023; Liu et al., 2022).

Comparing college students' education for sustainable development (ESD) in Taiwan (n=617) and Sweden (n=583) found Sweden has a long history in environmental education while in Taiwan environment became a focus area with the 1998 educational reform (Berglund et al., 2020).



Eco-Friendly Diet

An older study in 5 university in Taipei and Taichung (n=255) found 78.04% of respondents consumed beef in the month prior and were concerned with food safety, freshness, and quality (Hsu, Lu & Chen, 2014). (Thiagarajah & Kay, 2017) reports a general observation in their abstract (I was unable to access the full study) that most college students in all observed countries including Taiwan (n=534) regarded "*plant-based diets to have health benefits*".

The Effect of Climate Change on Taiwan

Taiwan has been affected by drought over 4 decades, rising temperatures and altered rainfall patterns, impacting water security and semiconductor manufacturing(Vo & Liou, 2024). Corals surrounding Taiwan are affected by marine heatwaves, ocean acidification and increased sea surface temperature affects coral bleaching level (Hsu et al., 2024). Biomarkers in the sediment core around Taiwan are being used to study variations in climate over past thousands of years (Wang et al., 2021). Taiwan is affected by Kuroshio (黑潮) like Estonia is affected by the Gulf Stream. Both oceanic

currents help regulate the climates of their respective regions and marine ecosystems. Kuroshio is a warm current of the Pacific Ocean. Rossby planetary waves driven by the Earth's rotation are crucial to keeping the atmosphere in balance by helping transfer tropical heat towards Earth's poles and cold air toward the tropics; interactions between oceanic currents, Rossby waves and nonlinear *mesoscale eddies,* which form complex undulations, and their effect on the climate are still not well understood (US Department of Commerce, n.d.; Belonenko, Sandalyuk & Gnevyshev, 2023; Liu et al., 2024; Lin et al., 2022b; Yin, Lin & Hou, 2019; Mensah et al., 2014; Shen et al., 2014). Around 33% of Taiwanese CO2e emissions is captured by the marine carbon sink, while the effect of forests in Taiwan needs further study (Hung et al., 2024).

Sustainability Tools in the Taiwanese Context

Musical garbage truck are a success story of the environmental progress in Taiwan (Helen Davidson & Chi Hui Lin, 2022). Indeed, they are a *user interface innovation* and the main way how people in Taiwan interact with sustainability issues.

The popular narrative about Taiwan recounts the story of the economic and environmental transformation of the country. In the late 1980s during the heights of an economic boom Taiwan became famous as the Taiwanese Miracle (臺灣奇蹟) (Gold, 1986; Tsai, 1999). By the early 1990s another less flattering nickname appeared: "garbage island", for the piles of trash covering the streets and overflowing landfills (Rapid Transitions Alliance, 2019; Ngo, 2020). In the two decades that followed, from 1998 to 2018, Taiwan made progress in municipal waste management, rising to the status of a world-leader in recycling (2nd *effective recycling rate* after Germany); in addition to an effective recycling system, the average waste amount generated per person by 700g (from 1140g to 400g) per day; nonetheless, industrial recycling rates were less stellar, standing at 80% in 2020 and there were unrealized opportunities in using industry 4.0 technologies, such as internet of things (IoT) sensors for better waste tracking (Wu, Hu & Ni, 2021; Bui et al., 2023).

Progress in sustainability is possible but achieving results takes time and innovation. (Rapid Transitions Alliance, 2019) credits the Taiwanese Homemakers United Foundation (財團法人主婦聯盟環境保護基金會) for initiating the transformation in 1987, suggesting a small group of people can have an outsized impact on the whole country. Their activity didn't stop there and (財團法人主婦聯盟環境保護基金會, 2020) recounts a timeline of their achievements on their website until the present day.

Trends in Taiwanese Companies

Between 1970 and 2019 CO2 was a prerequisite of economic growth in Taiwan (check this again) (Chang et al., 2023). Taiwan is a net CO2 exporter since 1990s through emissions embedded in the industrial production oriented economy (Huang, Lv & Li, 2020).

TIME Magazine and Statista collaborative *"World's Most Sustainable Companies Of 2024"* includes 17 Taiwanese companies (Alana Semuels, 2024).

Table 6: Data from (Alana Semuels, 2024).

Rank	Company	Score
24	Delta Electronics	77.18
63	Taishin Holdings	73.50
68	Fubon Financial	73.01
80	Chunghwa Telecom	71.69
91	Yuanta Financial Holdings	70.94
92	Cathay Financial Holdings	70.79
108	Taiwan Mobile	69.72
200	First Financial Holding	64.17
300	Far EasTone	60.04
301	SinoPac Holdings	60.04
344	Wistron	58.44
356	Acer	58.02
395	Nanya Technology	56.35
409	InnoLux	55.82
416	Wiwynn	55.67
421	Taiwan Cement	55.49
497	Advantech	53.14

Meanwhile, Corporate Knights which has been ranking global sustainable companies since 2005, including analysis of 7000 public companies with a revenue over US$1 billion, only includes TSMC in the top 100 (placed 20th in 2021 and 44th in 2022, dropping out in 2023) and Taiwan High Speed Rail Corp and Giant Manufacturing Co Ltd since 2023. (Corporate Knights, 2024)

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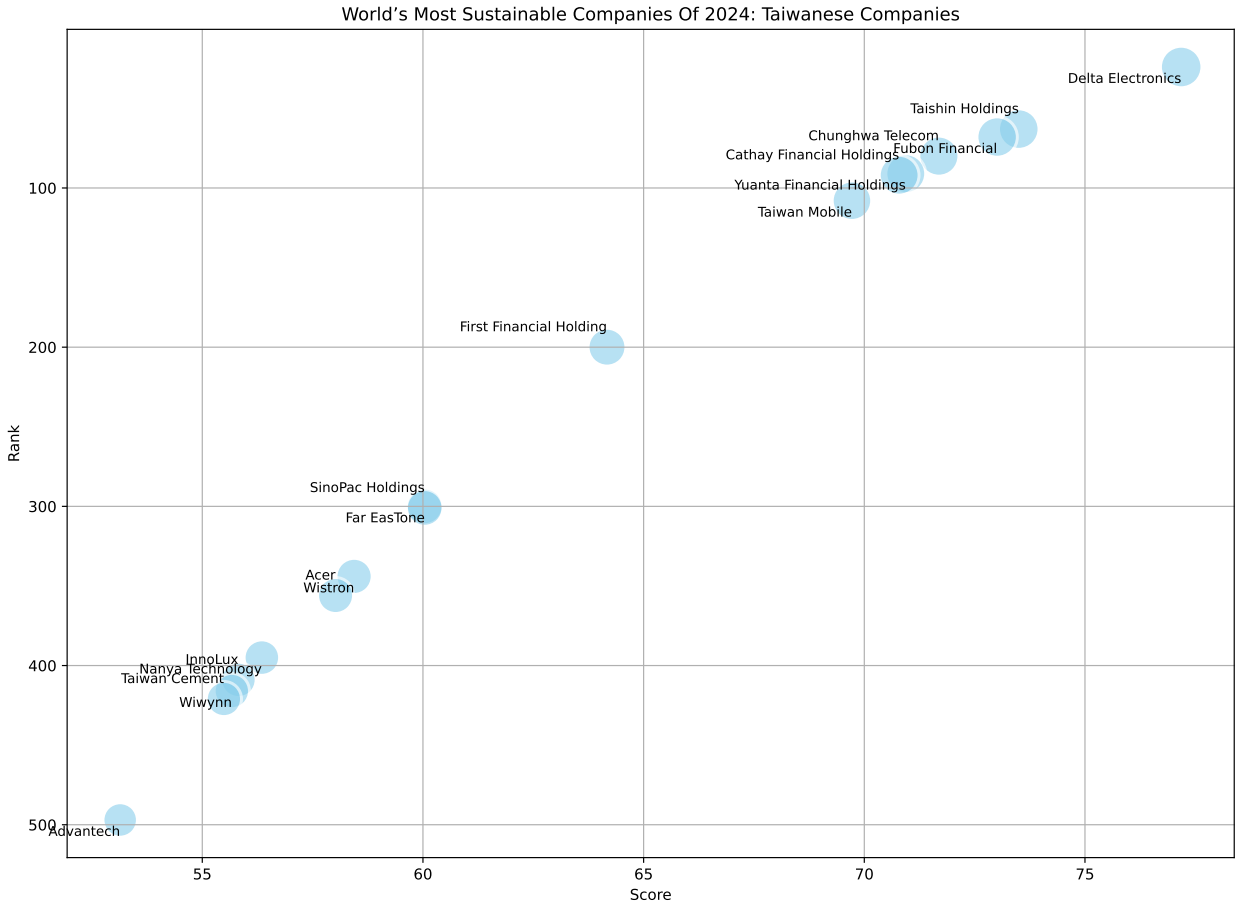
Online Shopping Trends in Taiwan

- In Online Shopping, (聯合新聞網, 2024 predicts Momo and Coupang will compete for Taiwanese market leadership).
- intsifying competition, Coupang stepping on Shopee's and MOMO's toes Anon (2024j)



- "Taiwan's Financial Supervisory Commission's (FSC) requirements for Taiwan's corporates to disclose their carbon emissions starting in 2023," Reformosatw (2024)

Gen-Z in Other Countries

- In Japan, Gen-Z wants privacy and 75% feel others overshare on social media and 49 percent were concerned about their personal data https://www.mckinsey.com/~/media/mckinsey/email/genz/2022/06-07b.html
- (Manchanda et al., 2023) survey (n=726) administered at shopping malls in New Delhi, India, found similar levels of sustainability consciousness between Millenial (n=206) and Generation-Z (n=360) age groups; people with high level of materialism were found to be less sustainability-conscious; the effect of mindfulness on sustainability was found to be stronger among females than males, supporting the hypothesis of the moderating effect of gender.

There's evidence young people have money. In the United States, the combined annual consumer spending of Gen-Z and Millennials was over 2.5 Trillion USD in 2020 (YPulse, 2020). Over the decade from 2020 to 2030, in the U.S., UK, and Australia, Millennials are projected to inherit 30 trillion USD from their parents (Calastone, 2020). There's also some evidence of investment interest, however there's large geographic variance. According to a (Calastone, 2020) study (n=3000) surveying people in the millennial age group between ages 23 and 35 in Europe

(UK, France, Germany), U.S.A., Hong Kong, and Australia, 48% of respondents located in Hong Kong owned financial securities (such as stocks) while the figure was just 10% in France.

Table 7: From millennial investors (Calastone, 2020).

Place of Comparison	Financial Security Ownership
Hong Kong	48%
France	10%

There is extensive research on the attitudes of U.S. college students towards climate change. (American Press Institute, 2022) reports only 37% percent of U.S. Generation-Z and Millenials follow news related to environmental issues. (Schwartz et al., 2022) reports some adult US students in a small study (18-35, n = 284) express feelings of insignificance of their actions to achieve any meaningful impact. (Thomaes et al., 2023) reports U.S. adolescents don't find sustainability relevant to their daily life. (Ross et al., 2016) says most people in the U.S. don't act on climate change. "Action on climate change has been compromised by uncertainty, aspects of human psychology".

- In Portugal, Estonia, and elsewhere young people are suing companies for eco-problems: Flor (2024)
- The En-ROADS climate change solutions simulator allows governments, organizations and individuals explore climate scenarios based on interactive changes in a visualization tool (Czaika & Selin, 2017; Creutzig & Kapmeier, 2020; Climate Interactive, 2023, n.d.).
- "Research shows that showing people research doesn't work," John Sterman

Pollution Levels

Taiwanese college students are subjected to high levels of pollution. University campuses are somewhat healthier than other areas. There are several decades of research on pollution levels in Taiwan, most with very scary correlations to health.

- Taiwan air pollution, the worst (highest PM2.5 concentration) were found in Changhua (24.5 µg/m^3), Tainan (20.9 µg/m^3), and Pingtong (20.7 µg/m^3) (Chang Hsiung-feng, Wu Che-hao & Wu Kuan-hsien, 2024).

Religion plays a role in air pollution: Tang & Pan (2014)

Developing Personas for College Students

User research makes extensive use of user *personas* to represent a group of people with similar attributes. Designers use personas to *articulate assumptions,* which, if used well, is useful for *user-centered design*, to create better products. Personas help to reflect on what kind of *biases* might exist in the design. Within the larger cohort of college students several different personas could be defined, for example grouping people by interests, knowledge, habits, levels of anxiety, and other attributes.

There have been concerns about food safety in Taiwan.

Humans have a long list of cognitive biases, which a good design should take into account.

Students ride bicycles and scooters. Many circular economy service such as YouBike and transport sharing platforms like Uber are available.

Many students live in dorms and shared housing, meaning their impact per square meter is low.

- Students in the Generation-Z age bracket (abbreviated as Gen-Z or Zoomers) are born between 1997 and 2012 (Branka Vuleta, 2023). Over 98% of Gen-Z owns a smartphone while only 80% of the general world population does (Global Web Index, 2017; BankMyCell, 2022).
- High levels of technology adoption worldwide
- (Credit Suisse, 2022) suggests young consumers are more eco-friendly and drive the speed of change. Yet the Economist has ran a few anonymous articles calling gen-z green ideals into question (The Economist, 2023; Anon, 2023o).
- Deyan Georgiev (2023a)
- Alex Reice (2021)
- (Wood, 2022) suggests in the U.S. Gen-Z is willing to pay 10% more for ethically goods, spend 24% more on sustainable products than Generation X and 75% of Gen Z would prioritize sustainability over brand loyalty.

The above studies give foundation for creating a persona of a U.S. College Student who doesn't follow environmental news and thinks climate action doesn't make a difference. This doesn't necessarily mean this group of people with similar ideas would deny climate change is happening. Rather "Climate Denier" could be another persona, grouping people into a cohort who thinks climate change is not real. Further research would be needed to define relevant personas which have meaningful predictive and generalizing power.

Table 8: College Student Personas

Description	Name	Beliefs
Climate Change Denier	Jake Alice Sam	Climate change doesn't exist.

- Crabb (2023)

Rooney-Varga et al. (2019) shows the effectiveness of ***The Climate Action Simulation*** in educating users about **success scenarios**.

Social Trust

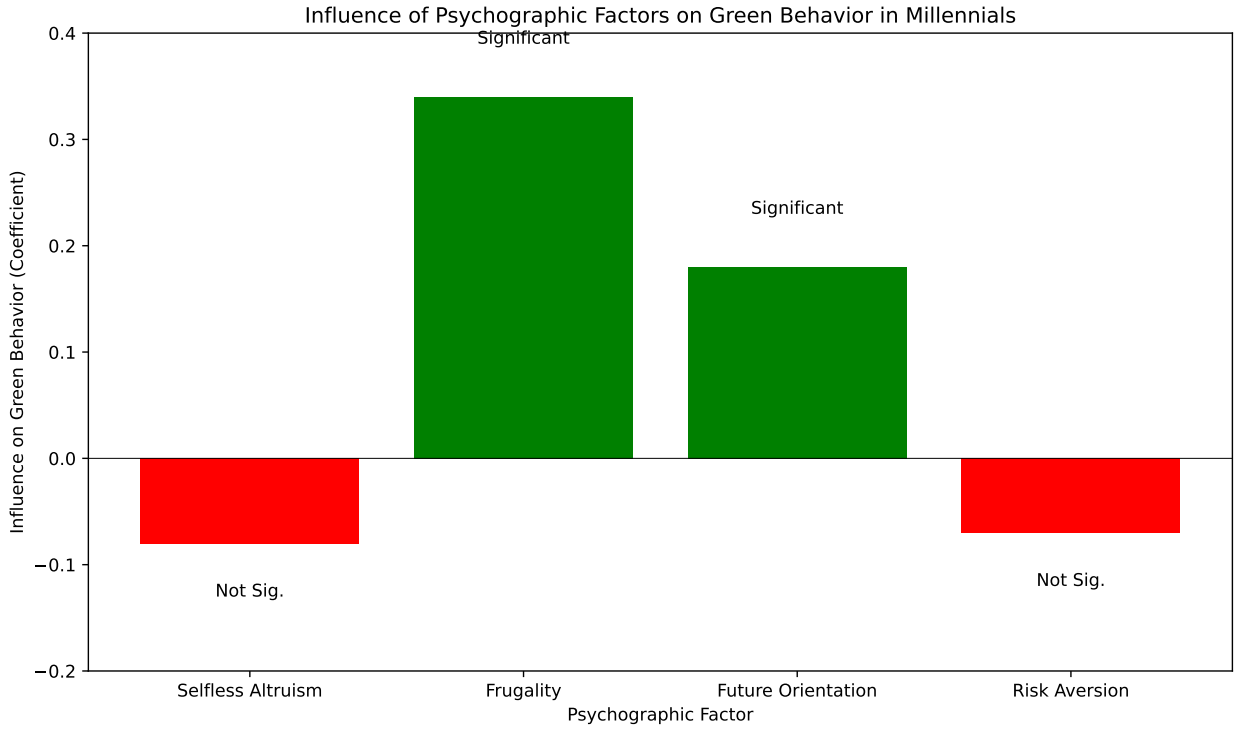
- When disaster hits we need high levels of social trust.

Climate Anxiety

A large worldwide study (n=10000, age 16-25) by (Hickman et al., 2021) provides evidence the youth is anxious about climate in Australia, Brazil, Finland, France, India, Nigeria, Philippines, Portugal, the UK, and the USA. Similarly, (Thompson, 2021) finds young people around the world have climate anxiety. (Whitmarsh et al., 2022) shows worry about the climate in the UK is generally widespread (over 40% of the respondents, n=1332), while climate anxiety is highest among young people and is a possible motivator for climate action. Additionally, (Ogunbode et al., 2022) finds climate anxiety in 32 countries and also supports the idea that climate anxiety leads to climate activism. (Thibodeau, 2022): "In 2021, the BBC polled 1,000 people in Scotland to understand the barriers to taking climate action. What they found was even though many people were aware of actions needed to take to address climate change, and had intentions to their behaviors didn't change. This is a phenomenon called the intention-action gap."

- (Osaka, 2023) argues *doomerism* is an excuse for climate in-action. Hope is necessary for people to make changes in their habits (Marlon et al., 2019).
- Designing for Health and Sustainability: Health and sustainability are intrinsically connected. (Kjaergard, Land & Bransholm Pedersen, 2014) shows how "understanding health and sustainability as a duality, health both creates conditions and is conditioned by sustainability, understood as economic, social and environmental sustainability, while on the other hand sustainability creates and is conditioned by human health"
- Design for Human Rights (UNFCCC, 2023b)] text refers to "human right to a clean, healthy and sustainable environment".
- Refi podcast: "people need agency".
- Martiskainen et al. (2020) (need access, ncku doesn't subscribe)
- Seabrook (2020) (need access)
- Older research on young adults (Millenials at the time) highlights how Millenials "use Google as a reference point for ease of use and simplicity" (Kate Moran, 2016).

Psychological factors influencing millenials to engage with sustainability (Naderi & Van Steenburg, 2018)



Community

Humans working together are able to achieve more than single individuals. "Any community on the internet should be able to come together, with capital, and work towards any shared vision. That starts with empowering creators and artists to create and own the culture they're creating. In the long term this moves to internet communities taking on societal endeavors."

- Building a culture of sustainability? (Lakshmi Rebecca, 2018; Armstrong & Staff, 2021).

The focus on *group consciousness* suggests community-based sustainability action may be effective.

Zero Waste Lifestyle is the opposite of overconsumption. Zero waste suggests people buy in bulk to save. Buying in bulk for more savings and to reduce packaging. Through group purchases and community investing while also reducing consumption. - Zero waste municipality in Treviso

Minimalism is a movement of people living a simple life. This is always going to be a small percentage of people. (Costa, 2018): Finnish socialists: minimalism. Tokyo (Tokyo Simple Eco Life, 2021). - consumers choose to engage in becoming minimalist in a non-linear process with overlapping stages (Oliveira De Mendonça, Coelho Rocha & Bogéa Da Costa Tayt-son, 2021).

What are the building blocks of a thriving community?

Luxury - Conversely, Taiwan is a growing market for luxury brands (Karatzas, Kapoulas & Priporas, 2019).

Empowerment

- I would like to have an AI agent to set my requirements and preferences and give a "fuck you" middle finger to companies that don't meet them. I could also give a thumbs up to companies that meet my expectations. Perhaps the user interface could like Tinder where I can swipe left and right.

Trends and Memes

- 2024 "underconsumption" and "deinfluencing" are trends on TikTok Fares, Lee & Lee (2024)
- https://www.tiktok.com/search?q=underconsumption
- https://www.tiktok.com/search?q=deinfluence
- https://www.tiktok.com/tag/deinfluencing
- https://www.tiktok.com/tag/underconsumption
- Coined by Richard Dawkins in 1976 in the context of biology.
- Internet memes and meme stocks
- Memes from daily life, business to war, are relevant to penetrating through the noise of the web.
- Memes and sustainability?
- Meme research has become an academic discipline
- Memes have become a popular communication tool..
- Zidani (2021)
- Zidani & Miltner (2022)
- Irina Lyan, Limor Shifman & Sulafa Zidani (2015)
- Zannettou et al. (2018)
- Peters-Lazaro, Shresthova & Jenkins (2020)

Design Implications

College Students Need Tools for Action

Environment shapes action.. create an environment where college students can influence companies.

Category	Implication
Community	Taiwanese students are influenced by the actions of their peers; the app should show what other people are doing. People exist in relation to other people. Psychology of 'fundraising clubs' vs individual investing

Category	Implication
	Anon (n.d.bu) Ukraine DAO to support Ukraine through web3.
	These social movements are small and require too much effort to be feasible for the app?
	Most college students are not zero waste or minimalist.
	Group Purchases.
	Find Your Composting Community.
	Provides a community for pooling money with like-minded investors.
Climate Anxiety	How to support the youth? Design to reduce climate anxiety? Is getting people to go to nature more a good way to increase ecological awareness? Empowered by Design. Youth empowerment: The design should empower young people.
	Consumer branded carbon credits like angry teenagers?
	Invest time not money, student don't have money?
Social Trust	**Show Success Scenarios!**
	Ask how much time you want to contribute.
	Match with other people based on time.
	Create a group chatroom.
	Use AI to help out with tips.
	Ask university students what do they study and match with that industry to become expert and sustainability leader in this field.
	People want to help and make a difference. Give people things to do. The Don't Look Up (n.d.) part of the ***Don't Look Up*** movie's social campaign provides 5 user models / roles for the audience to follow: Consumer, Investor, Activist.
	Choose Your Climate Solutions.
	Younger people show higher motivation (participants in climate protests). How to be relevant for a younger audience?
	Yet action remains low.
	Targeted and gated to college students.
	FB, etc, Gas all had the same launch strategy - start with students
	Kuzminski (2015) ecology of money
	Young people are mobile-first
	Persona: I care mostly about… fashion, art, …
	Young people like to follow trends.
	Food ordering apps are popular.
	Monoculture to regenerative food forests Oil to electric cars / bicycles.
	Social Educational Edutainment Fun
	aespa (2020): Karina from Korea. It makes sense your sustainability assistant would talk to you. Studies show gen N is speaking to computers all the time. Interacting with the user is on the rise. For example, Chime makes tipping suggestions on the place of purchase.
	The demographics that stand to win the most from the green transformation of business are the youngest generations, with more years of life ahead of them, and more exposure to future environmental and social risks. It would be advisable for Generation Z and their parents (Millennials) to invest their resources in greener assets, however, it's still difficult to pick and choose between 'good' and 'bad' financial vehicles to invest in.
	This creates an opportunity for a new generation of sustainable investment apps, focusing on the usability and accessibility of ESG for a mainstream audience. Generation Z and Millennials expect a consumer-grade user experience.

Category	Implication
	What would that experience look like? I've chosen these demographics with the assumption that if given the right tools, the emotional demand for sustainability could be transformed into action. The exploration of systems of feedback to enable consumers to apply more direct positive and negative pressure to the businesses and consumers signal consequences for undesirable ecological performance is a major motivation of this study.

Feature Ideas

The current environmental upheaval, led by Gen-Z and Millennials, and the business adaptation (or lack thereof) to sustainable economic models, taking into account the hidden social and environmental costs we didn't calculate in our pricing before.

- We also need to consider environmental effects (E in ESG). We haven't taken into account the whole cost of production, leading to the wrong pricing information. To achieve this, we need expert governance (G).
- I was unable to find similar research on university and post-graduate level students in Taiwan.
- Taiwanese college students and SDGs (Ho et al., 2022).
- College students in tourism and related fields . and sustainability
- Consumers may be turned off by mentioning AI in product description. Cicek, Gursoy & Lu (2024)
- Progress in other areas of environmental protection has not made similar progress.
- There are documentaries about oil product
- Plastic production documentary
- I've seen several.. find and cite them to show the progression of the environmental movement in Taiwan ADD CITATION
- The Taiwanese Green party
- Contact SOAS?

Sustainability

The Roots of Sustainability in Environmentalism

"Nachhaltigkeit" - *sustainability* in German - was likely the first use of the concept of preserving natural resources, conceived by a tax accountant Hannß Carl von Carlowitz in 1713 in his seminal book on forestry - *Sylvicultura oeconomica* -, referring to the goal of achieving prudent forest management practices in his native Saxony in Southeastern Germany, which at the time was under severe *deforestation* pressure from mining, ship-building and agricultural production (Hannß Carl von Carlowitz, 1713; Gottschlich & Friedrich, 2014). This particular field of sustainability study is now known as *sustainable yield of natural capital*. The *principal* of the natural resource being managed, such as in fishing and forestry, shouldn't be over-harvested in order to maintain ***ecosystem services*** - a contemporary term from the theory of *natural capital*, referring to benefits humans receive from the stock of world's natural resources (Peter Kareiva et al., 2011).

Defining sustainability perhaps more poetically, the American wildlife ecologist Aldo Leopold proposed the idea of *land ethics* in 1972 as *"[a] thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise"* in his landmark work *A Sand County Almanac* (Leopold, 1972). In a similar vein, the 1987 United Nations' Brundtland Report titled "*Our Common Future"* defined *sustainable development* as *"Development that meets the needs of the present without compromising the ability of future generations to meet their own needs"* (Anon, 1987). Given these varied ideas for over 300 years, I believe some percentage of people have been concerned with our planet's natural environment and its preservation already for centuries. Yet, it is only in the last 100 and so years that human activities have begun to affect Earth's systems on a previously unseen scale - termed *Anthropocene* -, necessitating a deeper understanding of human-nature interactions, such as in the case of climate change, which is rapidly changing the face of our living environments.

Measuring, Visualizing Earth's Climate

Studies of Earth's climate go back for over 200 years, starting with Alexander von Humboldt,the founder of climatology, who revolutionized cartography by inventing the first *isothermal maps* in 1816; these maps showed areas with similar temperature, variations in altitude and seasons in different colors (Honton, 2022) now available as 3D computer models(Anon, 2023p). Already in 1896, the Nobel Prize winner Svante Arrhenius first calculated how an increase in CO_2 levels could have a warming effect on our global climate (Anderson, Hawkins & Jones, 2016; Wulff, 2020). In 1938, Guy Stewart Callendar was the first scientist to demonstrate the warming of Earth's land surface as well as linking the production of fossil fuels to increased CO_2e and changing climate (Hawkins & Jones, 2013). Early scientists pioneered climate modeling by calculating the first climate interactions which precede today's complex computer-based *Earth System Models (ESMs)* that integrate the various Earth systems and cycles run on supercomputers (Anderson, Hawkins & Jones, 2016).

Figure 5: Humboldt's Naturgemälde, early data visualization of ecology, rain, temperature, elevation, etc

Environmental activists have been calling attention to global warming for decades, yet the world has been slow to act (McKibben, 1989). While the scientific case for human-induced climate change was building, it took 120 years after Arrhenius' calculations, until the Paris Climate Agreement in 2016, that countries came to an agreement on non-binding targets on keeping CO_2 levels 1.5 °C below pre-industrial levels (defined as 1850–1900)(United Nations, 2016). Even though awareness of Earth's warming climate was growing ever stronger, the CO_2 emissions kept rising too. The hockey-stick growth of CO_2 concentration since the industrial revolution is clear in the data from 1958 onward, following a steady annual increase, called the *Keeling Curve* (Keeling & Keeling, 2017). Written records of global temperature measurements are available starting from the 1880s, when temperatures began to be documented in ship logs (Brohan et al., 2012). Finally, although perhaps less accurately, temperature estimations from tree-trunks allow some comparisons with the climate as far back as 2000 years ago (Rubino et al., 2019).

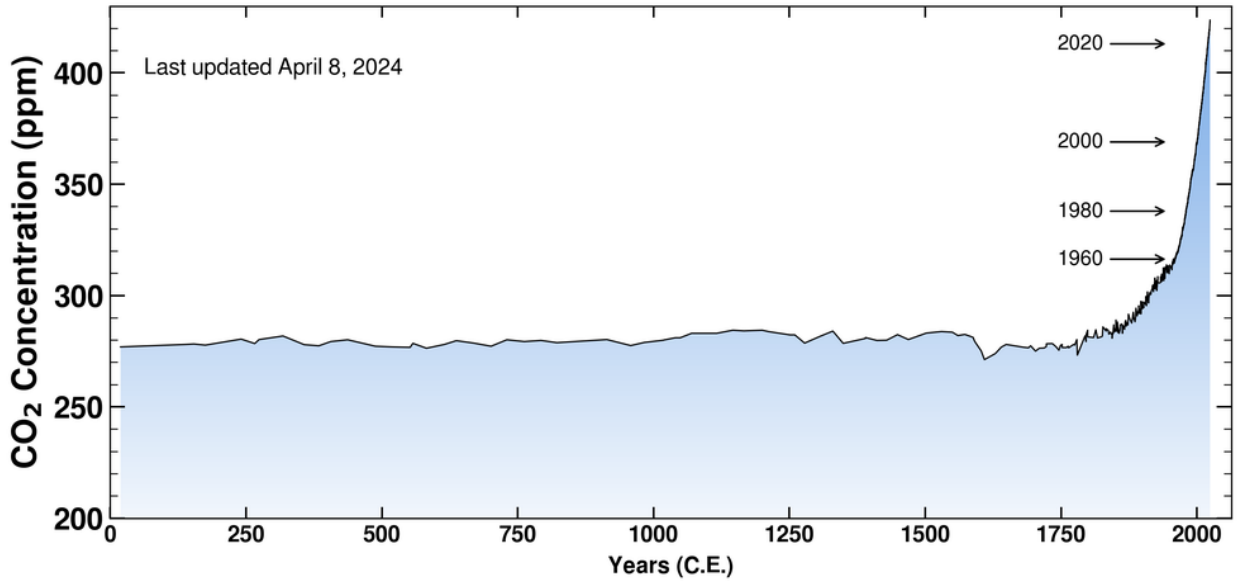


Figure 6: CO_2 concentration in the atmosphere as of Ap. Image Credit: Scripps Institution of Oceanography at UC San Diego.

The latest data from 2023 shows our current world population of 8 Billion people emitted 37.2 gigatonnes (i.e. billion metric tons) of CO_2e per year, the highest emissions recorded in history (Statista, 2023a). In order to limit global warming to 1.5 °C as agreed by the world nations in Paris, removal of 5-20 gigatons of CO_2e per year would be needed according to reduction pathways calculated by the Intergovernmental Panel on Climate Change (IPCC) (Wade et al., 2023). Yet, most countries are missing the mark (Climate Analytics & NewClimate Institute, 2023; United Nations Environment Programme, 2023). The European Union's Copernicus Climate Change Service (C3S) reports 1.5 °C global warming has already been breached in 2024 temperatures (Anon, 2024i; Anon, 2024c). Given the current pace of climate change action, the G7 countries (Canada, France, Germany, Italy, Japan, United Kingdom, United States) are heading for 2.7 °C of warming by 2050 (CDP, 2022).

Earth's physical systems are very sensitive to small changes in temperature, which was not understood until the 1970s(McKibben, 2006). A comprehensive review of evidence from paleoclimate records until current time, including ocean, atmosphere, and land surface of points towards substantial climate change if high levels of greenhouse gas emissions continue, termed by the authors as *climate sensitivity* (Sherwood et al., 2020). Global warming may lead to the slowing down and complete stop of the Atlantic meridional overturning circulation (AMOC) which helps maintain climate stability (Ditlevsen & Ditlevsen, 2023).

Measuring CO_2e Emissions

Technology improves and measurements have become more accurate yet CO_2e emissions are not yet completely accounted for. (Crippa et al., 2020) reports the latest figures CO_2e from the EU's Emissions Database for Global Atmospheric Research (EDGAR). The EU Copernicus satellite system reveals new greenhouse emissions previously undetected (Daniel Värjö, 2022). *Copernicus*

Climate Change Service (C3S) provides "[n]ear-real time updates of key global climate variables"(The Copernicus Climate Change Service, 2024).

- [@matthewgoreEmissionsRegulationsShipping2022] reports the International Maritime Organization (IMO) targets cutting CO_2 equivalent emissions in shipping 50% by 2050 compared to 2008.

Emissions production is highly unequal, with *"[t]he world's top 1% of emitters produce over 1000 times more CO2 than the bottom 1%"* (IEA, 2023a)

CO_2e emissions by region (per year).

Table 11: Comparing highest per capita CO_{2e} emissions (mostly from oil producers) vs regional average per capita CO_2 emissions vs total CO_2 emissions(Ivanova et al., 2020; World Resources Institute, 2020; European Commission. Joint Research Centre., 2022; Crippa et al., 2020; Liu et al., 2023d).

Regional Average Per Capita Emissions (2020)	**Highest Per Capita Emissions (2021)**	**Highest Total Emissions (2021)**
North America 13.4 CO_2e tonnes	Palau	China
Europe 7.5 CO_2e tonnes	Qatar	United States
Global Average 4.1 CO_2e tonnes	Kuwait	European Union
Africa and the Middle East 1.7 CO_2e tonnes	Bahrain	India
	Trinidad and Tobago	Russia
	New Caledonia	Japan
	United Arab Emirates	Iran
	Gibraltar	Germany
	Falkland Islands	South Korea
	Oman	Indonesia
	Saudi Arabia	Saudi Arabia
	Brunei Darussalam	Canada
	Canada	Brazil
	Australia	Turkey
	United States	South Africa

Scoping CO_{2e} *emissions* into 4 main categories helps to organize calculating CO_{2e} emissions and corresponding reduction targets by looking at direct and indirect emissions separately. The U.S. National Public Utilities Council (NPUC) decarbonization report provides a useful categorization of *emission scopes* applicable to companies which helps organizing emission reduction schemes (National Public Utilities Council, 2022) based on the Greenhouse Gas Protocol defined in the 1990s (GHG Protocol, n.d.). For example, for consumers in Australian states and territories in 2018, 83% of the GHG emissions are Scope 3, meaning indirect emissions in the value chain (Goodwin et al., 2023). A newer concept is Scope 4 emissions also known as avoided emissions, proposed by the World Resources Institute (WRI) in 2013 (Plan A, n.d.).

Table 12: Definition of Emission Scopes From (National Public Utilities Council, 2022).

Emission Scope	Emission Source
Scope 1	Direct emissions
Scope 2	Indirect electricity emissions
Scope 3	Value chain emissions
Scope 4	Avoided emissions

One's scope 3 emissions are someone else's scope 1 emissions.

- Mapping pollution sources in China Xie et al. (2021)

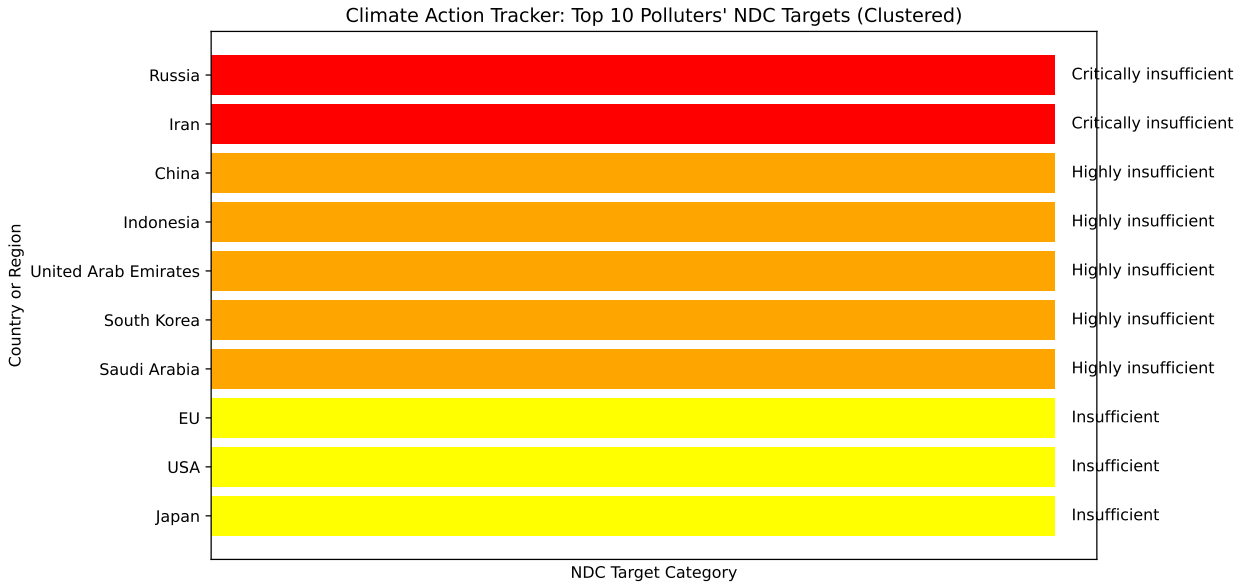
Countries have agreed up CO_{2e} Reduction Targets known as Country-Level Nationally Determined Contributions (NDCs)

- UNFCCC. Secretariat (2022) The State of Nationally Determined Contributions

While most countries have not reached their Nationally Determined Contributions, the Climate Action Tracker data portal allows to compare countries (Climate Analytics & NewClimate Institute, 2023). (Fransen et al., 2022) notes that the majority of Nationally Determined Contributions (NDCs) are dependent on financial assistance from the international community.

Table 13: Climate Action Tracker's country comparison of the 10 top polluters' climate action.

Country or Region	NDC target
China	Highly insufficient
Indonesia	Highly insufficient
Russia	Critically insufficient
EU	Insufficient
USA	Insufficient
United Arab Emirates	Highly insufficient
Japan	Insufficient
South Korea	Highly insufficient
Iran	Critically insufficient
Saudi Arabia	Highly insufficient



Fossil fuels are what powers humanity as well as the largest source of CO_2 emissions. IEA (2022) reports "Global CO_2 emissions from energy combustion and industrial processes rebounded in 2021 to reach their highest ever annual level. A 6% increase from 2020 pushed emissions to 36.3 gigatonnes". As on June 2023, fossil fuel based energy makes up 82% of energy and is still growing Institute (2023). The 425 largest fossil fuel projects represent a total of over 1 gigatons in CO_2 emissions, 40% of which were new projects Kühne et al. (2022). Tilsted et al. (2023) expects the fossil fuel industry to continue grow even faster. In July 2023, the U.K. granted hundreds of new oil and gas of project licenses in the North Sea (Anon, 2023ab).

Markets for Ecosystem Assets: Pricing, Tracing and Trading

Markets for ecosystems assets are centered around *carbon credits*, a type of nature-backed financial derivative dependent on science-based methodologies for measurement, reporting, and verification (MRV), which are managed and regularly updated by certification organizations such as Gold Standard, Verra, and others.

Table 14: Criteria for carbon credit projects.

Criteria	Description
Baseline	Ecosystem carbon sequestration rate without the intervention (project)
Additionality	New carbon capture or prevention of emissions
Permanence	Carbon storage time (should be long-term)
Leakage	Risk of shift to causing emissions (for example because of deforestation)

Verra updated their Agricultural Land Management methodology for Verified Carbon Standard (VCS) last year (Verra, 2023). Gold Standard recently release a methodology for Mangrove-based carbon credits [ADD CITATION].

CO_{2e} assigning a monetary value to carbon emissions.

Trading CO_{2e} emissions can be divided into 2 categories - *Compliance Carbon Markets* (CCM) and *Voluntary Carbon Markets* (VCM).

The legislative baseline for Compliance Carbon Markets is so low, people want to retire more CO_{2e}, which they can do through *Voluntary Carbon Markets.*

For the individual person, there's no direct access to CO_2 markets. However, brokers do buy large amounts of carbon credits to resell in smaller quantities to retail investors.

"*Carbon pricing is not there to punish people,"* says Lion Hirth Lion Hirth (n.d.). *"It's there to remind us, when we take travel, heating, consumption decisions that the true cost of fossil fuels comprises not only mining and processing, but also the damage done by the CO_2 they release."*

Long term cost of insufficient climate action is more than *short-term gains* from delaying efforts to reduce carbon emissions.

- The total size of carbon markets reached 949 billion USD in 2023, including Chinese, European, and North American CO_2 trading (LSEG & Susanna Twidale, 02/12/2024, 02:37 PM).
- *The price of* CO_{2e} *differs across markets.* (Stern, 2022) argues carbon-neutral economy needs higher CO_{2e} prices and believes (Rennert et al., 2022) CO_{2e} price per ton should be 3,6x higher that it is currently. Contrary, (Ritz, 2022) argues optimal CO_2 prices could be highly asymmetric, low in some countries and high (above the social cost of CO_{2e}) in countries where production is very polluting.
- iGenius (2020)

The fossil energy production that's a large part of global CO2 emissions has caused several high-profile pollution events. Large ones that got international news coverage include Exxon Valdez and Deepwater Horizon.

- Lenton et al. (2023) quantifying human cost of global warming.
-

CO_{2e} credits has given rise to *Carbon Accounting industry.*

- Watershed is a large carbon accounting company.
- The legislation has created an industry of CO_2 accounting with many companies like Greenly, Sustaxo, etc.
- Quatrini (2021) sustainability assessments are complex and may give flawed results.
- Nonetheles, CO_2 emission reduction has the added positive effect of boosting corporate morale (Cao, Li & Hasan, 2023).

Compliance Carbon Markets

meet legal emission reduction targets

Cap & Trade

The share of CO_2 emissions among people around the world is highly unequal across the world (referred to as ***Carbon Inequality***). (Chancel, 2022) reports "one-tenth of the global population is responsible for nearly half of all emissions, half of the population emits less than 12%".

- One example is the ICT sector.
- Bajarin (n.d.) Over 300 million PCs sold in 2022
  - Anon (2021h) Estonian company "sustainable lifecycle management of IT equipment"
  - Ärileht (23.09.2022, 12:53) Recycle your phone, FoxWay and Circular economy for PCs.
  - Zhou et al. (2022a) ICT is an example of inequality, while emerging economies bear 82% of the emissions, developed countries gain 58% of value.

Emissions Trading Schemes

From Carbon Offsets to Carbon Credits

- "A carbon credit represents one tonne of carbon dioxide that has been prevented from entering or has been removed from the atmosphere" (Anna Watson, 2023, 2022).

Retiring CO_2 allowances

- Facilitating citizens' access to CO_2 emissions trading may be an efficient method to organize large-scale CO_2 retiring (Rousse, 2008).

As of 2024 there's no single global CO_2 trading market but rather several local markets as described in the table below.

Table 15: CO_2 credit trading markets around the world from Anon (n.d.ak).

CO_2 Market	Launch Date	Comments
EU	2005	EU: Araújo et al. (2020)
South Korea	2015	
China	2021	China's national emissions trading scheme (ETS) started in 2021 priced at 48 yuan per tonne of CO_2, averaged at 58 yuan in 2022 (Liu, 2021; Ivy Yin, 2023).
U.S.	2013	No country-wide market; local CO_2 markets in California, Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont
New Zealand	2008	New Zealand Rontard & Reyes Hernández (2022) (need access, important ncku doesn't subscribe)
Canada	2013	

Most of the world is not part of a CO_2 market.

- (Sipthorpe et al., 2022) compares traditional and blockchain-based solutions to carbon trading.

- "Blockchain solutions for carbon markets are nearing maturity" and offer many improvements. enhancing transparency, trust, and efficiency.
- (United Nations Environment Programme (UNEP), 2021) report. "The Emissions Gap Report (EGR) 2021: The Heat Is On shows that new national climate pledges combined with other mitigation measures put the world on track for a global temperature rise of 2.7°C by the end of the century. That is well above the goals of the Paris climate agreement and would lead to catastrophic changes in the Earth's climate. To keep global warming below 1.5°C this century, the aspirational goal of the Paris Agreement, the world needs to halve annual greenhouse gas emissions in the next eight years.
- (United Nations Environment Programme (UNEP), 2021) report "If implemented effectively, net-zero emissions pledges could limit warming to 2.2°C, closer to the well-below 2°C goal of the Paris Agreement. However, many national climate plans delay action until after 2030. The reduction of methane emissions from the fossil fuel, waste and agriculture sectors could help close the emissions gap and reduce warming in the short term, the report finds. Carbon markets could also help slash emissions. But that would only happen if rules are clearly defined and target actual reductions in emissions, while being supported by arrangements to track progress and provide transparency."
- (United Nations Environment Programme, 2022) 2022 Emissions Gap report.

Table 16: Compliance market CO_2 prices on August 12, 2023; data from (Ember, 2023; Trading Economics, 2023; CarbonCredits, 2023).

Compliance Markets	Price (Tonne of CO_2)
EU	83 EUR
UK	40 Pounds
US (California)	29 USD
Australia	32 USD
New Zealand	50 USD
South Korea	5.84 USD
China	8.29 USD

- tree bark absorbs methane, (Gauci et al., 2024).

Voluntary Carbon Markets

Verified Carbon Standard (VCS) and the Gold Standard, Climate Action Reserve (CAR), American Carbon Registry (ACR)

"BeZero Carbon is a ratings agency for the Voluntary Carbon Market."

https://bezerocarbonmarkets.com/

Voluntary Carbon Markets are …

Voluntary Carbon Markets (VCM) lack standardization and transparency (Ela Khodai, 2023).

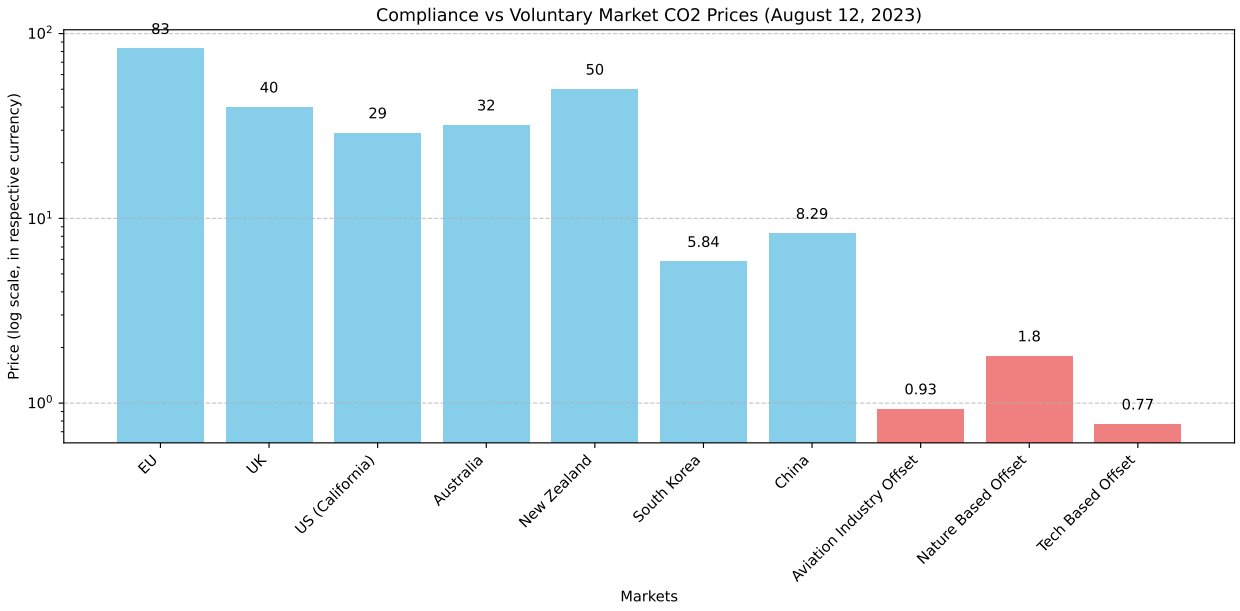
Carbon Credits are useful for private companies who wish to claim *carbon neutrality, climate positivity*, or other related claim, which might be viewed in good light by their clients or allow the companies to adhere to certain legislative requirements.

There are many companies which facilitate buy carbon credits as well as a few organizations focused on carbon credit verification.

- In Estonia, startups Arbonic and Single.Earth are trialing this approach in several forests.
- For example Flickr invested 3000 USD in carbon credits and got a carbon-neutral rating (?!).
- Carbon Credit Retirement?
- Methodologies: Anon (2022i)
- KlimaDAO (2023) call for an open standard

Table 17: Voluntary market CO_2 prices on August 12, 2023; data from (CarbonCredits, 2023).

Voluntary Markets	Price (Tonne of CO_2)
Aviation Industry Offset	$0.93
Nature Based Offset	$1.80
Tech Based Offset	$0.77



Overconsumption > Earth's Boundaries

Excessive consumer lifestyle - *overconsumption* - is one of the main drivers of climate change and environmental destruction, with *"2/3 of global GHG emissions are directly and indirectly linked to household consumption, with a global average of about 6 tonnes CO_2 equivalent per capita"* , according to (Renee Cho, 2020; Ivanova et al., 2020). An older study put the number as high as 60% percent (Ivanova et al., 2016) while (Ellen MacArthur Foundation, Material Economics, 2019)'s models 45% show of CO_2 equivalent emissions come from our shopping; produced by companies to make the products we consume.

With the trend of urbanization, it's not surprising (people living in) cities are responsible for 80% of the emissions (Rosales Carreón & Worrell, 2018). (Moberg et al., 2019) reports daily human activities emission contribution on average in four European countries (France, Germany, Norway and Sweden).

Table 18: Daily human activities emission contribution on average in France, Germany, Norway and Sweden from (Moberg et al., 2019).

Emission Share	Category
21%	Housing
30%	Food
34%	Mobility
15%	Other

Earth's growing population reached 8 Billion people In November 2022 and population projections by predict 8.5B people by 2030 and 9.7B by 2050 (The Economic Times, 2022; United Nations Department of Economic and Social Affairs, Population Division, 2022). Indeed, making *anything* consumes natural resources, which are limited on planet Earth. (Hassoun et al., 2023) forecasts increase of global food demand by 62% driven by the impact of climate change. Yet, while population growth puts higher pressure on Earth's resources, some researchers propose the effect is higher from wasteful lifestyles than the raw number of people (Cardinale et al., 2012). Meanwhile others, such as (Cafaro, Hansson & Götmark, 2022), believe *[o]verpopulation is a major cause of biodiversity loss and smaller human populations are necessary to preserve what is left."*

While the numbers on overconsumption are clear, the debate on overconsumption is so polarized, it's difficult to have a meaningful discussion of the topic (Ianole & Cornescu, 2013). Environmental risks from human activities are known as Anthropogenic Threat Complexes (ATCs) (Bowler et al., 2020). As long as humanity is a mono-planetary species, we have to come to terms with the limitations of our home, Earth.

Plastic Pollution

Overconsumption is also one of the root causes of plastic pollution. (Ford et al., 2022) and (Lavers, Bond & Rolsky, 2022) find strong links between climate change and marine plastic pollution *"along with other stressors that threaten the resilience of species and habitats sensitive to both climate change and plastic pollution"*.

Plastic pollution is pervasive around the Earth and is fundamentally linked to climate change, while microplastics are increasingly a real concern (Tiernan et al., 2022; Lavers, Bond & Rolsky, 2022). Several international studies report recent findings of microplastics everywhere in human bodies: the brain, lungs, digestive tissues, bone marrow, penis, testis, seminal fluid (semen), and placenta - causing serious health and reproductive concerns (Main, 2024; Guo et al., 2024; Hu et al., 2024; Codrington et al., 2024; Li et al., 2024; Montano et al., 2023; Garcia et al., 2024; Zhu et al., 2024)

- Jackson (2017) limits to growth update
- (Keeble, 1988) reported in April 1987 that *'residents in high-income countries lead lifestyles incompatible with planetary boundaries'*.
- Overconsumption and underinvestment.

- Armstrong McKay et al. (2022) discusses tipping points.

In addition to the enormity of over-reaching CO_2 emissions, humanity is facing other massive environmental problems. The Stockholm Resilience Centre reports we have already breached 4 out of our 9 *"planetary boundaries":* in addition to climate change, biodiversity loss (Extinctions per Million Species per Year aka E/MSY), land-system change (deforestation, land degradation, etc), and biogeochemical flows (cycles of carbon, nitrogen, phosphorus, etc); on a positive side, the challenges of fresh water use, ocean acidification and stratospheric ozone depletion are still within planetary limits (Persson et al., 2022).

- Ceballos, Ehrlich & Dirzo (2017) mass extinctions
- IUCN Red List: 45,300 species (28% of all assessed) under threat of extinction IUCN (2024)

Atmospheric aerosol loading and the biodiversity intactness index (BII) were quantified recently (ADD CITATION)

My home country Estonia at the time was considered low-income, a small nation in poverty behind the *Iron Curtain* occupation of the Soviet Union, we now in 2024, have also reached high-income status.

- De Balie (2018)
- Houdini (2018)
- Haeggman, Moberg & Sandin (2018)
- Richardson et al. (2023)

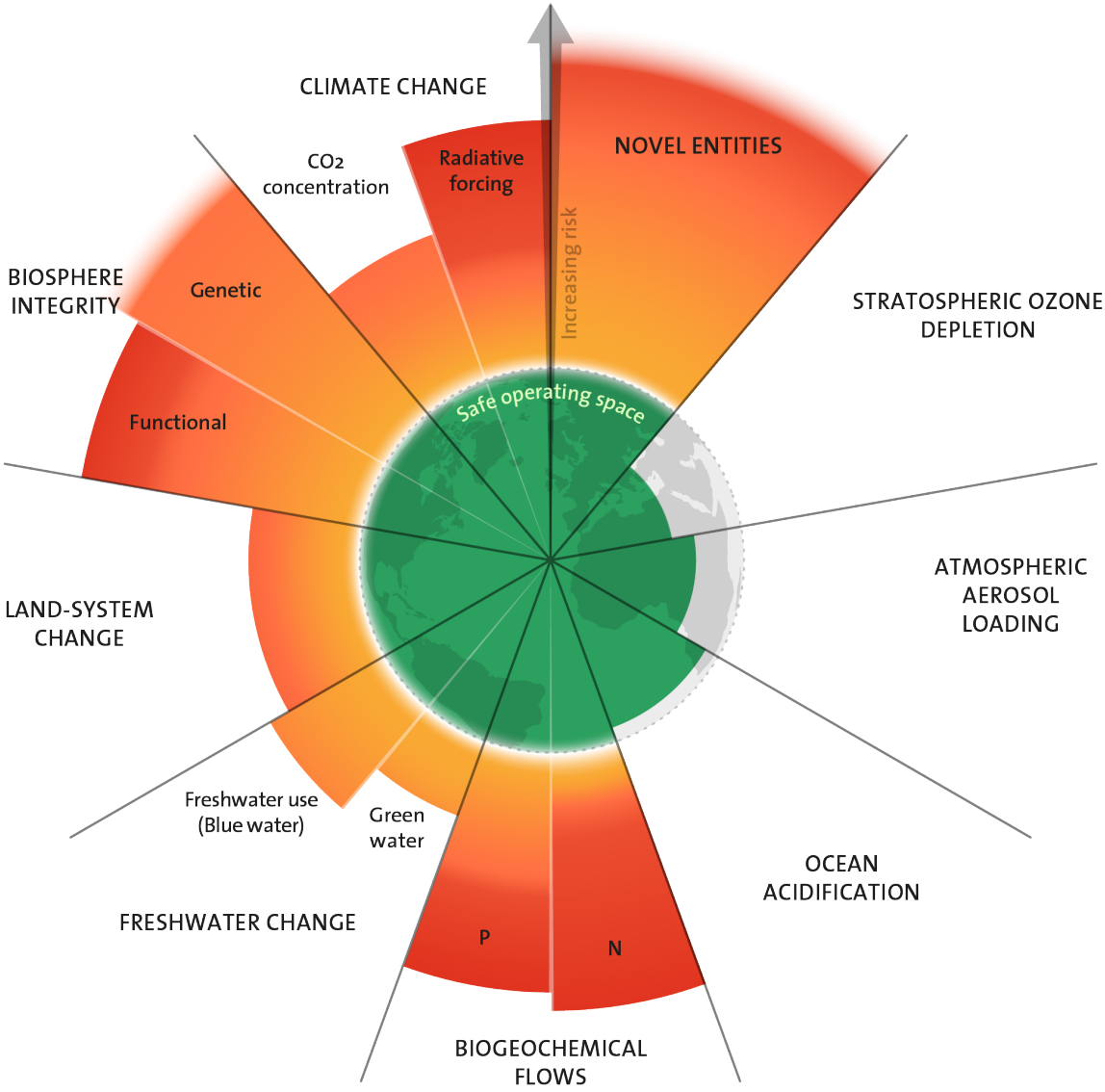


Figure 7: Planetary Boundaries 2023 update. Azote for Stockholm Resilience Centre, based on analysis in Richardson et al 2023

In 1948, the International Union for Conservation of Nature (IUCN) was founded, which in

LULUCF "Land Use, Land-Use Change, and Forestry" can both be a source of greenhouse gas emissions - or a carbon sink (removing CO2 from the atmosphere).

Earth System Law, Planetary Health, and Social Cost of CO_2

Planetary Health, *Earth System Law, and* Social Cost of Carbon are 3 approaches to address the complex interdependence of humans with our physical environment.

Scientists in cross-disciplinary teams have been working on integrating Earth systems and human society into cohesive frameworks.

Evolving Measurements from Planetary Boundaries to Planetary Health

- Planetary health (Planetary Health Alliance, 2024a, 2024b)
- Wardani et al. (2023) *"long-term human well-being is dependent on the well-being of the planet, including both biotic and abiotic systems. It recognizes interlinkages across environmental sustainability, public health, and socioeconomic development."*

Earth System Law is a framework for addressing interconnected environmental challenges (Du Toit & Kotzé, 2022).

Social Cost of Carbon attempts to measures the compound impact of CO_{2e} emissions on society. Sustainability is filled with complexities. CO_{2e} emissions are complicated by biodiversity loss, child labor, slavery, poverty, chemical pollution, etc. - many issues become intertwined (TEDx Talks, 2020). One attempt to measure these complexities, is the *Social Cost of Carbon* (SCC) which is defined as *"additional damage caused by an extra unit of emissions"* (Kornek et al., 2021; Zhen, Tian & Ye, 2018). For example the cost of damages caused by "one extra ton of carbon dioxide emissions" (Stanford University, 2021). SCC variations exist between countries (Tol, 2019) and regions (Wang, Ma & Wang, 2022).

-
- (Lin et al., 2022a) says, apart from CO_2, reduction of other atmospheric pollutants, such as non-CO_2 greenhouse gases (GHGs) and short-lived climate pollutants (SLCPs) is required for climate stability.
- (Wang & Teng, 2022): Quantifying climate damage proposes scenarios of climate damage.

Ecosystem Services: Quantifying Human Benefits from Nature

Ecosystem services measure the benefits humans receive from the biosphere. Put most simply, *ecosystem services* enable human life on Earth. While it can be assumed much of the flora and fauna are crucial for Earth's systems, science is still in the process of understanding and quantifying its contributions. The history of the valuation of nature's services goes back to the 18th century when David Ricardo and Jean Baptiste Say discussed nature's *work*, however both considered it should be free (Gómez-Baggethun et al., 2010). In 1997 (Anon, 1997) proposed the idea of *ecosystem services* and (Costanza et al., 1997) attempted to assess the amount of ecosystem services provided. (Le Provost et al., 2022)'s study shows *biodiversity* as one key factor to maintain delivery of ecosystem services. (Noriega et al., 2018) attempts to quantify the ecosystem services (ES) provided by insects.

The most complex computer models which attempt to capture ever more interactions happening in the physical realm are called *digital twins.* The EU is developing a digital twin of Earth to help sustainability prediction and planning, integrating Earth's various systems such as climate, hydrology, ecology, etc, into a single model Anon (2023f). We can use all the data being recorded to provide a digital twin of the planet, nature, ecosystems and human actions to help us change our behavior and optimize for planetary wellbeing.

- Jackson (1996) *preventive environmental management*

Biosphere

Earth's biosphere is made up of 846 terrestrial ecoregions, which are distributed across 14 major biomes and 8 biogeographical realms (Dinerstein et al., 2017).

Ecological Indicators

Sustainability can be measured using a variety of *ecological indicators*.

Ecological indicators for Earth - *I would like to coin the word "ecomarkers"* - are like *biomarkers* in human health.

Technological advances help scientist better understand nature. Cutting edge research uses AI-based voice recognition for listening to nature, assessing biodiversity based on species' sounds in the forest. Millions of detections of different species with machine learning passive acoustic AI models, can also assess species' response to climate change (AI for Good, 2023; Guerrero et al., 2023).

Environmental DNA (eDNA) helps scientists measure species abundance without direct observation through detection of DNA on genetic materials such as skin cells (Peter Andrey Smitharchive page, 2024). Cellular DNA can be isolated from various sediment types (Ogram, Sayler & Barkay, 1987). Beyond scientific applications, eDNa is being used to generate biodiversity credits by environmental asset rating companies such as BeZero (Ojoatre & Atkinson, 2023).

AI is being used to map icebergs and measure the change in size (European Space Agency, 2023).

Biodiversity

Why Protect Biodiversity?

(May, 2011) argues biodiversity loss is a concern for 3 points of views:

Table 19: From (May, 2011)@.

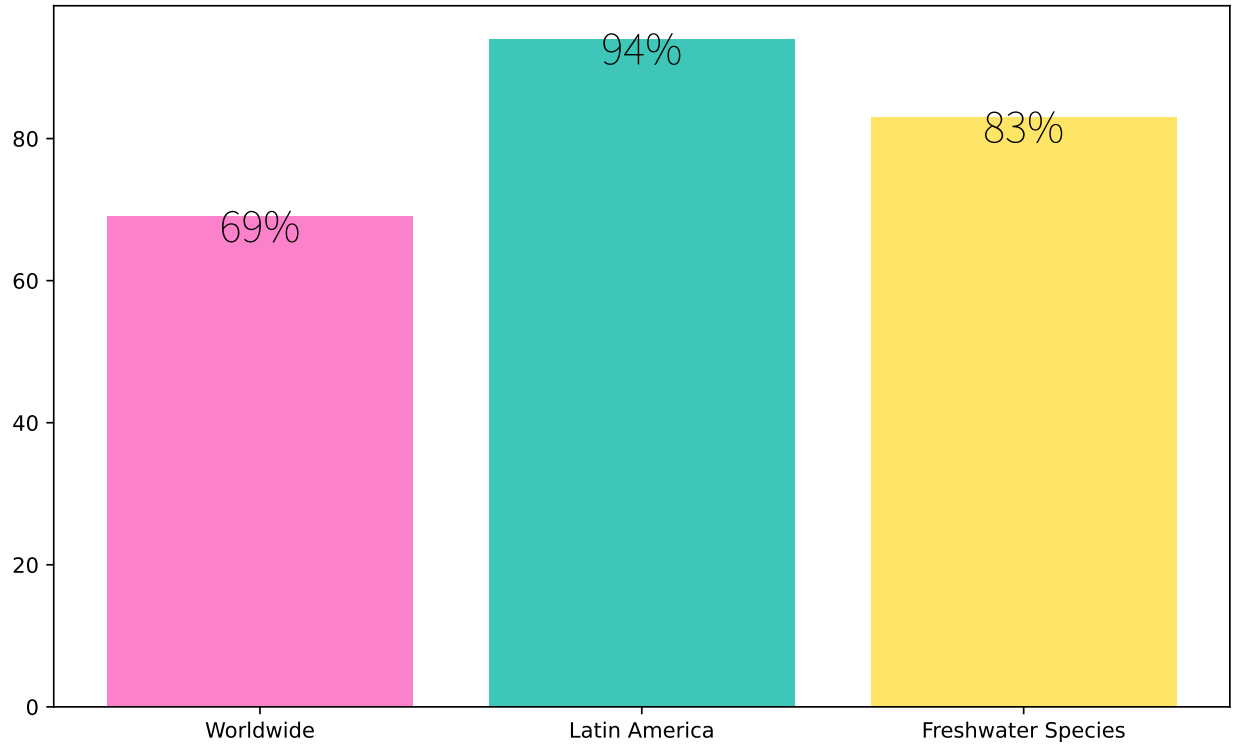
View	
Narrowly Utilitarian	Biodiversity is a resource of genetic novelties for the biotech industry.
Broadly Utilitarian	Humans depend upon biodiverse ecosystems.
Ethical	Humans have a responsibility to future generations to pass down a rich natural world.

-
- Meanwhile the destruction pressure on ecosystems is rapidly increasing (ADD CITATION A B C).
- Chen et al. (2023) Ecosystem vulnerability **(need access)**

- Zhang et al. (2023b) Integrating ecosystem services conservation into urban planning **(need access)**
- Li et al. (2023) tourism is a large industrial sector which relies on ecosystem services. In Taiwan, (Lee, Jan & Liu, 2021) developed a framework of indicators to assess sustainable tourism.

Measuring Environmental Degradation

(Almond, R.E.A. et al., 2022) reported, the number of species killed, mass destruction of nature. "69% decline in the relative abundance of monitored wildlife populations around the world between 1970 and 2018. Latin America shows the greatest regional decline in average population abundance (94%), while freshwater species populations have seen the greatest overall global decline (83%)."



Biodiversity loss is linked to overconsumption, weak legislation and lack of oversight. (Crenna, Sinkko & Sala, 2019) recounts European Union consumers' negative impact on biodiversity in countries where it imports food. WWF (2022) case study highlights how 4 biodiverse regions Cerrado in Brazil, Chaco in Argentina, Sumatra in Indonesia, and the Cuvette Centrale in Democratic Republic of Congo are experiencing rapid destruction due to consumer demand in the European Union. While the European Union (EU) has recently become a leader in sustainability legislation, biodiversity protection measures among private companies is very low Marco-Fondevila & Álvarez-Etxeberría (2023).

Meanwhile, there is some progress in biodiversity conservation as "[*b]iodiversity awareness is now at 72% or higher in all countries sampled, compared to only 29% or higher across countries sampled in 2009"* (UEBT, 2022)

Convention on Biodiversity

Similarly to climate protection, the UN has taken a leadership role in biodiversity protection. Unit (2023): The history of the United Nations Convention on Biodiversity goes back to 1988, when the working group was founded. UNEP (Tue, 12/20/2022 - 07:44): The Convention on Biodiversity 2022 (COP15) adopted the first global biodiversity framework to accompany climate goals.

Protecting biodiversity

Table 20: Biodiversity loss data from (Bradshaw et al., 2021).

What Happened?	How Much?
Vertebrate species population average decline	68% over the last 50 years
Land surface altered by humans	70% of Earth
Vertebrate species extinct	700 in 500 years
Plant species extinct	600 in 500 years
Species under threat of extinction	1 million

Oceans

Blue carbon.

Marine Heatwaves

- Gelles & Andreoni (2023) describe how marine heatwaves threaten global biodiversity. Ocean warming leads to coral bleaching of the Great Barrier Reef in Queensland, east coast of Australia (Pfeiffer, 2024).
- Espinosa & Bazairi (2023) marine ecosystem services **(need access, ncku doesn't sub)**
- Howard et al. (2017) argues Oceans play crucial role in carbon capture.

Forest

Forests are a crucial part of Earth's carbon cycle and the main natural CO_2 capture system; due to deforestation, Europe rapidly losing its forest carbon sink (Frédéric Simon, 2022). Around 27% of Earth's land area is still covered by forests yet *deforestation* is widespread all around the world; highest rates of deforestation happened in the tropical rainforests of South America and Africa, mainly caused by agricultural cropland expansion (50% of all deforestation) and grazing land for farm animals to produce meat (38,5%), totaling close to 90% of global deforestation (Anon, 2022f). The global forest cover change is visible on Google's Earth Engine (Hansen et al., 2013).

Around the world, there are many initiatives to increase forest cover, for example the *1 billion tree project* (Greenfield & @pgreenfielduk, 2021; Anon, 2020; Bastin et al., 2019). However, it's important to not planting trees (*afforestation)* is not the full solution, as *afforestation* is different from *reforestation*, which takes into account biodiversity. Also, while using remote-sensing and machine-learning to assess reforestation potential (see Klosterman et al., 2022), it doesn't take into account local political realities.

- Burning of biomass undermines carbon capture.
- Bousfield et al. (2022) reports there's evidence paying landowners for the ecosystem services their forests provide may reduce deforestation.
- nature-based solutions.

Pollution

Health and sustainability are inextricably linked. "Human health is central to all sustainability efforts.", *"All of these (food, housing, power, and health care), and the stress that the lack of them generate, play a huge role in our health"* (Sarah Ludwig Rausch & Neha Pathak, 2021).

Air Pollution

Clean air is a proposed as a *human right* (Baroness Jones of Moulsecoomb & Caroline Lucas, 2023) yet air pollution is widespread around the planet, with 99% of Earth's human population being affected by bad air quality that does not meet WHO air quality guidelines, leading to health problems linked to 6.7 million *premature deaths* every year (World Health Organization, 2022).

Air pollution is linked to cancer incidence. In Taiwan, South Korea, and England, groundbreaking research by (Lim et al., 2022) analyzed over 400000 individuals establishes exposure to 2.5 m PM (PM2.5) air pollution as a *cause for lung cancer.* In (Hannah Devlin, 2022), professor Tony Mok, of the Chinese University of Hong Kong: *"We have known about the link between pollution and lung cancer for a long time, and we now have a possible explanation for it. As consumption of fossil fuels goes hand in hand with pollution and carbon emissions, we have a strong mandate for tackling these issues – for both environmental and health reasons."*

The main way to combat air pollution is through policy interventions. (MARIA LUÍS FERNANDES, 2023) the EU has legislation in progress to curb industrial emissions. If legislation is in place, causing bad air quality can become bad for business. In China, (Gu et al., 2023) links air pollution to credit interest rates for business loans; companies with low environmental awareness and a history of environmental penalties pay 12 percent higher interest rates. In France, (Bouscasse et al., 2022) finds strong health and economic benefits across the board from air pollution reduction.

Water Pollution

Globally, 4.4 billion people only have access to water that's not safe for drinking (Soliman, 2024).

- Bioswales help catch storm debris and reduce water pollution.
- Clean water and water pollution
- Koch (2022) (**Need access! NYC times)**
- Paris cleans Seine river for Paris Olympics

Soil Pollution

- *"Wild and ruderal plants as bioindicators of global urban pollution by air, water and soil in Riyadh and Abha, Saudi Arabia"* (Picó et al., 2023) uses wild and ruderal plants to detect pollution by air, water and soil.
- Bioindicators of anthropogenic pollution, pharmaceuticals, pesticides, and other industrial chemicals.
- Both Abha and Riyadh showed notable levels of pollutants while Riyadh with more industry showed higher levels.

Ready for Disaster

The Word Economic Forums Global Risks Report 2024 paints a bleak picture of the future with expectations of increased turbulence across the board based on a survey of over 1400 topic experts (World Economic Forum, n.d.).

Weather

Global warming increases the risk of disasters and extreme weather events.

(Anon, 2023i) The US Global Change Research Program presented a comprehensive report to the US Congress, which links disaster-risk directly to global warming; for examples increased wildfires damage property, endanger life and reduces *air quality,* which in effect increases health challenges. As extreme temperatures are increasingly commonplace, with observed changes in heatwaves, there's increased risk of wildfires (Volkova, Roxburgh & Weston, 2021; Perkins-Kirkpatrick & Green, 2023), while flood risk mapping might lower property prices in at risk areas (Sherren, 2024). Summers of 2022 and 2023 were the hottest on record so far, with extreme heat waves recorded in places around the world (Venturelli et al., 2023; Serrano-Notivoli et al., 2023; Douglas, 2023; National Oceanic and Atmospheric Administration (NOAA), U.S. Department of Commerce, 2023; NOAA National Centers for Environmental Information, 2023; Falconer, 2023).

The part of Earth where the *human climate niche* is becoming smaller (McKibben, 2023). As temperatures rise, certain cities may become uninhabitable for humans (CBC Radio, 2021). The summer of 2023 saw extensive wildfires in Spain, Canada, and elsewhere; rapidly moving fires destroyed the whole city of Lāhainā in Hawaii [ADD CITATION]. In California, (Jerrett, Jina & Marlier, 2022) says, *"[w]ildfires are the second most important source of emissions in 2020"* and *"negate reductions in greenhouse gas emissions from other sectors."* Some parts of South America have seen summer heat *in the winter*, with heatwaves with temperatures as high as 38 degrees (Livingston, 2023).

In Taiwan disaster risk and hazard mapping is well-developed, with early warning systems, and comprehensive response preparedness - and painful experiences - instrumental to saving lives (Tsai et al., 2021). Intensifying storms forming near coastlines, can be expected with *"[c]hanges to tropical cyclone trajectories in Southeast Asia under a warming climate"* (Garner et al., 2024). The situation on the Pacific and Atlantic oceans is not dissimilar, with *"[o]bserved increases in North Atlantic tropical cyclone peak intensification rates"* (Garner, 2023).

In the Phillipines, with increasing extreme weather events, *"businesses are more likely to emerge in areas where infrastructure is resilient to climate hazards"* (Cheng & Han, 2022).

Climate-related disasters can spur action as extreme weather becomes visible to everyone. After large floods in South Korea in July 2023 with many victims, president Joon promised to begin taking global warming seriously and steer the country towards climate action (Web, 2023; AFP, 2023; Al Jazeera, 2023). South Korea has a partnership with the European Union (European Commission, 2023a).

- Chernobyl and Fukushima
- the Great Pacific Garbage Patch
- Disputes in Eerola (2022).

Financialization of Nature vs Nature is Sacred: Scaling Up Sustainable Action:

There are 2 main approaches to protecting nature:

Economics of Nature Commodification	**Economics of the Sacred**
Measure and assign monetary value to nature.	Nature is Sacred - such as are religious holy places - and can't be touched (Eisenstein, 2011, 2018)

- (Leverhulme Centre for Nature Recovery, 2023) asks should we put a price on nature?
- Is it time to leave utilitarian environmentalism behind? Muradian & Gómez-Baggethun (2021)

Table 22: From (Leverhulme Centre for Nature Recovery, 2023).

9 Steps
Identify ecosystem functions
Quantify ecosystem functions
Identify ecosystem services
Quantify ecosystem services
Quantify financial value of ecosystem services
Assign property rights
Create ecosystem service markets
Commodify nature

Individual Action

Sometimes individual environmental (climate) action *does matter* and can come at great personal cost, even loss of life. EJAtlas tracks environmental justice cases around the world, where human stakes are very high Scheidel et al. (2020).

However, for most of us individual climate action is *ineffective*. The effect of individual climate action such as *choosing a more sustainable product* is so limited to be next to meaningless. For individual consumer choices to make a difference, they need to be *aggregated* into a movement, collective action with scale, influence, and visibility.

There is no single solution to the environmental crisis. Given the enormity of environmental degradation, many different approaches are needed. This chapter documents some of the ongoing work which a sustainability companion could assist college students get involved with.

Restoration

Regenerative Action

- (Han & Chen, 2022) identifies nature-based solutions "land re-naturalization (such as afforestation and wetland restoration)"

Table 23: From Han & Chen (2022)

Non-Exhaustive list of
Afforestation
Wetland restoration

Ecology, Agroforestry & Permaculture

Some argue sustainability is not enough and we should work on *regeneration* of natural habitats.

The UN announced 2021-2030 the Decade on Ecosystem Restoration (Fischer et al., 2021).

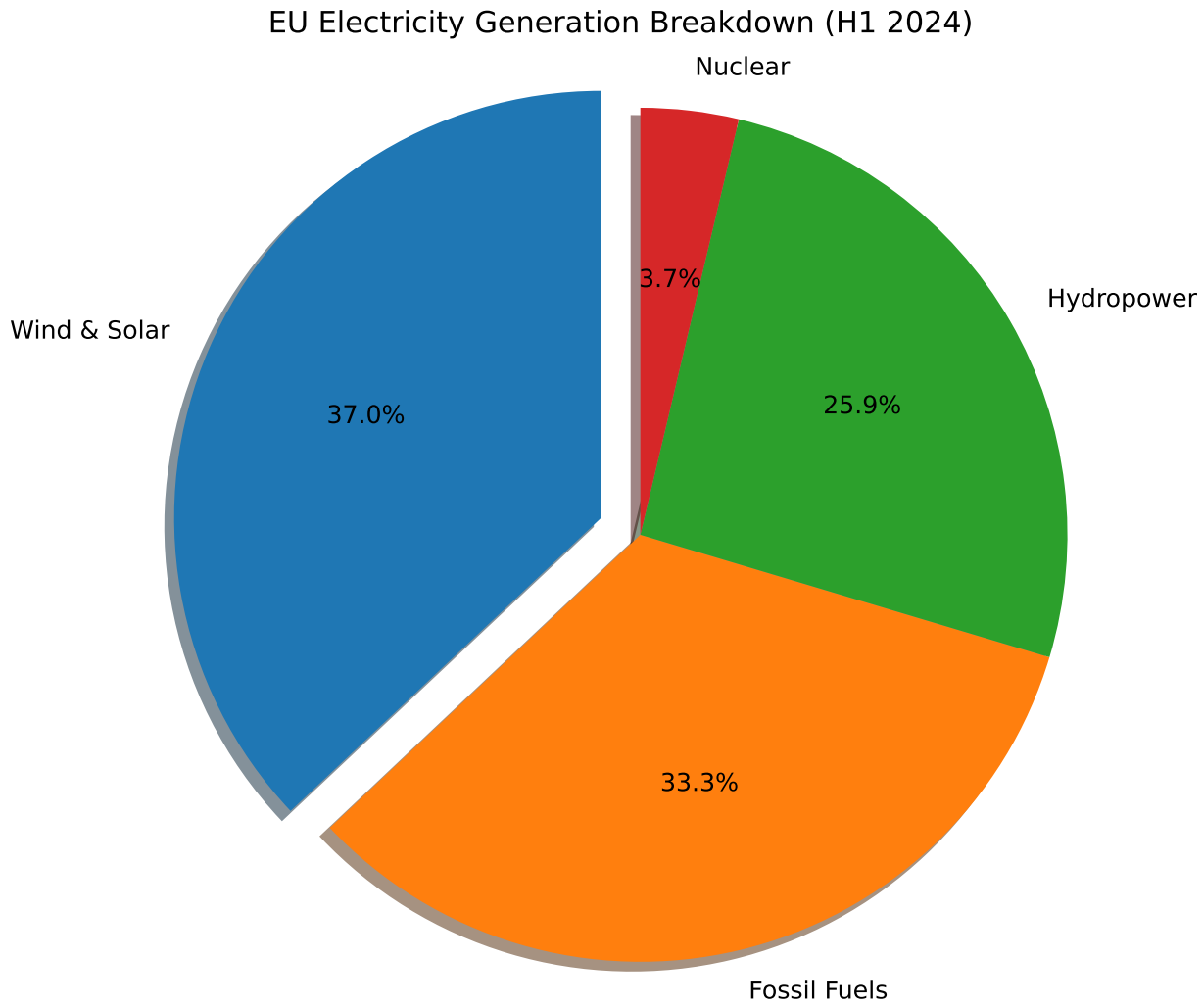
- Agroecology Baltic Sea Action Group (2023)

Agroforestry plays an active role in achieving Sustainable Development Goals (SDGs) (Ruba & Talucder, 2023);

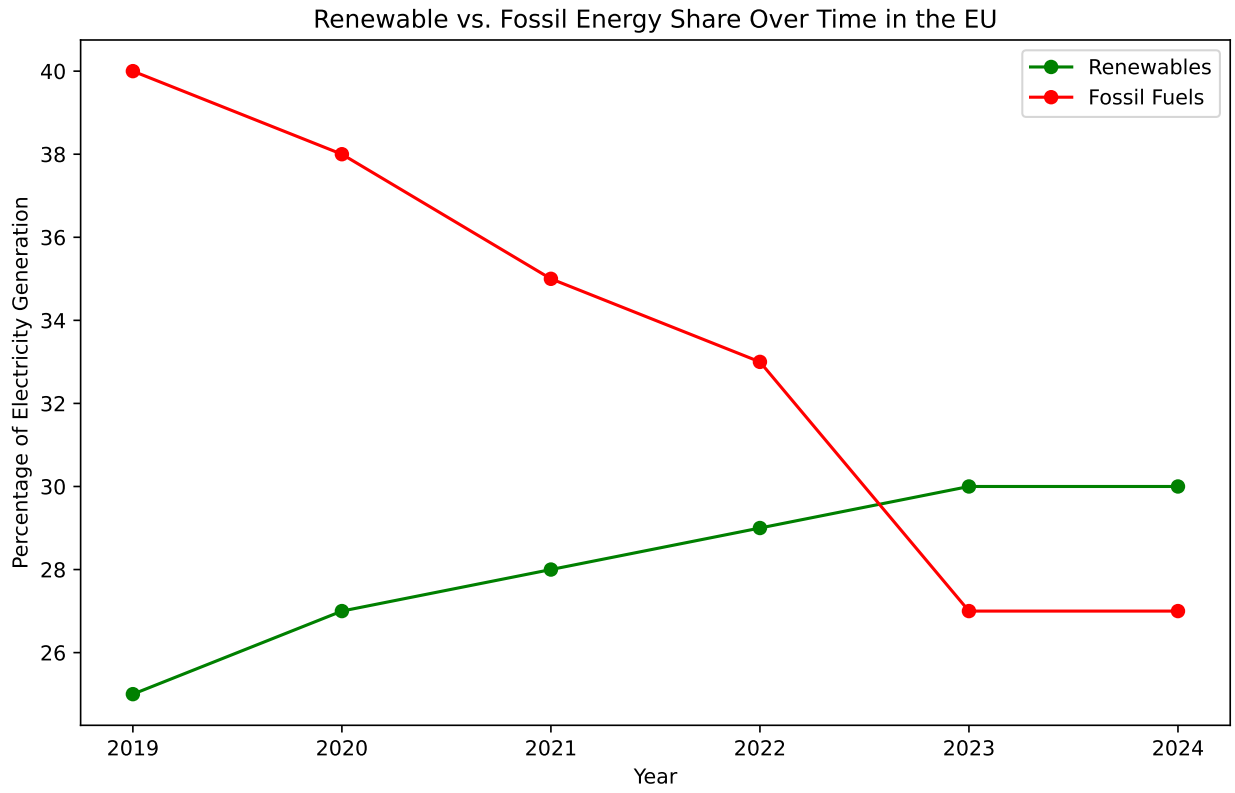
- Food forests for regenerative food systems.
- Svalbard Seed Vault
- Irwin et al. (2023)
- Yadav et al. (2023)
- Low, Dalhaus & Meuwissen (2023)
- Ollinaho & Kröger (2023) "bioeconomy is not inherently sustainable and may pose considerable risks to biodiversity."
- De Queiroz-Stein & Siegel (2023)
- Gamage et al. (2023) "Organic food and drink sales in 2019 totaled more than 106 billion euros worldwide."

Geopolitical situations can affect technology adoption; after Russia's war in Ukraine, Europe needed to quickly reduce consuming cheap Russan fossil fuel energy (in the form of gas) (Bonasia, 2024). In 2024, for first time in Europe, renewables in the form of wind and solar energy surged past production of fossil fuels (Graham & Fulghum, 2024; Beer, 2024)

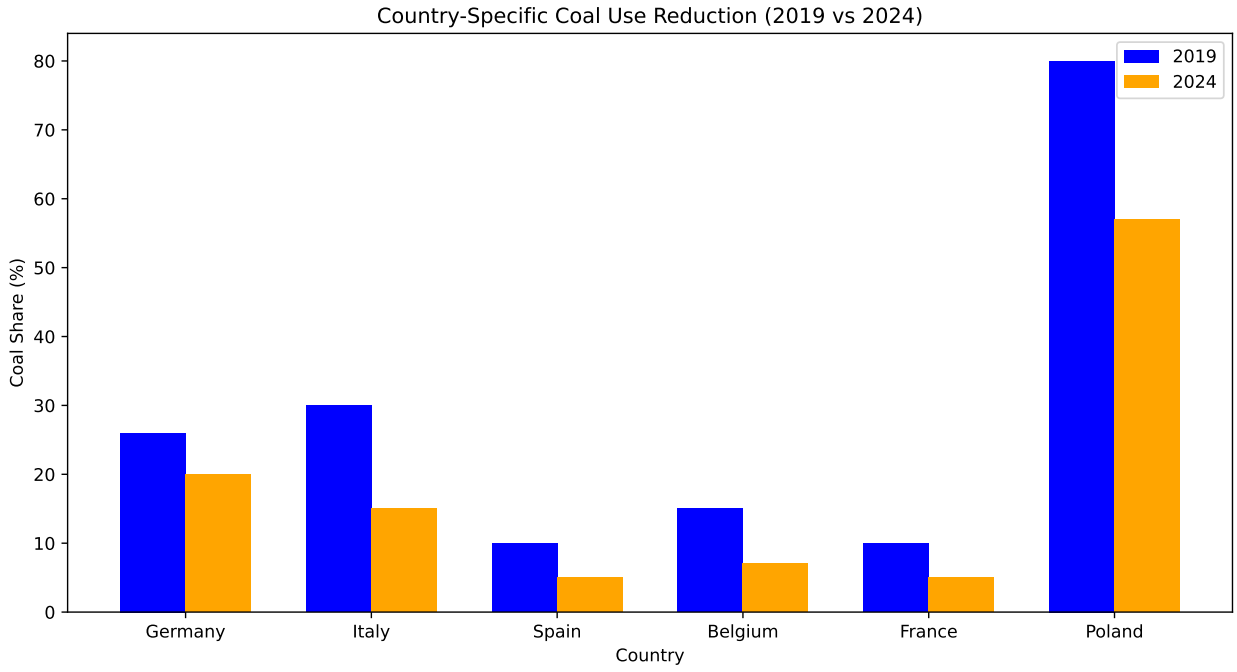
EU energy mix in 2024



Wind and solar energy overtook fossil energy.



Meanwhile reduction in coal-power was also possible. Coal is a large CO2 emitter.



"Climatech", Renewable Energy and Transforming Energy Production

Large technology conglomerates and newly founded startups working in climate solutions space (often referred to as *climatech* by the media) have proposed a range of approaches to CO_2 reduction

in Earth's atmosphere. These technologies include several types of *carbon capture*, directly from the air (direct air capture or DAC), from the source of pollution, such as using high–performance filters on factory chimneys, as well as nature-based solutions such as large scale tree planting using drones.

Each technology has their own pros and cons. (Vitillo et al., 2022) illustrates how direct air capture of CO_2 is difficult because of low concentration and CO_2 capture at the source of the emissions is more feasible.

- (Gaure & Golombek, 2022) simulate a CO_2 free electricity generation system in the European Union where "98% of total electricity production is generated by wind power and solar; the remainder is covered by a backup technology.". The authors stipulate it's possible to power the EU without producing CO_2 emissions.
- **Important: "creating sustainability trust in companies in realtime"**

Complexity: Towards Probabilistic Risk-Based Assessment

Sustainability is a complex web of interconnections.

- thread of commodification of nature. category mistake. impossible to bring back already destroyed biodiversity which took millennia to develop. humans create hugely complex systems instead of simply conserving nature.
- The concept of how a public resource is over-used until breaking down as each user only bears a fraction of the cost - know as *tragedy of the commons* -was described by the ecologist Garrett Hardin in 1968 (Hardin, 1968; Meisinger, 2022; Lopez, Pastén & Gutiérrez Cubillos, 2022; Murase & Baek, 2018).

Design Implications

Table 24: Implications

Category	Implication
Transparency	In unison, the reviewed technologies and practices move us closer to enabling *realtime ESG*: up-do-date transparent information about how our product are produced.
Speed	Realtime ESG is a building block to enable consumers and investors make more accurate, real-world purchase decisions.
Actionability	Simplify action
Pollution	*People live in the polluted areas are so used to it. What app to wake them up? "You live in a highly polluted area. Here's the TOP 10 companies causing pollution. Here's what you can do."*
Health Tracking	Blood testing and biomarkers allow people to track their health. I'm introducing the concept of 'eco-markers' to follow the sustainability of human activities.

Circular Economy	AI can help us make sense of the vast amounts of sustainability data generated daily.
EPR	ERP and CDP data should be part of Green Filter.
Eco-Design	How to find eco-designed products?
CE and EPC	Encouraging Sustainable Design
Politics Matter	
	Call for GOP contributors' transparency
	"triple turn"
	Lack of transparency
	Sustainability is part of product quality. If a product is hurting the environment, it's a low quality product.

Feature Ideas

Category	Idas

Design

Eco-Design: The Legislative Perspective

In Europe, *eco-design* has strong political support as part of the European Union's (EU) "Green Deal" legislative strategy, aiming to transform European economies into sustainability leaders. The Ecodesign for Sustainable Products Regulation (ESPR) entered into force in the EU on July 18, 2024 (European Commission, 2024) following the (European Parliament, 2022) proposal whereby the European Commission established a general framework for *eco-design: "requirements for sustainable products, repealing rules [referring to the previous Eco-Design Directive (2009/125/EC)] currently in force which concentrate on energy-related products only,"* setting up a level playing-field for the organizations operating on the EU single market. Virginijus Sinkevičius, the EU Commissioner for the Environment, Oceans and Fisheries, is quoted describing eco-design as design that *"respects the boundaries of our planet"* (European Commission, 2022c).

Eco-Design is a Key EU Sustainable Policy Design Tool. A large part of the proposal by (Commission et al., 2014) is *eco-design*, as a large part of product lifecycle environmental impact is defined in the design process.

Quality		
Durable	Reparable	Easy to recycle
Reusable	Easy to maintain	Energy efficient
Upgradable	Easy to refurbish	Resource efficient

Sustainable Products and EUDR (European Union Deforestation Regulation) work hand-in-hand as part of EU's legislative efforts to promote sustainability.

EUDR applies to all products placed on the market from 30 December 2024 and 30 June 2025 for small businesses.

ESPR, EUDR

ESRS, CSRD (Corporate Sustainability Reporting Directive) replaces NFRD (Non-Financial Reporting Directive)

EU "Green Deal" legislative is comprehensive.

ESRS reporting standard to meet CSRD requirements.

- Anon (2021a)
- Switch2Green (2023)

It's up to legislators to provide sustainable products on our marketplace… but until we do, use the green filter.

- One of the EU goals is reducing consumption
- Tacking our consumption habits
- Europe is the hotbed of sustainability
- Iman Ghosh (2020)
- Lamoureux (2018) Florida sustainable companies

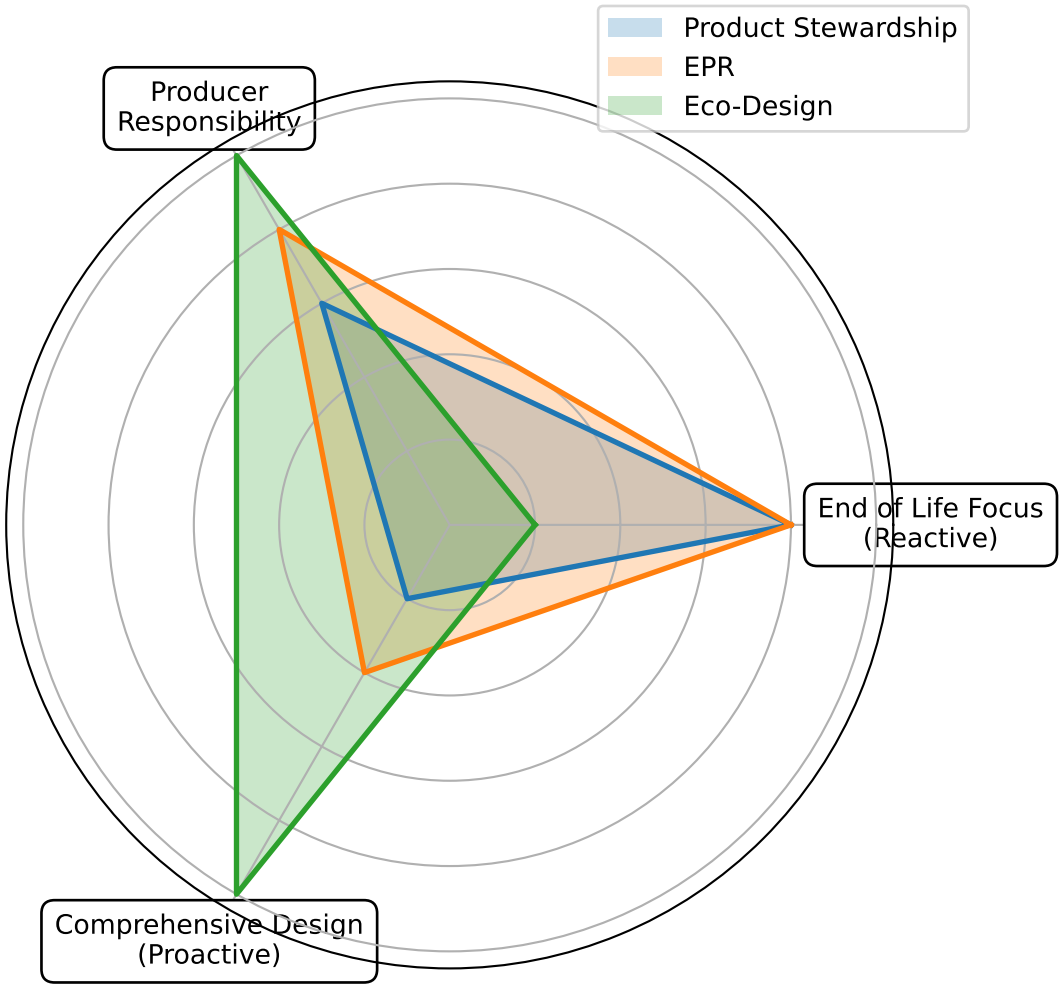
- MICHAEL HOULIHAN & BONNIE HARVEY (2018) customers prefer sustainable companies
- In the US, the *Inflation Reduction Act* provides funding to development of decarbonizing technologies and includes plans to combat air pollution, reduce green house gases and address environmental injustices (Rajagopalan & Landrigan, 2023).

Combined Concept Map of EU Green Deal Regulations and Categories

Many other jurisdictions also have laws that aim to reduce the environmental impact of products throughout their life cycles. For instance Australia has a Product Stewardship (PS) scheme, which also includes an investment fund targeted at increasing the recycling rates of specific products (Australian Government, 2024). Australia, Japan, and Taiwan all have Sustainable Procurement schemes prioritizing greener products in public purchases [ADD CITATION]. While Taiwan doesn't yet have a specific eco-design law, there are various pieces of legislation promoting circular economy

[ADD CITATION]. Already in 1988 Taiwan implemented an Extended Producer Responsibility (EPR) scheme, followed by a recycling system (initially focused on electronic items) in 1998 (Chong et al., 2009). Eco-design initiatives in Taiwan started at least as early as 1994, when Taiwanese companies and universities noticed international sustainability trends and began to implement their own sustainable design initiatives (Jahau Lewis Chen et al., 2005).

The key to comparing Product Stewardship, Extended Producer Responsibility (EPR), and Eco-Design is the scope, as illustrated in the chart below. While Product Stewardship (PS) and Extended Producer Responsibility (EPR) deal mostly with the end of the product lifecycle (they are *reactive*), including their disposal and recycling (EPR going a step further than PS by shifting the responsibility to the producer), Eco-Design moves sustainability up the design chain (being *pro-active*), setting standards for making better products - in essence, attempting to *design-out* the waste.



Political Action

I was torn whether to put politics under Sustainability or Design, and decided for the latter - as sustainability is most descriptive, using science to measure and present the real situation, while Design - like politics - is prescriptive: making decisions about how do we live.

Design *is* political.

- Pater (2021)
- 10 countries use almost 100% renewable energy

There's ample evidence from several countries suggesting moving to renewal energy brings environmental benefits:

- Amin et al. (2022) suggests "removing fossil fuel subsidies and intra-sectoral electricity price distortions coupled with carbon taxes provides the highest benefits" for both the economy and the environment in Bangladesh.
- Luo et al. (2022) suggests using reinforcement learning to reduce energy use in cooling systems.
- Montreal protocol eradicates CfCs and the ozone holes became whole again.

***Mitigating* Climate Change**

The monumental task of removing several gigatons of CO_2 from the atmosphere requires massive policy shifts and collaboration across countries and industries (Mackler, Fishman & Broberg, 2021).

Warming global climate has concrete effects on daily life. Warmer climate helps viruses and fungi spread (Press, 2023). (Williams & Joshi, 2013) higher CO_2 concentrations in the air can cause more turbulence for flights.

***Adapting* to Climate Change**

Many companies are developing technologies for mitigation.

Politics matters in sustainability. In Brazil, deforestation fell 60% in 1 year, based on remote satellite reconnaissance, after the election of a more pro-environment leadership (Watts, 2023).

- Eesti Vabariigi Valitsus (2022) Estonian Green Deal Action Plan (Eesti Rohepöörde Tegevusplaan).

In the European Union (EU), a wide range of legislative proposals, targets, organizations, and goals already exists across diverse countries. Upcoming laws aim to harmonize approaches to sustainability and raise standards for all members states, in turn influencing producers who wish to sell in the EU common market.

- (Anon, n.d.x) report: The EU has a *taxonomy of environmentally sustainable economic activities* published by the Technical Expert Group (TEG) on sustainable finance.

Taxes

- There have been proposal of a "meat tax".

SDGs

- SDGs need to discussed in their totality Popkova et al. (2022).
- German Institute of Development and Sustainability (IDOS) connects SDGs to NDCs. Dzebo, Iacobuţă & Beaussart (2023)

- International Energy Agency (IEAs), Decarbonisation Enablers IEA (2023b)

Sustainbility Policy context is Shifting Around the World

- "In the context of the EU Plastics Strategy, the European Commission has launched a pledge to increase the use of recycled content to 10 million tons by 2025. To address this, Circularise Plastics Group launched an "Open Standard for Sustainability and Transparency" based on blockchain technology & Zero-knowledge Proofs" Circularise (2020b)
- "data-exchange protocol with privacy at its heart" Circularise (2020a)
- EU AI Law Lomas (2024)

Kunming-Montreal Global Biodiversity Framework

- The proposal for a Nature Restoration Law by the European Commission requiring member countries to restore 20% of EU's degraded ecosystems by 2030 and full restoration by 2050 has not yet passed Anon (2023ac) and is facing a backlash David Pinto (2023).
- Manzardo et al. (2021) **(need access!)**
- Iñarra et al. (2022) **(need access!)**
- Munaro, Tavares & Bragança (2022) **(need access!)**
- Bassani et al. (2022) **(need access!)**
- Van Doorsselaer (2022) **(need access!)**

Calculating what's sustainable is hugely complex because decisions may have unforeseen ramifications. For example (Nuez, Ruiz-García & Osorio, 2022) shows how electric vehicles may increase CO_2 emissions in some areas, such as Canary Islands, where electricity production is polluting.

- Rossi, Cappelletti & Germani (2022) shows how introducing sustainability early in the design process and providing scenarios where sustainability is a metric, it's possible to achieve more eco-friendly designs.
- Arranz, Sena & Kwong (2022) developing circular economy is really complex
- Cheba et al. (2022)
- Ruiz-Pastor et al. (2022)
- Miyoshi et al. (2022) takes the example of ink toner bottles and shows in a case study how standardized compatibility between older and newer systems can save resources and results in sustainability savings.
- Finding green products and supporting companies making them
- Supporting legislative changes
- Track you consumption, saving, investing. Shift balance towards saving and investing.
- Nastaraan Vadoodi (2022)
- European Commission (2022b) Ecodesign for sustainable products

Europe From 2023 to 2030

- EU releases strategic foresight reports since 2020 (European Commission, 2023b).

Figure 8: EU Policy Context Timeline

We have an opportunity to re-imagine how every product can be an eco-product and how they circulate in our circular economy.

Timeline of the Policy Context:

- In 2019 by the von der Leyen commission adopted the European Union (EU) Green Deal strategy.
- In 2021 the Commision proposed a goal of reducing CO2e emissions by 55% by 2030 under the *Fit for 55* policy package consisting of a wide range of economic measures.
- In November 2022, the proposal was adopted by the EU Council and EU Parliament with an updated goal of 57% of CO2e reductions compared to 1990. This proposal is set to become a binding law for all EU member countries (European Commission (2019c); European Commission (2019a); Anon (2022d); European Council (2022)).
- In March 2022, the EU Circular Economy Action Plan was adopted, looking to make sustainable products *the norm* in EU and *empowering consumers* as described in European Commission (2022a). Each product covered by the policy is required to have a ***Digital Product Passport*** which enables improved processing within the supply chain and includes detailed information to empower consumers to understand the environmental footprint of their purchases. It's safe to say the large majority of products available today do not meet these criteria.

Quality of Life

Wellbeing Economy Governments is an Example of Country-level Collaboration

- Finland, Iceland, New Zealand, Scotland, Wales, Canada (Fioramonti et al., 2022).
- Kaklauskas et al. (2023)
- Anon (2023al) Integrated science of wellbeing
- Fabris & Luburić (2022)

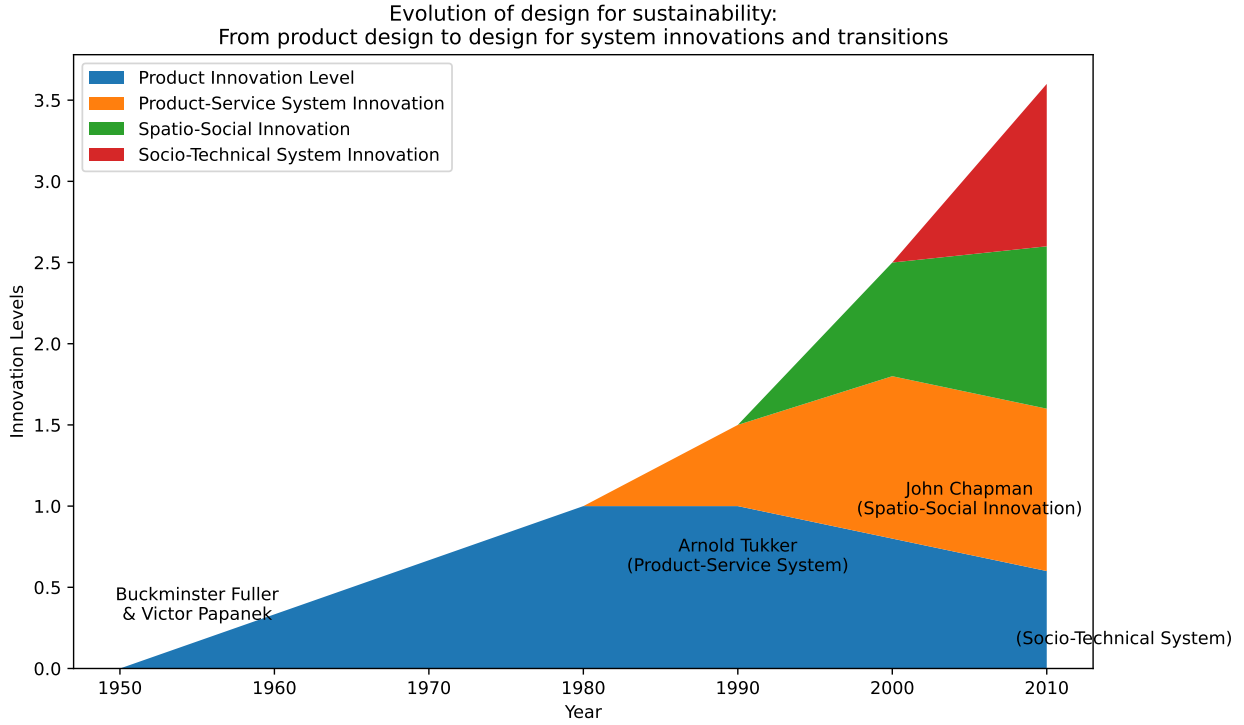
How to Design for Sustainability: A Diversity of Approaches

Designing for Sustainability (DfS) has many names, with subtle differences of emphasis and nuance. While the ESPR legislation chose *Eco-Design* as the overarching title, researchers and practitioners discuss and use *Circular Design*, *Cradle-to-Cradle Design*, *Green Design*, *Regenerative Design*, *Climate-Responsive Design*, *Life-Centered Design*, and many others.

In most cases, designing for sustainability makes use of *systems thinking*, underlining the importance of looking at the entire lifecycle of a product or service. Sustainable design encompasses all human activities, making this pursuit an over-arching challenge across all industries and all human activities with the complex interdependencies contained within. (Ceschin & Gaziulusoy, 2016) gives a comprehensive overview of the main themes of sustainable design and the main contributions and limitations in the well–researched *"Evolution of design for sustainability: From product design to design for system innovations and transitions"*.

R. Buckminster Fuller "Operating Manual for Spaceship Earth", Victor Papanek "Design for the Real World", Jonathan Chapman "Emotionally Durable Design", Carlo Vezzoli "Product-Service System Design for Sustainability", Ezio Manzini "Design, When Everybody Designs".

Service Design, Ceschin & Gaziulusoy (2016) shows how design for sustainability has expanded from a product focus to systems-thinking focus placing the product inside a societal context of use. For example Anon (n.d.i), recycled clothing maker FREITAG offers sustainability-focused services such as cargo bikes so you can transport your purchases and a network for *shopping without payment* = swapping your items with other members, as well as repairs of their products. Loaning terminology from *service design*, the user journey within an app needs to consider each touchpoint on the way to a state of success.



As this research is *practice-oriented* (i.e., my goal here is to find design approaches that could influence my prototype), I will focus on some fields of design which I hope relevant, fruitful, or contextual to my project.

I will start with *Human-Centered Design*, the grandfather of design with attitude. There's even an ISO standard for human-centered design, with the designated code ISO9241-210, revised as ISO 9241-210:2019 titled *"Ergonomics of human-system interaction"* and up for revision soon (ISO standards are reviewed every 5 years). Some of the key takeaways include "Understanding and specifying the context of use", "Involving users throughout design and development", "Specifying user requirements", "Evaluating designs", "Multi-disciplinary Collaboration", "Iterative process" and "Continual Improvement", and finally - usability is not enough, the design should provide a user experience (UX) for human "emotional responses and satisfaction" (ISO, 2019).

While *Human-Centered Design* focuses exactly on what it says - humans - *Life-Centered Design* recognizes human impact on our surrounding environment as well - making sure we include non-human animals among our stakeholders. This is where we are getting on the *territory* of sustainability. While *Human-Centered Design* is ever popular, the effect humans are having on biodiversity is rarely considered when designing. *"[T]he design phase of a physical product accounts for 80% of its environmental impact"* notes(Borthwick, Tomitsch & Gaughwin, 2022) in their framework for life-centered design.

If we're including *other* lifeforms among our stakeholders, what can we learn from them? *Biomimicry* is about being inspired by nature while *Biodesign* focuses on design involving biology in the design itself. Janine Benyus, who coined the word *Biomimicry* (Benyus, 2009) looks at very practical cases of innovation where engineers and biologist meet and (Dicks, 2023) provides a much more philosophical account of following the example of nature. Focusing on the financial sector, (Thomas & Mantri, 2022)'s philosophical account advocates for an "inside-out" design pattern, much like natural systems, starting from the smallest structures to guarantee resilience and survival, instead of trying to control their external environment.

In a similar vein, *Material Ecology* is the wording preferred by the architect Neri Oxman based at the MIT Media Lab working with biomaterials as a proponent of *Nature-Centric Design* that adheres to the principles of ecological sustainability with both an ecologically conscious mindset and practical toolset (Hencz, 2022). Language and our mental concepts shape our reality, which makes language-creation an important tool for sustainability. Neri Oxman's expressions in her (World Economic Forum, 2016) interview introduce some new vocabulary: *"ecology-indifferent"*, *"naturing"*, *"mother naturing"*, *"design is a practice of letting go of all that is unnecessary"*, *"nature should be our single client"*, which reminds me how self-invented language gives un child-like freedom to imagine new worlds.

Speculative Design can help us imagine *non-anthropocentric* (Hupkes & Hedman, 2022; Edwards & Pettersen, 2023)as well as *dystopian* futures (Pinto et al., 2021). First introduced by (Dunne & Raby, 2013) in their seminal book, the field aims to question the intersection of *user experience design* and *speculative fiction*. (Barendregt & Vaage, 2021) explores the potential of speculative design to stimulate public engagement; thought experiments can spur public debate on an issue chosen by the designer. Phil Balagtas, founder of The Design Futures Initiative at McKinsey, discusses the value of building future scenarios at his talk at Google. His favorite example, the Apple Knowledge Navigator, first appeared in an Apple vision video in 1987 and took two decades to materialize in the real world. It was inspired by a similar device first shown in a 1970s episode of Star Trek as a *magic device* (a term from participatory design), which then inspired subsequent

consumer product development. It took another two decades, until the launch of the iPhone in 2007 - a total of 40 years.

Participatory Design and *Speculative Design* can be complementary as in the work of (Neuhoff, Simeone & Laursen, 2023), used together to focus on engaging users deep in the design process to truly understand their needs, contexts and interactions on a non-superficial level. For both speculative and participatory design, the cost and makes it into a niche activity. Generative AI holds the promise to allow designers to dream up and prototype quicker. In order to build a future, it's relevant to imagine and critique a future. By being quickly generate prototypes, once can test out ideas with the future users involving more of the community and stakeholders. To be able to build something, one first needs to imagine it; imagination is crucial for change.

Speculative Design helps us envision future scenarios

Massachusetts Institute of Technology (MIT) is a source of many fantastic innovations, and another.

Regenerative Design suggests *de*materializing (digitizing) economies is not enough to be sustainable (by reduction of physical impact). Design should look beyond reducing harm and find avenues to *regenerate* damaged or even completely destroyed natural systems – ecosystems, biodiversity, land, forests, lakes, rivers - natural habitats.

Sufficiency

Moving from products and (digital) experiences towards the built environment and architecture, *Climate-Responsive Design* embeds a building within the environmental constraints of a place and looks for opportunities use the land, wind, sun, local materials, and local vernacular history and culture when considering a design. Architect Susanne Brorson suggests sustainability should be considered in the earlier phases of design instead of trying to fix problems later discussing *climate-responsive design principles* (EVM maaarhitektuuri keskus, 2019). The sentiment is echoed by (Lee & Doevendans, 2011) who edited a volume on sustainable approaches of world-renowned architects: "*The principles of sustainable design are rooted in the building's relationship to the site and its environmental conditions such as topography, vegetation, and climate.*"

Architecture of the Well-Tempered Environment (Banham, 1999)

Designing for Trust, Weinschenk (2011) says *"People expect most online interactions to follow the same social rules as person-to-person interactions. It's a shortcut that your brain uses to quickly evaluate trustworthiness."*

Cradle-to-Cradle Design, focusing on recyclability of products. Anon (2021r) and 活動通 (n.d.) Cradle to Cradle Nordic circular design in Taiwan

Durability is an important dimension for sustainability. High quality durable products are more sustainable as they last longer and less likely to be thrown away. Forming an emotional bond with the product makes it feel more valuable (Zonneveld & Biggemann, 2014). (Chapman, 2009) argues in his seminal paper (and later in his book) for *"Emotionally Durable Design"*, the simple idea that we hold to things we value and thus they are sustainable. We don't throw away a necklace gifted to us by mom, indeed this object might be passed down for centuries. (Rose, 2015) has a similar idea, where *"Enchanted Objects"* become so interlinked with us, we're unlikely to throw them away. This has implications for sustainability as the object is less likely to be thrown away.

As the above shows, there are many partially overlapping design words created by different people for diverse purposes. Design vocabulary may be created for distinguishing a particular type of design from another - or to market oneself as the creator of the word. There are designers who define / brand themselves by their design method. Design Studies, a field that studies *design* as a subject.

Here I will use the lens of *sustainability* - another complex term - to look at how design can contribute to eco-friendly products. I advocate looking at design methods as a toolbox, where I can pick the tool suitable for the problem set in front of me. Here I look at a small number of design practices I find relevant to designing a sustainability app for college students.

than traditional design methods. While AI allows us to look at a larger number of design scenarios thank previously feasible, there are many approaches looking for ways to design for sustainability. Designing for Sustainability is fundamentally a hopeful act imbibed with the dream a healthier world is possible.

Future Scenarios: Avoiding the Worst Cases

In sustainability there are rarely good choices. Rather it's a question of avoiding the worst choices.

Scenario-building is a key tool for sustainability. Because sustainability is so complex, sustainable design makes use of scenarios.

Life Cycle Assessment and *Environmental Impact Analysis* are needed to provide eco-design scenarios (de Otazu et al., 2022).

user experience, iteration (Google Design, 2019)

In Practice Sustainability Begins in Software

Designing user interfaces for sustainable interactions means incorporating data and toolsets to enable designers to make decisions which reduce emissions of their design. Companies like AutoDesk are putting CO_2 calculations inside their design software, helping designers reduce material usage, energy consumption, CO_2 emissions, while increasing recyclability(Mike Haley, 2022). Software is key to building more sustainable products, already for decades (Gupta et al., 2023). AI-assisted design enables design for sustainability because the design process is where sustainability begins. AI has the potential to provide the parameters for sustainability. (Singh & Sarkar, 2023) proposes an AI tool for deciding the suitable life cycle design parameters.

Design encompasses most everything in our daily lives. Humans live in artificial environments where *most things* are designed by humans. The *experiences* we take part in are increasingly created based on some type of data.

- Involving young HCI designers in AI-oriented workshops can show the future of UI/UX ? (Battistoni et al., 2023)

Data is the interface between idle resources and retail demand, which makes *exchange of value* possible.

- Different Gets Ignored Luke Wroblewski (2024)

Digital Sustainability, information pertaining to emissions would flow through the economy not unlike the carbon cycle itself.

- Pan & Nishant (2023) important

Interaction Design for Climate Change: how can we change common UIs so they take into account sustainability?

- UIA World Congress of Architects (2023) "Design for climate adaptation"
- Andrew Chaisson (2019)
- Dzigajev (2019)
- Mankoff et al. (2007)
- Borthwick, Tomitsch & Gaughwin (2022)
- Lose (2023b) is worried about applying UX skills for Climate Change

AI-Assisted Design

Tool vs Assistant? (Tools are mostly non-anthropomorphic?). Tools do not call attention to themselves. They don't necessarily rely on human-like representations that call attention to themselves but rather are available in-context to help streamline specific tasks.

- September 16, 2020 (2020) "What is AI-assisted Design?"
- Clipdrop (n.d.) AI Design Assistants
- Architechtures (2020) Architecture with the help of AI
- Zakariya (2022) Canva image generator
- Kore.ai (2023) Kore.ai developing custom AI-chatbots for business usage.
- Anon (n.d.j) storytelling by AI

Data-Driven Design: Sustainable Personalization at Scale

Data-Driven Design Enables Sustainability. Sustainability touches every facet of human existence and is thus an enormous undertaking. Making progress on sustainability is only possible if there's a large-scale coordinated effort by humans around the planet. For this to happen, appropriate technological tools are required.

Data-driven design has limitations.

Coputer

One mode

- Konings (2020)
- "Digital sustainability principles"
- Eminent journal Design Studies, 1st design journal
- Part of digital product design are **design systems** to keep consistency across the experience. Create a design system to best to showcase my analytic skills:
  - Design System: https://zeroheight.com/8bf57183c/p/82fe98-introduction
  - Anon (n.d.e)
  - Suarez et al. (n.d.)
  - Anon (n.d.as)

  - Anon (n.d.f)

- Kolko & Connors (2010) and IxDF (n.d.) believe interaction design is still an emerging (and changing) field and there are many definitions. I prefer the simplest version: interaction design is about creating a conversation between the product and the user.
- AI gives designers new tools. In AI development, design is called alignment. What is the role of an AI Designer? Linden (2021)
- Anon (n.d.bc)
- Anon (n.d.ao)
- Parundekar (2021)
- Richard Yang (2021) and Justin Baker (2018) say some of the tools used by interaction designers include
- AI for design: Figma (2023)

The concept of *Social Objects*: People need something to gather around and discuss. Sharing.Lab (2015): I'm interested in the concept of a "social object".

Red Route Analysis is an user experience optimization idea inspired by the public transport system of London (Oviyam™, 2019; Anon, 2021j; Xuan, 2022).

- Product marketers focus on the *stickiness* of the product, meaning low attrition, meaning people keep coming back.
- What percent of all design is "sustainable design" ? Promoting sustainable design.
- Josh Luber (2021) Trading cards are cool again
- Jesse Einhorn (2020)
- Connie Loizos (2021)
- Natasha Mascarenhas (2021)
- JEFF JOHN ROBERTS (April 23, 2020 at 2:00 PM GMT+3)

Narrative Design, Humans respond well to ***storytelling***, making ***character design*** and ***narrative design*** relevant to interaction design. Large language models (LLMs) such as ChatGPT are able to assume the personality of any character that exists inside of its training data, creating opportunities for automated narrative design.

- The rising availability of AI assistants may displace Google search with a more conversational user experience. Google itself is working on tools that could cannibalize their search product. The examples include Google Assistant, Google Gemini (previously known as Bard) and large investments into LLMs.
- Alethea AI (2021): discusses writing AI Characters, creating a personality.
- Writing as training data? large language models. GTP3.
- Stories start with a character.

Designing for College Students

- plap

Personalization

- Personal User Experience. social apps require personalization, trust and k-factors (sharing and inviting your friends). (Baron, 2023; Kim, 2023).

Growth Design

- For digital products (apps) the main application of interaction design is for *growth* in usage, how to get more people (user journey and conversion funnels) to use the product i.e user acquisition, retention, engagement, and monetization and keep using it (retention and engagement), often optimizing onboarding, features, and personalization (Steger, 2019; Kende, 2023).
- Hypothesis and validation for iterating on features.
- Total addressable market (TAM), serviceable addressable market (SAM), target audience (TA)

Digital Platforms Grow into Superapps

Superapps are the latter stage of the Digital Platform Economy.

Platform economy companies popularized and expanded Data-Driven Design in the service of growth marketing (also known colloquially as growth hacking). Capturing User Data was part of this strategy which enabled improving the products. Digital Product Design is increasingly data-driven. Digital platforms operate a *design as a process* in a continuous feedback loop, where *measurements*, *experiments,* predictive analytics and personalization form a data-drive design culture. As we humans go about our daily business, governments and companies track our activities using various technologies, which produces massive amounts of user interaction data. Platform economy companies are the capture and use large amounts of data from users. Data is useful for designing better products. Designing for high retention (users keep coming back). Network Effects, the more people use a platform, the more valuable it becomes. Platforms that continuously add features (provided consumer legislation allows it) may eventually evolve into superapps, which are useful for providing services for a wide category of human needs. Bundling many services under one super-brand. Superapps are possible thanks to Nudge, Economies of Scale, Network Effects, Behaviour Design. Large Digital Platforms have a very small number of workers relative to the number of users they serve. This creates the necessity for using automation for both understanding user needs and providing the service itself. Creating a good product that's useful for the large majority of users depends on *Data-Driven Design.*

Design is as much about how it works as it's about the interface.

Digital product design can be seen as a specific discipline under the umbrella of Experience Design. In Michael Abrash (2017) Meta Oculus augmented reality incubation general manager Laura Fryer: *"People buy experiences, not technology."*

Young people expect a product. Intelligent Interfaces use interaction design to provide relevant and personalized information in the right context and at the right time.

There are many approaches to design - from playful to practical to critical and to data-driven. Nonetheless, many types of design share a common goal designing for a good *user experience*. Simplifying.

Personalization: the largest businesses today (measured in number of users) design the whole user experience.

Scale, Popular consumer platforms strive to design solutions that feel personalized at every touch-point on the user journey (to use the language of service design) at the scale of hundreds of billions of users.

Superapps are honeypots of data that is used for many types of behavior modeling. (Suarez et al., 2021) suggests using alternative data from super-apps to estimate user income levels, including 4 types of data: Personal Information, Consumption Patterns, Payment Information, and Financial services. (Roa et al., 2021) finds super-app alternative data is especially useful for credit-scoring young, low-wealth individuals. The massive amounts of data generated by these companies are used by smart cities to re-design their physical environments.

Twitter (now X) is becoming a financial app.

Inspiration from WeChat.

How can the mobile devices which the majority of us are carrying with us every day, help us make decisions about the businesses we engage with? In terms of user experience, can personalized AI advisors empower our financial actions from shopping to saving and investing?

Enablers of Platform Economics	Pros	Cons
Network effects	The more people use a platform, the more valuable it becomes both for the company and the user.	Data is not portable or difficult to migrate. You can't leave because you'll lose the audience. There's a lock-in effect.
Scalability		
Data-driven Design		
Behaviour Design		

- *Platform Economy* marketplace companies like Airbnb, Uber among many others match optimize how our cities work.Superapps are prevalent in China and South-East Asia. (Giudice, 2020) finds WeChat has had a profound impact on changing China into a cashless society, underlining how one mobile app can transform social and financial interactions of an entire country. China is the home of many superapps and (Vecchi & Brennan, 2022) discusses the strategies Chinese apps are taking to expand to other markets. (Shabrina Nurqamarani et al., 2020) discusses the system consistency and quality of South-East Asian superapps Gojek and Grab.
- Platform economy companies have been criticized for their lack of workers rights (ESG). (Anon, 2024f) uses portable air pollution tracking devices to documents how gig workers are subjected to pollution.

- Uber is creating an all-purpose platform; only 4.1% of rides were electric (Levy, 2023).
- X (formerly Twitter) is becoming a superapp?

Could there be Sustainability Superapps?

- How to design sustainability superapps? Lots of options in a single app. (Fleet Management Weekly, 2022) "Sustainability and superapps top Gartner's Top 10 2023 Trends List". (Dave Wallace, 2021) "The rise of carbon-centric super apps". (goodbag, 2023) "goodbag: Sustainable Super App". What would a sustainable investment platform that matches green investments with the consumers look like, if one saw the side-by-side comparison of investment vehicles on their ESG performance? Also (Bernard, 2022).
- Undheim (2024) Ecotech
- Lori Perri (2022)
- Anon (2022k)
- Anon (2021o) PayPal dominance
- Zeng (2015) **(need to pay for article!)**
- Huang & Miao (2021) **(need to pay for article!)**
- Anon (2022r)
- (Cuppini, Frapporti & Pirone, 2022) historical overview of the development of capitalism from linear ***Fordism*** through platform economy and logistics' revolution which allows for circular economies to happen in a city.
- Adaptive AI

Behavioral Design

For decades, marketers and researchers have been researching how to affect human behavior towards increasing purchase decisions in commerce, both offline and online, which is why the literature on behavioral design is massive. One of the key concepts is *nudge*, first coined in 2008 by the Nobel-winning economist Richard Thaler; nudges are based on a scientific understanding of human psychology and shortcuts and triggers that human brains use and leverages that knowledge to influence humans in small but powerful ways (Thaler & Sunstein, 2009).

The principles of nudge have also been applied to sustainability. For example, a small study (n=33) in the Future Consumer Lab in Copenhagen by (Perez-Cueto, 2021) found that designing a "dish-of-the-day" which was prominently displayed helped to increase vegetarian food choice by 85%. Experiments by (Guath, Stikvoort & Juslin, 2022) focused on environmentally friendly online purchases in Sweden (n=200) suggest nudging can be effective in influencing online shopping behavior towards more sustainable options. A study of behavior change in Australia at large university setting (N = 156) by (Novoradovskaya et al., 2021) found nudging behavioral change had a significant effect and the author suggested it may help to avoid some of the *"16 billion paper coffee cups are being thrown away every year"* globally (based on the abstract - I was unable to access the full paper).

Google uses nudges in Google Flights and Google Maps, which allow filtering flights and driving routes by the amount of CO_2 emissions, as well as surfacing hotels with Green Key and EarthCheck credentials, while promising new sustainability features across its portfolio of products (Sundar Pichai, 2021). Such tools are small user interface nudges which Google's research calls *digital decarbonization*, defined by (Implement Consulting Group, 2022) as *"Maximising the enabling role of digital technologies by accelerating already available digital solutions"*.

In (Kate Brandt & Matt Brittin, 2022), Google's Chief Sustainability Officer Kate Brandt set a target of "at least 20-25%" CO_2 emission reductions in Europe to reach a net-zero economy and the global announcement set a target of helping 1 billion people make more sustainable choices around the world (Jeni Miles, 2022). In addition to end–users, Google offers digital decarbonization software for developers, including the Google Cloud Carbon Footprint tool and invests in regenerative agriculture projects (Anon, 2021i; Google, 2023).

Google VERY IMPORTANTT Google (2021). Justine Calma (Oct 6, 2021, 10:01 AM GMT+3) Google UX eco features. Anon (2021g) Google green routes. Sarah Perez (2022) shows how google added features to Flights and Maps to filter more sustainable options. How CO2 is shown by Google starts hiding emissions? Anon (2022g)

Table 28: Examples of CO_2 visibility in Google's products.

Feature	Product	Nudge
Google Maps AI suggests more eco-friendly driving routes Mohit Moondra (n.d.)	Google Maps	Show routes with lower CO_2 emissions
Google Flights suggests flights with lower CO_2 emissions	Google Flights	Show flights with lower CO_2 emissions
Wizzair Check carbon impact Anon (n.d.ay)	WizzAir	Offset on Checkout

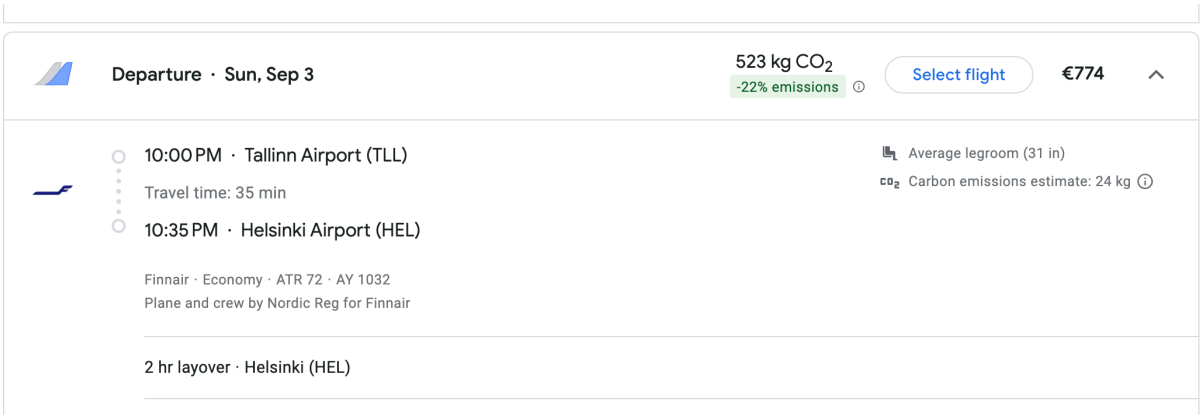


Figure 9: Google's view of flight emissions

- The founder of the Commons (Joro) consumer CO_2 tracking app recounts how people have a gut feeling about the 2000 calories one needs to eat daily and daily CO_2 tracking could develop a gut feeling about one's carbon footprint (Jason Jacobs, 2019).

Some notable examples:

- Eriksson, Christensen & Malefors (2023) discusses best practices for reducing food waste in Sweden.
- Acuti, Lemarié & Viglia (2023) makes the point that physical proximity to a drop-off point helps people participate in sustainability.
- Wee, Choong & Low (2021) proposes types of nudging technique based on an overview of 37 papers in the field.

Table 29: Types of nudge by Wee, Choong & Low (2021)

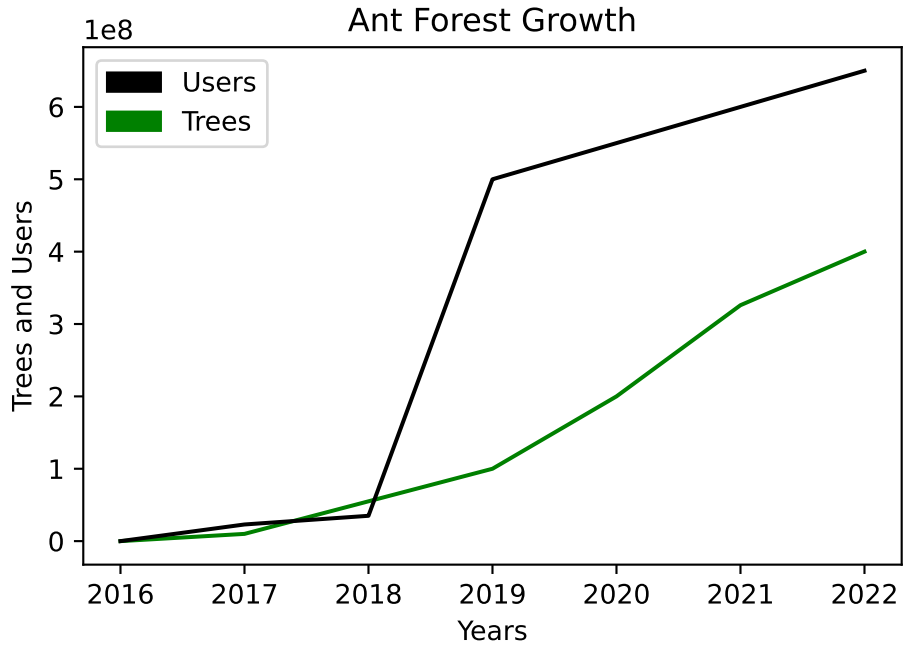
Name	Technique
Prompting	Create cues and reminders to perform a certain behavior
Sizing	Decrease or increase the size of items or portions
Proximity	Change the physical (or temporal) distance of options
Presentation	Change the way items are displayed
Priming	Expose users to certain stimuli before decision-making
Labelling	Provide labels to influence choice (for example CO_2 footprint labels)
Functional Design	Design the environment and choice architecture so the desired behavior is more convenient

- Bain et al. (2012) "Promoting pro-environmental action in climate change deniers" **(Need access!)**
- Allcott (2011) "Social norms and energy conservation" **(Need access!, ncku doesn't subscribe)**
- Schuitema & Bergstad (2018) "Acceptability of Environmental Policies" **(Need access!)**
- Nilsson et al. (2016) "The road to acceptance: Attitude change before and after the implementation of a congestion tax" **(Need access!)**
- Berger, Lange & Stahl (2022) **(Need access!)**
- Anon (2022n)
- United Nations Conference on Trade and Development (last) (2023)
- Climatiq (2023) Automate GHG emission calculations
- EarthCheck (2023) sustainable tourism certification
- LFCA (2023) corporate climate action
- Greenhouse Gas Protocol (2023) standards to measure and manage emissions
- Playing for the Planet Alliance (2021)
- Aka Gamification. Gamification makes uses of nudges. Students in Indonesia enjoy using Kahoot and it's gamification elements are perceived to have positive impact on individual learning outcomes so they are happy to continue using it (Wirani, Nabarian & Romadhon, 2022).
- Anon (n.d.bk) game company going green

Alibaba's Ant Forest (螞蟻森林) has shown the potential gamified nature protection, simultaneously raising money for planting forests and building loyalty and brand recognition for their sustainable action, leading the company to consider further avenues for gamification and eco-friendliness.

Table 30: Table of Ant Forest assisted tree planting; data compiled from (李连环 & 姜舒译, 2017; Yang et al., 2018; UNFCCC, 2019; Wang & Yao, 2020; Anon, 2021m; Zhang, Hu & Gu, 2022; Wang, Ibrahiem & Li, 2022; Zhou, Lin & Mou, 2023; Cao & Liu, 2023).

Year	Users	Trees	Area
2016	?	0	
2017	230 million	10 million	
2018	350 million	55 million	6500 acres??
2019	500 million	100 million	112,000 hectares / 66, 000 hectares?
2020	550 million	200 million	2,7 million acres?
2021	600 million	326 million	
2022	650 million	400 million	2 million hectares



Open Data Sharing

Open Data Enables Collaboration

- Taiwan is a proponent of Open Gov OP-MSF OGP (Open Government Partnership, 2021; Lab, 2021)

Data-driven design requires access to data. making the movement towards *open data sharing* very important. Some countries and cities are better than others at sharing data openly.

Table 31: Examples of cities and countries that share data openly.

Country	Project	Reference
Sweden	Swedish open data portal	Anon (n.d.bn)

- When will Bolt show CO_2 emissions per every trip?
- Sustainable finance data platform:
- WikiRate (2021) WikiRate defines Data Sharing Archetypes

Type	Example
Transparency Accountability	
Advocate	
Compliance Data Aggregator	
Data Intelligence Hub	
Worker Voice Tool	Caravan Studios (2022): **"Worker Connect"**
Traceability tool	trustrace.com
Open data platform	
Knowledge sharing platform	business-humanrights.org

- WikiRate is a tool for checking green credentials Transparency
- Laureen van Breen et al. (2023)
- Wikirate (2022a)
- Anon (n.d.af)
- Ray (2023) comprehensive overview of Web3.
- Rehash: A Web3 Podcast (2022) human-centered web3

Data Privacy

Sustainability needs to be balanced with privacy.

- Sanchez et al. (2022) suggests tracking users using their smartphones and attributing points for actions deemed beneficial yet this has potentially privacy issues.

Self-Monitoring

Research on *personal data tracking* also known as *quantified self* or *self-monitoring* is abundant. Wearable devices including the Apple Watch, Oura Ring, Fitbit and others, combined with apps, help users track a variety of health metrics. Apart from health, wearable devices have been used to track other metrics such as physiological parameters of students at school to determine their learning efficiency (Giannakos et al., 2020). Not only can health metrics be tracking, but exposure to pollution as well as personal carbon footprint, are all to some extent trackable (if not traceable).

Carbon Tracking

Personal carbon footprint tracking apps (aka CO2 calculators) in a mid-sized German city (N=216) helped overall emission reduction by 23% correlating with feedback from the app specifically reducing emissions from heating 26.9%, food 16.4%, household 34.7% reduction, and mobility 12%(Hoffmann et al., 2024).

We have a limited carbon budget so calculating CO2e-cost become integrated into every activity.

- CO2e calculations will be part of our everyday experience
- Zhang's Personal Carbon Economy conceptualized the idea of carbon as a currency used for buying and selling goods and services, as well as an individual carbon exchange to trade one's carbon permits (Zhang, 2018).

Personal Carbon Trackers

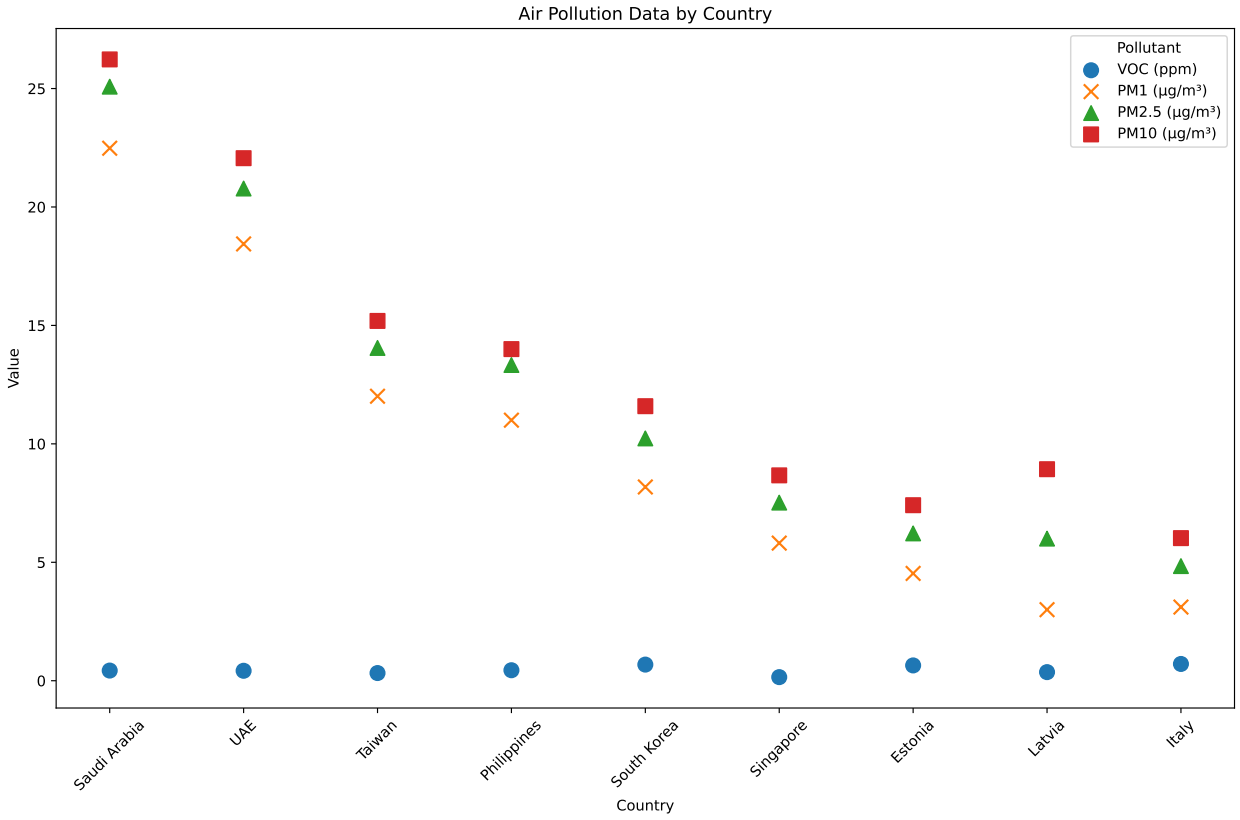
Personal carbon footprint calculators have been released online, ranging from those made by governments and companies to student projects. Similar to personal health trackers, personal CO_2 trackers help one track emissions and suggests sustainable actions.

Table 33: A selection of personal sustainability apps. See *greenfilter.app* for an updated database.

App	Description
Commons (Formerly Joro)	Finacial Sustainability Tracking + Sustainable Actions
Klima	Offset Subscription
Wren	Offset Subscription
JouleBug	
eevie	
Aerial	
EcoCRED	
Carbn	
LiveGreen	
Earth Hero	

Pollution Exposure Tracking

My personal air pollution exposure tracked using the Atmotube device attached to my backpack. Tracking air pollution and realizing how bad the over in my grandma's house is: add picture. Quantified Self is an example of Digital Health. There is a parallel in health to sustainability and indeed both are inextricably linked. Open Source code for calculating air pollution exposure AQI (Atmotech, 2024).



Health and Fitness Tracking

EEG (electroencephalogram), ECG (Electrocardiogram), EDA (Electrodermal Activity): tracking features of brain, heart and nervous system activity. Brain Music Lab founder and brain researcher Grace Leslie: "brain music sounds like a warm bathtub". Tracking blood sugar with app and patches. Blood sugar trackers. Blood glucose tracking is popular even for people without diabetes, to optimize their activity (Anon, 2021k). Tracking urine consistency inside your toilet with WithThings. Companies like NeuralLink are building devices to build meaningful interactions from brain waves (EEG).

Apple is a leader in health tracking. In 2022 Apple outlined plans for *"empowering people to live a healthier day"* and Apple's HealthKit provides a growing list of health metrics, which app developers can tap into (Apple, 2022a, 2022b). Liu et al. (2019) tracks how wearable data is used for tracking sleep improvements from exercise. Grigsby-Toussaint et al. (2017) made use of sleep apps to construct humans behaviors also known as *behavioral constructs*. The Oura ring is an example of *calm technology*, providing helpful data without calling an attention to itself (Phelan, 2024).

Use technology Wearables to be more aware of one's health. Example of quantified self device.

fitness metrics

Could one track personal sustainability in a similar fashion? (Shin et al., 2019)'s synthesis review of 463 studies shows wearable devices have potential to influence behavior change towards healthier

lifestyles. Saubade et al. (2016) finds health tracking is useful for motivating physical activity. The urban environment has an influence on health.

While so of the behavior changes may sound simple - like switching from driving to walking - and would have a large environmental effect, they are hindered by factors from personal motivation to (lack of) suitable urban architecture. (Delclòs-Alió et al., 2022) discusses walking in Latin-American cities. Walking is the most sustainable method or transport but requires the availability of city infrastructure, such as sidewalks, which many cities still lack.

Personal data enables behavior change.

While the scale of climate change is too big for individual action to make a difference, individual action can foster hope and a sense of collective responsibility (Nature, 2020).

- Kristian Steensen Nielsen (2022) **Individual climate action!!!**
- The UN has been handing out Global Climate Action Awards since 2011 for idea such as the Climate Credit Card in Switzerland, which automatically tracks emissions of purchases, creates emissions' reports for the user which can then be offset with investments in climate projects around the world (UNFCCC, 2023a).
- Give Gen-Z the tools to turn climate anger into positive change to transform companies
- Echeverría, Gimenez-Nadal & Molina (2022) suggests greener modes of mobility.
- Anon (2017b)
- Brantley (2021)
- Contact Kalle Lasn, Culture Jam
- "ESG Accessibility", Large-scale accessibility to ESG,
- increase ESG accessibility
- Shop sustainability in Estonia (Lilleväli, 2022; Anon, n.d.v). Tarbimise jalajälg poes (Helen Saarmets, 2021). Offsets at the point of sale (Anon, n.d.ad).
- Green Finance Platform (2020) report predicts the rise of personalizing sustainable finance, because of its potential to grow customer loyalty, through improving the user experience. Similarly to good design, interacting with sustainable finance for the 'green-minded' demographics, providing a reliable green product is a way to build customer loyalty.

Another aspect is tracking one's mental health. (Tyler, Boldi & Cherubini, 2022) surveys the use of self-reflection apps in the UK (n=998).

- Popular Strava (100+ million users) sports assistant provides run tracking and feedback (Strava, 2022).

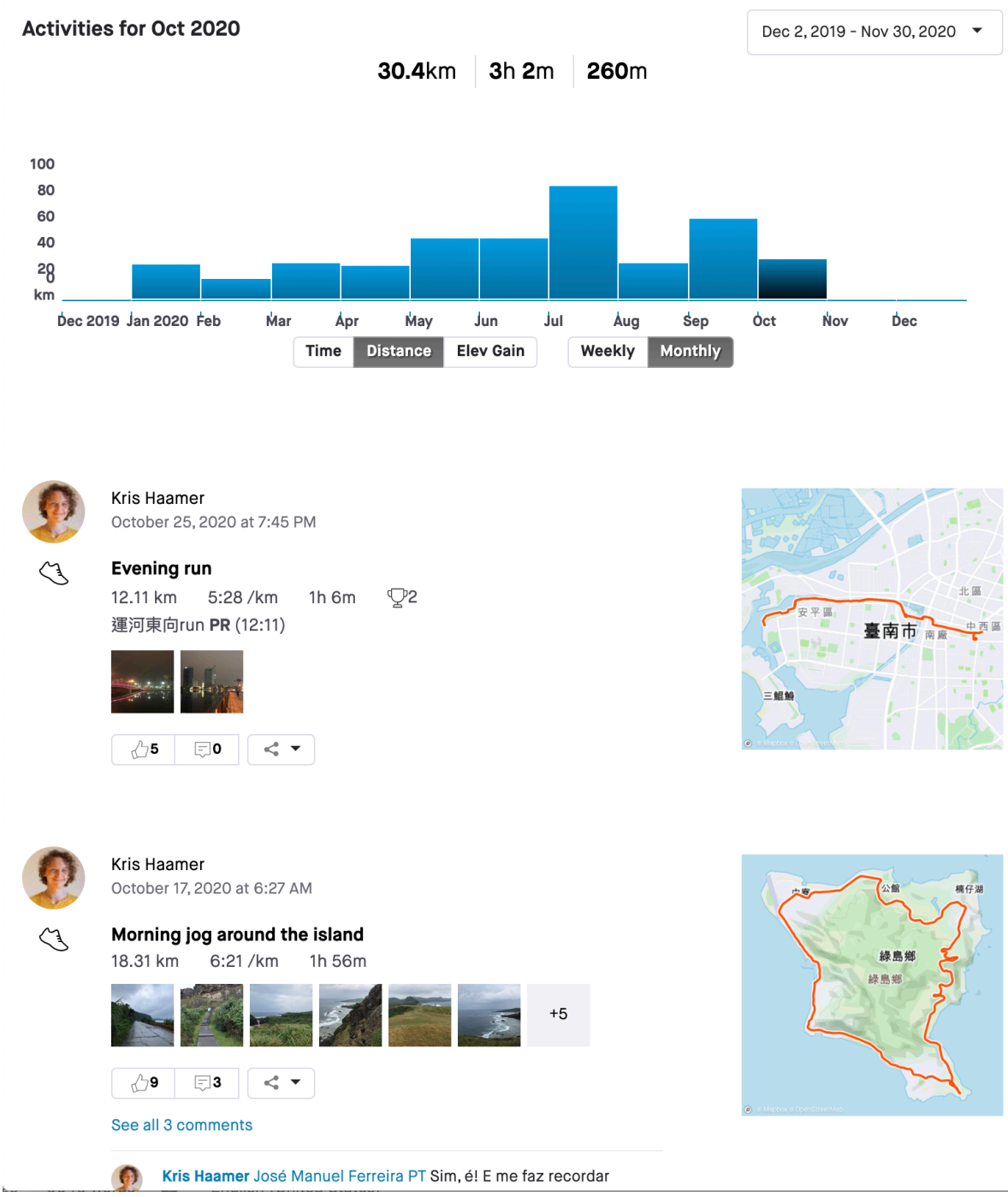


Figure 10: Popular Strava sports assistant provides run tracking and feedback

- AI Financial Advisors will need to go further to motivate users.
- DBS digibank app added a financial advisor named "Your Financial GPS" in 2018 DBS (2018)
- "urban metabolism" (Anon, 2021s; Claire Moran, 2018), city in-out flows accounting method
- Tsai et al. (2019)

- Burger, White & Yearworth (2019)
- Aromatario et al. (2019) behavior changes
- Ayoola et al. (2018) wellbeing data
- Godfrey et al. (2018)
- Thomas et al. (2018)
- Tonne et al. (2017)
- Anselma, Mazzei & De Michieli (2017)
- Forlano (2017) post-humanism and design
- Greenbaum & Gerstein (2016)
- Millings et al. (2015)
- Reis et al. (2015)
- Bower & Sturman (2015)
- Fletcher (2022)
- Ryan (2022) uses the "capability methodology" to evaluate if apps help people eat healthily.
- Baptista et al. (2022) apps for sleep apnea

The small screen estate space of mobiles phones and smart watches necessitates displaying content in a dynamic manner. Virtual reality glasses (called AR/VR or XR in marketing speak) need dynamic content because the user is able to move around the environment. These are questions that interaction design is called upon to solve. Hoang (2022): *"Dynamic interfaces might invoke a new design language for extended reality".*

Speaking is one mode of interaction that's become increasingly possible as machines learn to interpret human language.

Table 34: Modes of interaction

Mode of Interaction
Writing
Speaking
Touching
Moving

Re-Designing Industries for Circularity

Circular Economy

We're in an industrial revolution. Many companies are investing into transforming their processes. *"[T]ransition to a low carbon economy presents challenges and potential economic benefits that are comparable to those of previous industrial revolutions"* (Pearson & Foxon, 2012). It's possible to re-design entire industries and that is exactly the expectation sustainability sets on businesses. Across all industries, there's a call for more transparency. Conversations about sustainability are too general and one needs to look at the specific sustainability metrics at specific industries to be able to design for meaningful interaction. There's plentiful domain-specific research showing how varied industries can develop eco-designed products. I will here focus on 3 industries that are relevant for college students.

Food and clothes (I'm omitting housing and transport here) are part of the immediate environmental impact of college students.

- 5th industrial revolution, advanced robotics
- 6th industrial revolution, quantum computing, nanotechnology Chourasia et al. (2022)
- 7th industrial revolution futurists are looking at current trends and building scenarios for 2050 envisioning a world where the convergence of bio-based and mineral-based technologies, widespread sustainability and energy-abundance (Ruiz Estrada, 2024).

…for Provenance and Traceability

Companies like Qima provide inspection and certification services QIMA (2024)

Circular Economy

Circular economy is a tiny part of the world economy. (Circle Economy, 2022) reports only 8.6% of world economy is circular and *100B tonnes of virgin materials* are sourced every year.

Encouraging Sustainable Design and Reducing Waste.

(Liu et al., 2023b) reports, e-waste is growing 3%-5% every year, globally. (Thukral & Singh, 2023) identifies several barriers to e-waste management among producers including lack of awareness and infrastructure, attitudinal barriers, existing *informal* e-waste sector, and the need for an e-waste license.

- McDonough & Braungart (2002) from Cradle to Grave book was released over 2 decades ago, change is slow.
- McGinty (Thu, 08/06/2020 - 11:25): How to Build a Circular Economy
- Dull (2021) book, many current technological hurdles can be overcome by supply chain professionals who are experts in connecting supply streams.

also known as circular economy. Assuming that as individuals we want to act in a sustainable way, how exactly would be go about doing that?

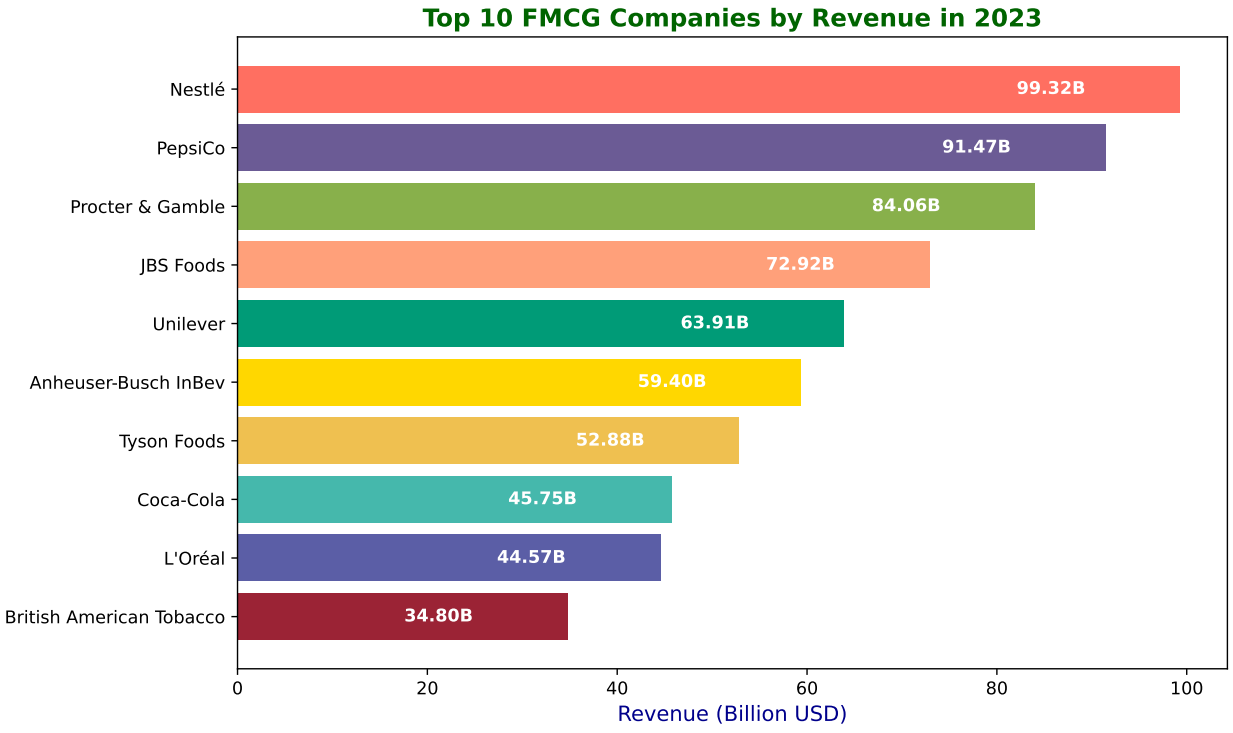
…for Sustainable Products

How can design enable/help/encourage sustainability?

- Use imagination
- Societal movements change things: implication for design: build a community
- Growing public understanding of how nature works and intersects with our use of money.
- Hedberg & Šipka (2021) argues digitization and data sharing is a requirement for building a circular economy.
- "Circular Petrochemicals" Lange (2021)
- Supply chain transparency enables stakeholder accountability (Circularise, 2018; Doorey, 2011; Fox, 2007).
- Recycling Critical Raw Materials, digitization of mining allows enhance the reliability of supply chains (CRM Alliance, 2020).
- EIT RawMaterials

Case: Fast-Moving Consumer Goods (FMCG)

Fast-Moving Consumer Goods (FMCG) also known as Consumer Packaged Goods (CPG) are large global congloremates operating with low margins and high volumes (Toh, 2024). The largest of them have several billions in revenue (Kenton, 2024).



Rise of e-commerce has pushed logistics companies to increase delivery efficiency to keep up with FMCG sales (Deliverect, 2024).

Case: Fashion

Just like Fast-Moving Consumer Goods, fast fashion operates with low margins and follows consumer trends. Young people are the largest consumers of fast fashion (Anon, n.d.bx). (In European Environment Agency, 2022 European Environment Agency (EEA)) estimates based on trade and production data that EU27 citizens consumed an average 15kg of textile products per person per year. The European Commission wants to reduce the impact of fast fashion on EU market (ERR, 2022). (Millward-Hopkins, Purnell & Baurley, 2023) shows how 50% of the textile waste in the UK is exported to other countries.

"26 million tons of clothing end up in China's landfills each year, propelled by fast fashion" (Tian Macleod Ji, 2024).

Greenwashing is prevalent in the fashion industry. **Problem**: Emily Chan (2022a) report says there's not enough transparency in fashion. Fashion Revolution Foundation (2022) Fashion transparency index. (Wikirate, 2022b): "Among the Index's main goals are to help different stakeholders to better understand what data and information is being disclosed by the world's largest fashion brands and retailers, raise public awareness, educate citizens about the social and environmental challenges facing the global fashion industry and support people's activism". Consumer understanding of sustainability is limited. Mabuza, Sonnenberg & Marx-Pienaar (2023) shows consumer knowledge of apparel coloration is very limited.

2.4 Trillion USD fashion industry contributing 2%-8% of total global GHG emissions, 100B USD lost to lack of recycling, contributes 9% of microplastics (Adamkiewicz et al., 2022). (Centobelli et al., 2022) Fashion industry year uses 9B cubic meters of water, 1.7B tonnes of CO_2, 92 million tonnes of textile waste. Köhler et al. (2021) Globally 87% of textile products are burned or landfilled after 1st consumer use.

Towards Sustainable Clothes

- There are local policy initiatives aiming to tackle the waste problem. For example the New Standard Institute's proposed "Fashion Act" to require brands doing business in New York City to disclose sustainability data and set waste reduction targets (Emily Chan, 2022b) .
- (Leung & Luximon, 2021) There's a growing know-how on how to produce sustainably and which materials to use. "Handbook of Footwear Design and Manufacture" Chapter 18 - Green design. Industry collaboration can raise the bar for everyone, such as the Better Cotton Initiative (Better Cotton, 2023).
- Story of Patagonia (Chouinard, 2005)].

Sustainable Fashion, Textile Design

- There are signs of young Chinese consumers valuing experiences over possessions (Jiang, 2023).

Across industries, reports are saying there isn't enough transparency.

- (Hannah Ritchie, 2020; US EPA, 2016) GHG emission inventory by sector
- Marrucci, Marchi & Daddi (2020) Italian retail supermarkets carbon footprint?

- Gyabaah et al. (2023) research across several dumpsites across Ghana revealed up to 12% of the landfill consisted of textile waste.
- imperfectidealist (2020) Fashion sustainability vs greenwashing
- Anon (2023ah) Ethical Shopping
- Anon (2023ad) Ethical brand?
- Good On You (2023) Sustainable fashion company evaluations
- Anon (n.d.aq) Garment Worker's rights
- Emily Chan (2022c): fashion companies can't be held accountable for their actions (or indeed, their lack of action).
- WikiRate (2023)
- Anon (2022h): "Political consumerism", "Instant Gratification for Collective Awareness and Sustainable Consumerism"
- FashionChecker (2023)
- Eesti Disainikeskus I Estonian Design Centre (2021) Circular textiles
- Eesti Kunstiakadeemia (2022) Sustainable Fashion education
- Anon (n.d.k)
- "The mainstream fashion industry is built upon the exploitation of labor, natural resources and the knowledge of historically marginalized peoples."
- Anon (n.d.bo)
- "Secrecy is the linchpin of abuse of power…its enabling force. Transparency is the only real antidote." Glen Greenwald, Attorney and journalist.
- Stand.earth (2023)
- Anon (n.d.av)
- Anon (n.d.g) Bangladesh Garment Manufacturers and Exporters Association
- Minimize shopping, buy quality, save CO_2, invest.
- Textile Exchange (2023) Ethical fashion materials matter
- Textile Exchange (2021): Policy request
- Free clothes
- Vanish UK (2021) "Generation rewear" documentary, sustainable fashion brands
- Storbeck (2021) and Remington (2020): Zalando says Fast fashion must disappear
- Infinited Fiber (2023)
- Cleantech Group (2023) Global cleantech 100
- Anon (2023ae) Alterations and repairs made easy
- Anon (2023l) Ethical brand ratings

Case: Food

Re-designing industrial food systems for an increasing global population is a challenge. Supply chain innovation in food industries may enable more transparency. **provenance and traceability of food has implications for sustainability and health.**

Global warming leading to droughts and extreme weather, wars and conflicts increased volatility in food prices (Eshe Nelson, Ana Swanson & Jeanna Smialek, 2023).

"The agricultural sector contributes to approximately 13.5% of the total global anthropogenic greenhouse gas emissions and accounts for 25% of the total CO_2 emission" (Nabipour Afrouzi et al., 2023). Poore & Nemecek (2018) suggests 26% of carbon emissions come from food production. Saner et al. (2015) reports dairy (46%) and meat and fish (29%) products making up the largest GHG emission potential. Springmann et al. (2021) proposes veganism is the most effective decision to reduce personal CO_2 emissions.

Farm to Fork is a European Union policy to shorten the supply chain from the producer to the consumer and add transparency to the system. Patel et al. (2023) livestock products (meat) are 15% of agricultural foods valued at €152 billion in 2018 globally.

- Farm to Fork Financial Times (2022)
- Fake honey, DNA-analysis to find real honey, synthetic honey can pass laboratorty tests (ERR, 2023)
- China is the largest honey producer.
- Food fraud

Anon (n.d.bm)

Anon (n.d.az) app for nutrition and sustainability data

Fishing

- 75% of fishing is done using industrial Trawling, which has environmental impact
- Bailey & Eggereide (2020) shows how the Norwegian government plans to increase salmon production 5x by 2050. How can this be sustainable? Mostly this means fish-farming
- Complex supply chains make seafood (marine Bivalvia, mollusks) logistics prone to fraud, leading to financial losses and threats to consumer health (Santos et al., 2023). (Chang et al., 2021) *fish fraud* is a large global problem but it's possible to use DNA-tracking to prove where the fish came from. In "2019, the 27 KURA SUSHI branches in Taiwan sold more than 46 million plates of sushi. in Taiwan". Illegal, unreported and unregulated fishing (IIU) fishing is widespread; the EU is adopting countermeasures (Kim & Lim, 2024). Muñoz et al. (2023) Is there such a thing as sustainable fishing? Bottom trawling is the worst and should be banned. Katie Gustafson (2022) proposes a **"Uniform traceability system for the entire supply chain"** for seafood. Mamede et al. (2022) proposes *Seafood tracing*: Fingerprinting of Sea Urchin.
- The same is true for cocoa beans, which are at risk from food fraud (Fanning et al., 2023).

- **Perennial Crops,** Multi-year crops reduce inputs of gasoline, labor, etc. (Aubrey Streit Krug & Yin Lu, 2023). Large agritech companies like Monsanto rely on selling seeds annually for profits putting them at odds with **Perennial crops**. Single-year seeds have led to farmer suicides when crops fail in poor communities.
- Sustainability Accounting Standards Board, part of the International Financial Reporting Standards Foundation
- Global Reporting Iniative
- Anon (2022m)
- Anon (2021n) "Real Time ESG Tracking From StockSnips"
- Waters (2015) **(Need access!)**
- Cawthorn & Hoffman (2016) **(Need access! ncku doesn't subsribe)**
- Gamborg & Jensen (2017) **(Need access!)**
- Neethirajan & Kemp (2021) using biometric sensors to track livestock sustainability.
- Inc (n.d.)
- Tim Nicolle (2017)
- EAT-Lancet diet

Culture, Community, Cuisine, Storytelling

- Tsing (2015) mushrooms
- Food is about enticing human imagination and taste buds. Potato used to be a newcomer and innovative crop in Europe, and now it's so common, Europeans forget it's no originally from Europe. Food is also about cuisine and culture; foods become popular if we hear stories and see cuisine around a particular crop (Aubrey Streit Krug & Yin Lu, 2023).
- IARC warns aspartame (artificial sweetener found in many soft drinks) could cause cancer [ADD CITATION].
- Yap et al. (2023) Singapore disposes of 900,000 tonnes of plastic waste out of which only 4% is recycled.
- Kiessling et al. (2023) Single-use plastics make up 44-68% of all waste mapped by citizen scientists.

Food Waste

There are several initiatives to reduce food waste by helping people consume food that would otherwise be throw away.

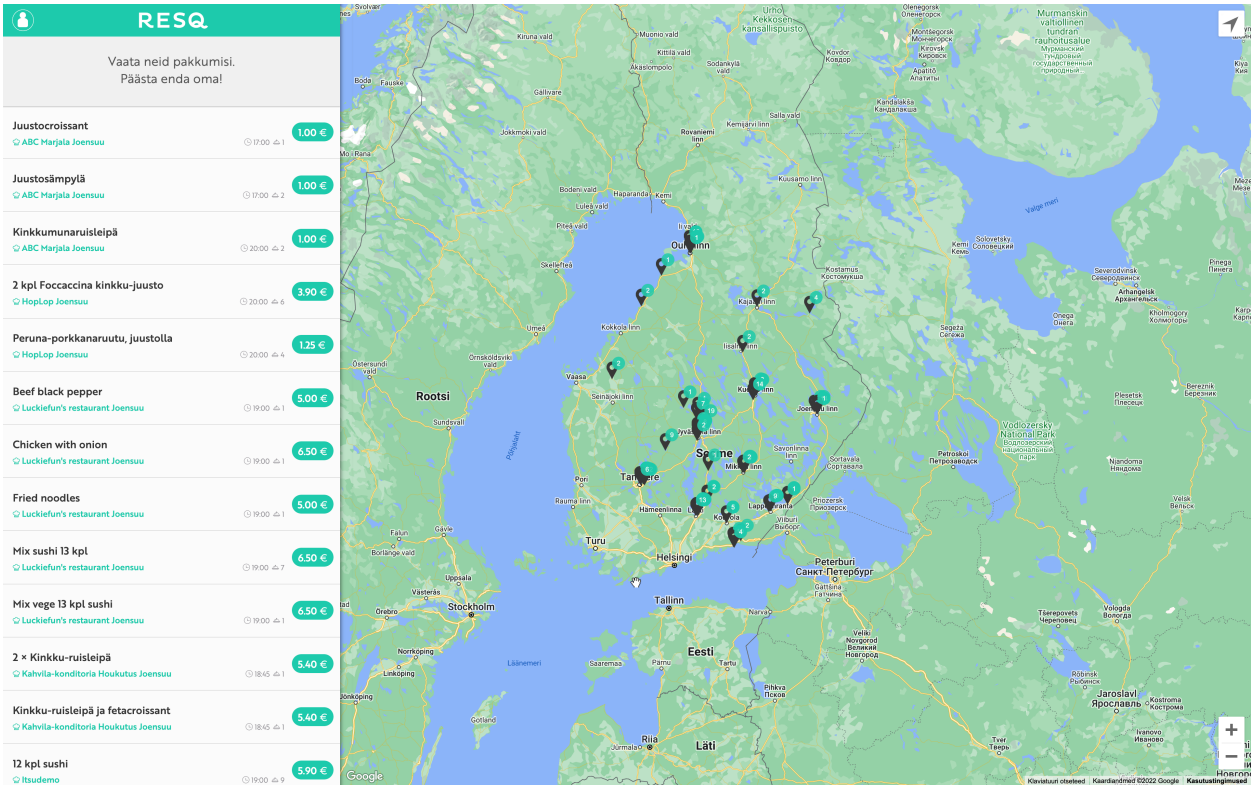


Figure 11: ResQ Club saves food waste by selling left-over foods cheaply

Table 35: Food saving apps

Name	
Karma	
ResQ Club	(Kristina Kostap, 2022) ResQ Club in Finland and Estonia for reducing food waste by offering a 50% discount on left-over restaurant meals before they are thrown away.
Kuri	Haje Jan Kamps (2022) Less impact of food
Social media groups (no app)	

- Röös et al. (2023) identified 5 perspectives in a small study (*n=106*) of views on the Swedish food system:

Table 36: Perspective on food systems in Sweden.

Perspective	Content
"The diagnostic perspective"	*"All hands on deck to fix the climate"*
"The regenerative perspective"	*"Diversity, soil health and organic agriculture to the rescue"*

Perspective	Content
"The fossil-free perspective"	"*Profitable Swedish companies to rid agriculture and the food chain of fossil fuel"*
"The consumer-driven perspective"	*"A wish-list of healthy, high-quality and climate-friendly foods"*
"The hands-on perspective"	"Tangible solutions within the reach of consumers and the food industry"

- "regenag", Václav Kurel, we need help consumers demand regenerative agriculture Baltic Sea Action Group (2023)
- Kommenda et al. (2022) Carbon Food Labels
- Food Sovereignty: "The global food sovereignty movement, which had been building momentum since its grassroots conception in the late '90s, quickly gained traction with its focus on the rights of people everywhere to access healthy and sustainable food. One of the pillars of the movement lies in using local food systems to reduce the distance between producers and consumers."
- CAITLIN STALL-PAQUET (2021): "We can grow foods just as well in the inner city as we can out in the country because we're agnostic to arable land," says Woods. "Because we grow indoors and create our own weather, [climate change] doesn't affect our produce."
- Renée Salmonsen (2018): Vertical farm in Taoyuan
- Catherine Shu (2023): *Intensive Farming Practices vs* Farm to table
- Akshat Rathi (2021) and Lowercarbon Capital (2023) climate startup funding.
- Only make what is ordered.

Circular Design

Circular design is only possible if supply chains become circular as well.

It's important in which structure data is stored, affecting the ability to efficiently access and manage the data while guaranteeing a high level of data integrity, security, as well as energy usage of said data.

The complexity of resource and delivery networks necessitates more advanced tools to map supply chains (Knight et al., 2022). The COVID19 pandemic and resulting blockages in resource delivery highlighted the need to have real-time visibility into supply chains (Finkenstadt & Handfield, 2021).

Blockchains are a type of shared database where the data is stored in several locations with a focus on making the data secure and very difficult to modify after it's been written to the database. Once data is written to the blockchain, modifying it would require changing all subsequent records in the chain and agreement of the majority of validators who host a version of the database. Blockchain is the main technology considered for accounting for the various inputs and complex web of interactions between many participants inside the supply chain networks. There are hundreds of paper researching blockchain use in supply change operations since 2017 (Dutta et al., 2020). Blockchains

enable saving immutable records into distributed databases (also known as ledgers). It's not possible to (or extremely difficult) to change the same record, only new records can be added on top of new ones. Blockchains are useful for data sharing and auditing, as the time and place of data input can be guaranteed, and it will be easier to conduct a search on who inputted incorrect data; however the system still relies on correct data input. As the saying goes, *"garbage in, garbage out"*.

There are several technologies for tracking goods across the supply chain, from shipping to client delivery. Data entry is a combination of manual data input and automated record-keeping facilitated by sensors and integrated internet of things (IoT) capabilities. For example (Ashraf & Heavey, 2023) describes using the Solana blockchain and Sigfox internet of things (IoT) Integration for supply chain traceability where Sigfox does not need direct access to internet but can send low powered messages across long distances (for example shipping containers on the ocean). (Van Wassenaer et al., 2023) compares use cases for blockchains in enhancing traceability, transparency and cleaning up the supply chain in agricultural products.

- Several startups are using to track source material arriving to the factories and product movements from factories to markets.
- Wagenvoort (2020) Self-driving supply chains.. (contact Japanese factory?)

Table 37: Blockchain supply chain companies as of summer 2023 include.

Company	Link	Literature	Comments
Ocean Protocol	oceanprotocol.com		
Provenance	provenance.io		
Ambrosius	ambrosus.io		
Modum	modum.io		
OriginTrail	origintrail.io		
Everledger	everledger.io		
VeChain	vechain.org		
Wabi	wabi.io		
FairFood	fairfood.org		
Bext360	bext360.com		
SUKU	suku.world	Miller (2019) SUKU makes supply chains more transparent	Seems to have pivoted away from supply chains

- Oikos Denktank (2021) circular material procurement requires new skills. How to reuse old paint? Small projects can have large social impact.
- For example, Duriez et al. (2022) shows how simply by reducing material weight it's possible to design more sustainable transportation.
- Embodied Carbon
  - "embodied carbon"
  - Carbon Neutral Cities Alliance
  - Builders for Climate Action (2021)

Tracking Transport Supply Chains

Products are made from resources distributed across the planet and transported to clients around the world which currently causes high levels (and increasing) of greenhouse gases. *"Transport greenhouse gas emissions have increased every year since 2014"* (Anon, 2023d). Freight (transport of goods by trucks, trains, planes, ships) accounts for 1.14 gigatons of CO_2 emissions as per 2015 data or 16% of total international supply chain emissions (Wang et al., 2022).

Table 38: Share of CO_2 of CO_2 emissions by type of transport globally (Statista & IEA, 2022).

Type of Transport	Percentage
Passenger cars	39%
Medium and heavy trucks	23%
Shipping	11%
Aviation	9%
Buses and minibuses	7%
Light commercial vehicles	5%
Two/three-wheelers	3%
Rail	3%

- Platzer (2023), a scientist working on the Apollo space program, calls for emergency action to develop *green aviation*.
- The California Transparency in Supply Chains Act which came into effect in 2012 applies to large retailers and manufacturers focused on pushing companies to to eradicate human trafficking and slavery in their supply chains.
- The German Supply Chain Act (Gesetz über die unternehmerischen Sorgfaltspflichten zur Vermeidung von Menschenrechtsverletzungen in Lieferketten) enacted in 2021 requires companies to monitor violations in their supply chains (Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung, 2023; Stretton, 2022b).

Ethics & Cruelty

Can data transparency provide tools for reducing cruelty.

- Traceability and animal rights. Animal rights vs animal welfare. Ethereum blockchain and animal rights. "Blockchain can provide a transparent, immutable record of the provenance of products. This can be especially useful for verifying claims made about animal welfare. For example, products claiming to be"free-range," "organic," or "sustainably sourced" could have their entire lifecycle recorded on the blockchain, from birth to shelf, allowing consumers to verify these claims."
- Cruelty free brands
- BCorp
- ESG
- Trash found in ocean / nature etc
- Increase your investment point by matching with your contribution /.

- Point of Sales integration (know the SKU you buy). Integrate to the financial eco footprint (no need to scan the product). What's the name of the startup that does this?
- Precision Fermentation and Cultivated Meat: Meat products without farm animals

Factories Can Become More Transparent

- Regional supply chains for decarbonising steel: "co-locating manufacturing processes with renewable energy resources offers the highest energy efficiency and cost reduction" Japanese-Australia study (Devlin & Yang, 2022).
- Transparency about the polluting factories where the products come from.. the product journey
- virtual factories
- Tracing emissions from factory pipes… what's the app?
- Factories should be local and make products that can be repaired.
- Carbon-neutral factories "made in carbon-neutral factory" list of products
- Stefan Klebert (2022)
- VDI Zentrum Ressourceneffizienz (2020)
- Anon (n.d.m) and Anon (n.d.aj) CO_2 neutral factories?
- (Anon, n.d.ar; Anon, n.d.q) CO_2 neutral websites
- Eric fogg (2020) Lights-Out Manufacturing
- Mowbray (2018) "World's first free digital map of apparel factories"
- Anon (n.d.y) Factory compliance - Fair Factories
- Planet Factory
- Anon (n.d.bs) Plastic waste makers index, sources of plastic waste

Extended Producer Responsibility

Extended Producer Responsibility Enables Companies to be Resposible.

Popular blogs such as (Kohli, 2019) and (Lose, 2023a) offer many suggestions how designers can help people become more sustainable in their daily lives yet focusing on the end-user neglects the producers' responsibility (termed as Extended Producer Responsibility or ERP) in waste management studies.

Extended Producer Responsibility (EPR) is a policy tool first proposed by Thomas Lindhqvist in Sweden in 1990 [ADD CITATION], aimed to encourage producers take responsibility for the entire life-cycle of their products, thus leading to more eco-friendly products. Nonetheless, EPR schemes do not guarantee circularity and may instead be designed around fees to finance waste management in linear economy models (Christiansen, Hasse & Tønder, 2021). The French EPR scheme was upgraded in 2020 to become more circular (Jacques Vernier, 2021). In July 2024, Latvia was the 4th EU country to join an textile-EPR scheme (Anon, 2024d).

In any case, strong consumer legislation (such as EPR) has a direct influence on producers' actions. For example, in HKTDC Research (2022), the Hong Kong Trade Development Council notified textile producers in July 2022 reminding factories to produce to French standards in order to be able enter the EU market. Peng, Shi & Tong (2023) finds that the ***Carbon Disclosure Project*** has been a crucial tool to empower ERP in Chinese auto-producers.

- The success of EPR can vary per type of product. For car tires, the EPR scheme in the Netherlands claims a 100% recovery rate Campbell-Johnston et al. (2020).

One type of legislation that works?

- (Steenmans & Ulfbeck, 2023) Argues for the need to engage companies through legislation and shift from waste-centered laws to product design regulations.
- In Europe, there's large variance between member states when in comes to textile recycling: while Estonia and France are the only EU countries where separate collection of textiles is required by law, in Estonia 100% of the textiles were burned in an incinerator in 2018 while in France textiles are covered by an Extended Producer Responsibility (EPR) scheme leading to higher recovery rates (Ibid).
- Greyparrot AI to increase recycling rates (Natasha Lomas, 2024).

Return, Repair, Reuse

- There's a growing number of companies providing re-use of existing items.
- Anon (n.d.bh) For example, Swap furniture in Estonia

Bring back your bottle and cup after use.

- Ruiz-Pastor & Mesa (2023) proposes a **product repairability index (PRI)**
- Formentini & Ramanujan (2023)
- Recycling (Lenovo, 08-29-22) "rethinking product design and inspiring consumers to expect more from their devices"
- "design is a tool to make complexity comprehensible" like the Helsinki chapel. there's either or a priest or a social worker. it's the perfect public service. "limit the barrier of entry for people to discover". elegant.
- Zeynep Falay von Flittner (n.d.)

Packaging is a rapidly growing industry which generates large amounts of waste Ada et al. (2023). Bradley & Corsini (2023): "Over 161 million tonnes of plastic packaging is produced annually."

- Anon (2022a)
- Anon (2022l)
- Anon (2010)
- (Lerner, 2019) Coca Cola plastic pollution. ESG ratings have faced criticism for lack of standards and failing to account for the comprehensive impact a company is having. (Foley et al., 2024) notes how Coca Cola fails to account the supply chain water usage when reporting becoming "water neutral" and calls on companies to release more detailed information.
- Anon (n.d.bl)

Digital Product Passports

Even though this topic belongs under Circular Economy, I've chose to highlight *digital product passports* here as it's the main design implication from this chapter - an emerging technology which needs to be designed for the user.

I will being with a bit of history to contextualize what has already been tried. CO_{2e} labeling initiatives are an early form of communicating the environmental cost of each product. Using carbon labels to communicate CO_{2e} emission of consumer products has been a topic of discussion for decades (Adam Corner, 2012). Academic literature has looked at minute details such as color and positioning of the label (Zhou et al., 2019). There's some indication consumers are willing to pay a small premium for low-CO_{2e} products; all else being equal, consumers choose the option with a lower CO_{2e} number (Xu & Lin, 2022; Carlsson, Kataria & Lampi, 2022). (Cohen & Vandenbergh, 2012) argues labeling the carbon footprint of products does help inform consumer choice towards sustainability and help promote a green economy. A large-scale study of UK university students finds some evidence to suggest labeling low CO_{2e} food enables people to choose a *climatarian diet*, however the impact of carbon labels on the market share of low-carbon meals is negligible (Lohmann et al., 2022).

Labels alone are not enough. A study in Sweden underlines a negative correlation between worrying about climate impact and interest in climate information on products (Edenbrandt & Lagerkvist, 2022). This latter finding may be interpreted to suggest a need for wider environmental education programs among consumers. (Asioli et al., 2022) found differences between countries, where Spanish and British consumers chose meat products with *'No antibiotics ever'* over a *Carbon Trust* label, whereas French consumers chose CO_2 labeled meat products.

however several studies show their effect is negligible. Nonetheless, the idea of *Carbon Labelling* is yet to find mainstream adoption.

Carbon labeling is voluntary. Only a handful of companies practice carbon-labeling but the number is growing. The U.S. restaurant chain *Just Salad* , U.K.-based vegan meat-alternative *Quorn* and plant milk *Oatly* are some example of companies that provide carbon labeling on their products (Brian Kateman, 2020). (ClimatePartner, 2020): Companies like ClimatePartner and Carbon Calories offers labeling consumer goods with emission data as a service. (The Carbon Trust, n.d.): The Carbon Trust reports it's certified 27 thousand product footprints.

Table 39: Companies with Carbon Labels (Brian Kateman, 2020)

Company	Country
Just Salad	U.S.A.
Quorn	U.K.
Oatly	U.K.
IKEA	Sweden

Table 40: Organization to Certify Carbon Labels (ClimatePartner, 2020).

Organization	Country	Number of Product Certified
ClimatePartner		

Organization	Country	Number of Product Certified
Carbon Calories		
Carbon Trust		27000

- Digitalisation and digital transformation; Digital Receipts are one data source for tracking one's carbon footprint (Anon, n.d.p).
- Ivanova et al. (2020) "establish consumption options with a high mitigation potential measured in tonnes of CO_2 equivalent per capita per year."
- 55% of emissions come from energy production.
- 1.7 trillion tons of CO2e emissions since the 1760s (start of the industrial revolution) (Global Carbon Budget, 2023; Marvel, 2023).
- Carto (2023) Making advanced maps to convince people to make changes
- similar to Nutritional Facts Labeling

Transitioning from simpler Carbon Labels to data-driven Digital Product Passports requires comprehensive data collection, digital infrastructure, industry collaboration, regulatory frameworks and consumer engagement.

- Circularise introduced an early blockchain-based sustainability system in 2016 aiming to improve transparency across several industries and is currently the market leader in providing *Digital Product Passports* (Stretton, 2022a) "Ecodesign for Sustainable Products Regulation (part of the Sustainable Products Initiative) and one of the key actions under the Circular Economy Action Plan (CEAP). The goal of this initiative is to lay the groundwork for a gradual introduction of a digital product passport in at least three key markets by 2024" "Connecting the Value Chain, One Product at a Time". "Circularise aims to overcome the communication barrier that is limiting the transition to a circular economy with an open, distributed and secure communications protocol based on blockchain technology."
- product's history, composition, and environmental impact.

Table 41: Digital Product Passport goals Stretton (2022a)

Goal	Description
Sustainable Product Production	
Businesses to create value through Circular Business Models	
Consumers to make more informed purchasing decisions	
Verify compliance with legal obligations	

Digital product passports are a further development of the idea of carbon labels.

- The European Commision has proposed a *Digital Product Passports* to help companies transfer environmental data (Nissinen, Seppälä & Heinonen, 2022). Carbon labels are needed for green transformation.
- Reich et al. (2023) "Information gaps are identified as one of the major obstacles to realizing a circular economy."

- Jensen et al. (2023) "support decision-making throughout product life cycles in favor of a circular economy."
- King, Timms & Mountney (2023) "influence consumer behavior towards sustainable purchasing and responsible product ownership by making apparent sustainability aspects of a product life cycle."
- Berger et al. (2023c) "support Sustainable Product Management by gathering and containing product life cycle data. However, some life cycle data are considered sensitive by stakeholders, leading to a reluctance to share such data."
- Plociennik et al. (2022) "Digital Lifecycle Passport (DLCP) hosted on a cloud platform and can be accessed by producers, users, recyclers"
- Berger et al. (2023b) challenges with Electric Vehicle Batterys. Berger et al. (2023a) proposes Digital Battery Passports
- Van Capelleveen et al. (2023) literature overview
- Sustainable Product Management: Korzhova (2020)
- What data does a digital product passport hold? Tian Daphne & Chris Stretton (2023)
- Gitcoin Passport — Sybil Defense. Made Simple. [@gitcoinpassport] (2023) discusses ow to build an antifragile scoring system (antifragile passport) inspired by Nassim Taleb's popular book that discusses antifragile systems that get better in difficult situations (Taleb, 2012).

Design Implications

This chapter has the following design implications.

Category	Implication
Greenwashing	Personal CO2 tracking is ineffective and the focus should be on systematic change towards circular design and zero waste practices.
	Help consumers to demand more
Lack of transparency	Make open data easy to use in everyday life
Transparency	The key idea is making CO_2 Visible.
Greenwashing	Ranking companies based on sustainability
	Help you to decide: what to buy, how to save, where to invest.
Decision Fatigue	What if there was a "Green Filter" on every product everywhere?
	Become a Sustainability-Aware App or Game.
	Focus on how college students can invest in specific industries?
	Where to shop rankings for groceries: list worst offenders in terms of products; shop and invest according to your values.
	What Quantified Self look like for sustainability?

Category	Implication
	Empowering people to live a sustainable day
	What if there was a “Green Filter” on every product everywhere?
	Become a Sustainability-Aware App or Game.
	Guidance could help young people beat climate anxiety by taking meaningful action.
	The app is just as much about helping people deal with climate anxiety as it’s with solving the climate issue.
	List of metrics that should be tracked to enable useful analytics. Ex: % of beach pollution, air pollution, water pollution (I had this idea while meditating). In essence, “green filter” is a central data repository not unlike “Apple Health for Sustainability”.
	Health and fitness category apps
	Using “green filter” you can get a personalized sustainability plan and personal coach to become healthy and nature-friendly.
	All green categories — Green hub — Ask the user to prioritize
	In my “green filter” AI advisor app’s scenario, the AI is scanning for opportunities matching the user’s sustainable investment appetite and risk profile, using different methods of analysis, including alternative data sources. Traditionally, financial analysts only looked at traditional data, such as company reports, government reports, historic performance, etc., for preparing advisory guidance to their clients. With the advent of AI and big data analysis, many other options of research data have become available, for example, accurate weather predictions for agriculture can affect guidance, because of expected future weather disasters in the area. Other examples include policy predictions, pollution metrics, etc. Professional financial advisors use automated tools to analyze data and present it in human form to clients. Today’s ubiquitous mobile interfaces, however, provide the opportunity to ‘cut out the middleman’ and provide similar information to clients directly, at a lower cost and a wider scale, often without human intervention. Additional (more expensive) “human-judgment- as-a-service”, a combination of robots + human input, can help provide further personalized advice for the consumer, still at a cheaper price than a dedicated human advisor. Everyone can have a financial advisor.
	Narrative design bring together film school **storytelling** experience with design.
	Rebuilt the app as a personalized, narrative lifestyle feed.
	How the design can connect people to sustainable outcomes while shopping and investing? Perhaps even forming a community of sustainable action. What I showed in class looks like an app but it could also be a physical object (a speculative design). From the presentations I saw most students seemed to be interested in form and light (many lamps) and a couple were about medical uses. I don’t remember seeing one that could be compatible with the environmental sustainability focus unfortunately…
	Guided Sustainability “refers to a concept of using technology, such as AI and machine learning, to help individuals and organizations make more sustainable decisions and take actions that promote environmental and social sustainability. This can include things like analyzing data on resource usage and emissions, providing recommendations for reducing the environmental impact of operations, or helping to identify and track progress towards sustainability goals. The goal of guided sustainability is to make it easier for people to understand their impact on the environment and to take steps to reduce that impact.”
	Young people are stuck inside platforms. You don’t own the data you put on TikTok. You can’t leave because you’ll lose the audience.

Category	Implication
	With this perspective of scale, what would a shopping experience look like if one knew at the point of sale, which products are greener, and which are more environmentally polluting? AI Financial Advisors will need to go further to motivate users. because of the nature of the technology, which is based on the quality of the data the systems ingest, they are prone to mistakes.
Generative AI	Allow producers to make use of Speculative and Participatory design to test out new product ideas? • Processes sustain things: implication for design: built an app • If sustainability can't be automated, give the user buttons to choose a sustainable option. • The power of defaults. Make the sustainable option the default option. Gigerenzer (2008)

Feature Ideas

This chapter and design implications spurred the following feature ideas.

Alerts Your shopping products mostly come from Protector and Gamble (3x) and Nestle. These are large conglomerates with a massive CO_2 footprint. See the index to find some alternatives.
App shows traceability.

AI

Human Patterns

The fact that AI systems work so well is proof that we live in a measurable world. The world is filled with structures: nature, cultures, languages, human interactions - all form intricate patterns. Computer systems are increasingly capable in their ability copy these patterns into computer models - known as machine learning. As of 2023, 97 zettabytes (and growing) of data was created in the world per year (Soundarya Jayaraman, 2023). Big data is a basic requirement for training AIs, enabling learning from the structures of the world with increasing accuracy. Representations of the real world in digital models enable humans to ask questions about the real-world structures and to manipulate them to create synthetic experiments that may match the real world (if the model is accurate enough). This can be used for generating human-sounding language and realistic images, finding mechanisms for novel medicines as well as understanding the fundamental functioning of life on its deep physical and chemical level (No Priors: AI, Machine Learning, Tech, & Startups, 2023).

In essence, Human Patterns Enable AIs. Already ninety years ago (McCulloch & Pitts, 1943) proposed the first mathematical model of a neural network inspired by the human brain. Alan Turing's Test for Machine Intelligence followed in 1950. Turing's initial idea was to design a game of imitation to test human-computer interaction using text messages between a human and 2 other participants, one of which was a human, and the other - a computer. The question was, if the human was simultaneously speaking to another human and a machine, could the messages from the machine be clearly distinguished or would they resemble a human being so much, that the person asking questions would be deceived, unable to realize which one is the human and which one is the machine? (Turing, 1950).

> Alan Turing: *"I believe that in about fifty years' time it will be possible to program computers, with a storage capacity of about 10^9, to make them play the imitation game so well that an average interrogator will not have more than 70 percent chance of making the right identification after five minutes of questioning. … I believe that at the end of the century the use of words and general educated opinion will have altered so much that one will be able to speak of machines thinking without expecting to be contradicted."* - from (Stanford Encyclopedia of Philosophy, 2021)

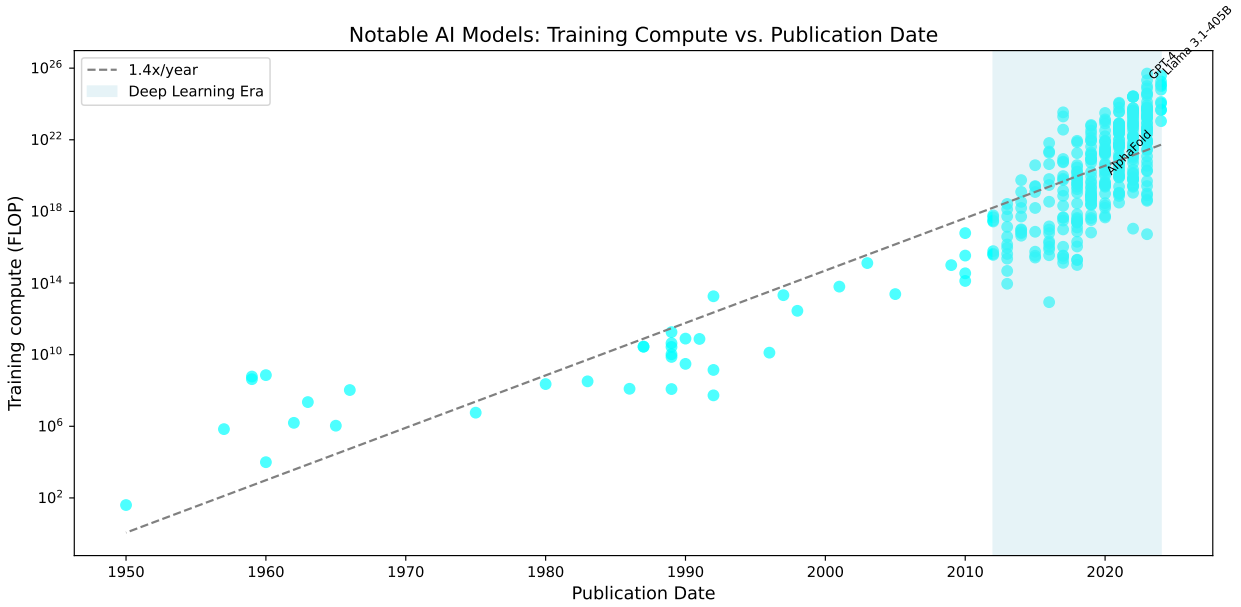
By the 2010s AI models became capable enough to beat humans in games of Go and Chess, yet they did not yet pass the Turing test. AI use was limited to specific tasks. While over the years, the field of AI had seen a long process of incremental improvements, developing increasingly advanced models of decision-making, it took an ***increase in computing power*** and an approach called ***deep learning***, a variation of ***machine learning (1980s),*** largely modeled after the ***neural networks*** of the biological (human) brain, returning to the idea of ***biomimicry***, inspired by nature, building a machine to resemble the connections between neurons, but digitally, on layers much deeper than attempted before.

"Generating structured data from unstructured inputs is one of the core use cases for AI" Pokrass (2024) How can AI interfaces enable/help/encourage sustainability? AI-fying User Interfaces (for Sustainability)

Reinforcement Learning with Human Feedback (RLHF)

Combining deep learning and reinforcement learning with human feedback (RLHF) enabled to achieve levels of intelligence high enough to beat the Turing test (Kara Manke, 2022; Christiano, 2021; Christiano et al., 2017). OpenAI co-founder John Schulman describes RLHF simply: *"the models are just trained to produce a single message that gets high approval from a human reader"* (Kara Manke, 2022).

The nature-inspired approach was successful. Innovations such as *back-propagation* for reducing errors through updating model weights and *transformers* for tracking relationships in sequential data (for example in sentences), enabled AI models to became increasingly capable (Vaswani et al., 2017; Merritt, 2022). Generative Adversarial Networks*** (GAN), (**ADD CITATION, 2016**), and ***Large Language Models (*ADD CITATION*, 2018)***, enabled increasingly generalized models, capable of more complex tasks, such as language generation. One of the leading scientists in this field of research, Geoffrey Hinton, had attempted back-propagation already in the 1980s and reminiscents how *"the only reason neural networks didn't work in the 1980s was because we didn't have have enough data and we didn't have enough computing power"* (CBS Mornings, 2023). (Epoch AI, 2024) reports the growth in computing power and the evolution of more than 800 AI models since the 1950s. Very simply, more data and more computing power means more intelligent models.



- How do transformers work? Illustration Alammar (2018)

By the 2020s, AI-based models became a mainstay in medical research, drug development, patient care (Leite et al., 2021; Holzinger et al., 2023), quickly finding potential vaccine candidates during the COVID19 pandemic (Zafar & Ahamed, 2022), self-driving vehicles, including cars, delivery robots, drones in the sea and air, as well as AI-based assistants. The existence of AI models has wide implications for all human activities from personal to professional. The founder of the largest chimp-maker NVIDIA calls upon all countries do develop their own AI-models which would encode their local knowledge, culture, and language to make sure these are accurately captured (World Governments Summit, 2024).

OpenAI has researched a wide range of approaches towards artificial general intelligence (AGI), work which has led to advances in large language models(Ilya Sutskever, 2018; AI Frontiers, 2018). In 2020 OpenAI released a LLM called GPT-3 trained on 570 GB of text (Alex Tamkin & Deep Ganguli, 2021) which was adept in text-generation. (Singer et al., 2022) describes how collecting billions of images with descriptive data (for example the descriptive *alt* text which accompanies images on websites) enabled researchers to train AI models such as ***stable diffusion*** for image-generation based on human-language. These training make use of ***Deep Learning***, a layered approach to AI training, where increasing depth of the computer model captures minute details of the world. Much is still to be understood about how deep learning works; the fractal structure of deep learning can only be called mysterious (Sohl-Dickstein, 2024).

The Idiot Savant

Hinton likes to call AI an *idiot savant*: someone with exceptional aptitude yet serious mental disorder (CBS Mornings, 2023). Large AI models don't understand the world like humans do. Their responses are predictions based on their training data and complex statistics. Indeed, the comparison is apt, as the AI field now offers jobs for *AI psychologists (ADD CITATION)*, whose role is to figure out what exactly is happening inside the 'AI brain'. Understading the insides of AI models trained of massive amounts of data is important because they are *foundational*, enabling a holistic approach to learning, combining many disciplines using languages, instead of the reductionist way we as human think because of our limitations (CapInstitute, 2023).

Standford "thorough account of the opportunities and risks of foundation models" (Bommasani et al., 2021).

Foundation models in turn enabled *generative AIs*, a class of models which are able to generate many types of *tokens,* such as text, speech, audio (San Roman et al., 2023; Kreuk et al., 2022), music (Copet et al., 2023; Meta AI, 2023), video, and even complex structures such 3D models and DNA structures, in any language it's trained on. The advent of generative AIs was a revolution in human-computer interaction as AI models became increasingly capable of producing human-like content which is hard to distinguish from actual human creations. This power comes with *increased need for responsibility*, drawing growing interest in fields like *AI ethics* and *AI explainability.* Generative has a potential for misuse, as humans are increasingly confused by what is computer-generated and what is human-created, unable to separate one from the other with certainty.

The technological leap is great enough for people to start calling it a start of a new era.(Noble et al., 2022) proposes AI has reached a stage of development marking beginning of the *5th industrial revolution*, a time of collaboration between humans and AI. Widespread Internet of Things (IoT) sensor networks that gather data analyzed by AI algorithms, integrates computing even deeper into the fabric of daily human existence. Several terms of different origin but considerable overlap describe this phenomenon, including *Pervasive Computing (PC)* (Rogers, 2022) and *Ubiquitous Computing*. Similar concepts are *Ambient Computing*, which focuses more on the invisibility of technology, fading into the background, without us, humans, even noticing it, and *Calm Technology*, which highlights how technology respects humans and our limited attention spans, and doesn't call attention to itself. In all cases, AI is integral part of our everyday life, inside everything and everywhere. Today AI is not an academic concept but a mainstream reality, affecting our daily lives everywhere, even when we don't notice it.

Human-in-the-Loop (HITL)

AI responses are probabilistic and need some function for ranking response quality. Achieving higher percentage or correct responses requires oversight which can come in the form of human feedback (human-in-the-loop) - or by using other AIs systems which are deemed to be already well-aligned (termed Constitutional AI by Anthropic) (Bailey, 2023; Bai et al., 2022). Less powerful AIs areFor example META used LLAMA 2 for aligning LLAMA 3.

One approach to reduce the issues with AI is to introduce some function for human feedback and oversight to automated systems. Human involvement can take the form of interventions from the AI-developer themselves as well as from the end-users of the AI system.

There are many examples of combination of AI and human, also known as *"human-in-the-loop",* used for fields as diverse as training computer vision algorithms for self-driving cars and detection of disinformation in social media posts (Wu et al., 2023; Bonet-Jover et al., 2023).

Also known as Human-based computation or human-aided artificial intelligence (Shahaf & Amir, 2007; Mühlhoff, 2019)

- Stanford Institute for Human-Centered Artificial Intelligence Ge Wang (2019)

Table 44: Examples of human-in-the-loop apps

App	Category	Use Case
Welltory	Health	Health data analysis
Wellue	Health	Heart arrhythmia detection
QALY	Health	Heart arrhythmia detection
Starship Robots	Delivery	May ask for human help when crossing a difficult road or other confusing situation

Algorithmic Experiences Before Non-Deterministic Systems

Even before AIs, as a user of social media, one may be accustomed to interacting with the feed algorithms that provide a personalized *algorithmic experience*. Algorithms are more deterministic than AI, meaning they would produce more predictable output in comparison AI models. Nonetheless, there are many reports about effects these algorithms have on human psychology **(ADD CITATION)**. Design is increasingly relevant to algorithms, and more specifically to algorithms that affect user experience and user interfaces. ***When the design is concerned with the ethical, environmental, socioeconomic, resource-saving, and participatory aspects of human-machine interactions and aims to affect technology in a more human direction, it can hope to create an experience designed for sustainability.***

Lorenzo, Lorenzo & Lorenzo (2015) underlines the role of design beyond *designing* as a tool for envisioning; in her words, *"design can set agendas and not necessarily be in service, but be used to find ways to explore our world and how we want it to be".* Practitioners of Participatory Design (PD) have for decades advocated for designers to become more activist through ***action research***. This means to influencing outcomes, not only being a passive observer of phenomena as a researcher, or only focusing on usability as a designer, without taking into account the wider context.

Shenoi (2018) argues inviting domain expertise into the discussion while having a sustainable design process enables designers to design for experiences where they are not a domain expert; this applies to highly technical fields, such as medicine, education, governance, and in our case here - finance and sustainability -, while building respectful dialogue through participatory design. After many years of political outcry (ADD CITATION), social media platforms such Facebook and Twitter have begun to shed more light on how these algorithms work, in some cases releasing the source code (Nick Clegg (2023); Twitter (2023)).

AI systems may make use of several algorithms within one larger model. It follows that AI Explainability requires ***Algorithmic Transparency***.

The content on the platform can be more important than the interface. Applications with a similar UI depend on the community as well as the content and how the content is shown to the user.

Transitioning to Complexity

AIs are non-deterministic, which requires a new set of consideration when designing AI.

Being Responsible, Explainable, and Safe

The problems of opaqueness creates the field of explainable AI.

"As humans we tend to fear what we don't understand" is a common sentiment which has been confirmed psychology (Allport, 1979). Current AI-models are opaque '*black boxes*', where it's difficult to pin-point exactly why a certain decision was made or how a certain expression was reached, not unlike inside the human brain. This line of thought leads me to the idea of ***AI psychologists,*** who might figure out the ***thought patterns*** inside the model. Research in AI-explainability (XAI in literature) is on the lookout for ways to create more ***transparency and credibility*** in AI systems, which could lead to building trust in AI systems and would form the foundations for ***AI acceptance***.

Red-teaming means pushing the limits of LLMs, trying to get them to produce outputs that are racist, false, or otherwise unhelpful.

There's an increasing number of tools for LLM evaluation:

- "Evaluate and Track LLM Applications, Explainability for Neural Networks" (TruEra, 2023; Leino et al., 2018)
- "evaluate your Retrieval Augmented Generation (RAG) pipelines, Metrics-Driven Development" Ragas (2023)
- LangSmith "developer platform for every step of the LLM-powered application lifecycle, whether you're building with LangChain or not. Debug, collaborate, test, and monitor your LLM applications." LangChain (2024)
- Tristan Greene (2022): when the quality of AI responses becomes good enough, people begin to get confused.