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從消費者到投資者的旅程：
設計適合年輕人的金融 AI 助手，推動可持續購物、儲蓄與投資

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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1 ABSTRACT

Taiwanese college students are concerned with environmental issues, yet they are hindered by the attitude-behaviour gap and lack simple tools to affect systemic change. At the same time, 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 decision, and finally post-purchase recycling, facilitates building *transparency* into opaque global supply chains. *Data-driven interaction design*, *large-language models*, and *artificial intelligence assistants* 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 2025, 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. By democratizing financial markets, young adults can gain greater access and influence over where their money goes, enabling them to support sustainable and environmentally responsible companies.

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 900 students across 20 universities in Taiwan was conducted, enhanced by 6 expert interviews providing industry insights. The major contribution of the study is an interactive AI-assistant prototype.

Keywords: Human-AI Interaction, Digital Sustainability, Transparency

2 摘要

台灣的年輕人，特別是大學生，關注環境問題，但因缺乏簡單的工具來影響系統性改變而受阻。同時，歐盟加強的環保政策引入了「數字產品護照」的概念，旨在區分由努力實現零廢棄的「循環經濟」公司製造的「生態設計」產品，與僅從事「漂綠」的公司。從原料開始追蹤產品數據，直到消費者的購買決策，最後到購後的回收，促進在不透明的全球供應鏈中建立透明度。「數據驅動的互動設計」、「大型語言模型」和「人工智慧助理」將複雜的環境數據轉換成人類可理解的語言。

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（如清潔的水、空氣、土壤）、氣候危機和人類健康之間存在著深刻的相互聯繫。截至 2024 年，由於生產我們日常購買的許多產品和服務的公司進行的開採性商業行為，地球的自然環境正被嚴重破壞。我們用金錢與公司互動的方式——作為消費者的購物和作為投資者的儲蓄/投資——對我們賴以維持地球宜居性的生命支持生物圈產生影響。從生態學角度來看，每一個財務行動不是支持更環保公司的投資決策，就是支持污染者。透過民主化金融市場，年輕人可以獲得更大的權限和影響力，控制他們的資金流向，使他們能夠支持可持續和對環境負責的公司。

我的研究針對了需要工具來使可持續的財務行動更便捷的需求，特別關注大學生。我利用設計研究來尋找簡單的基於 AI 的使用者介面的設計概念，也稱為生成式 UI，以幫助年輕人參與可持續的財務行動主義。在台灣 10 所大學進行了涵蓋 700 名學生的調查，並透過 5 次專家訪談提供行業見解。研究的主要貢獻是一個互動式 AI 助理原型。

關鍵詞：人機互動、數字可持續性、透明度

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3 ACKNOWLEDGMENTS

Thank you mom. Aitäh.

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4 LIST OF SYMBOLS AND ABBREVIATIONS

Some of the key terminology used in my thesis presented in a concise format.

- AI - Artificial intelligence, a field of computer science and an umbrella term focused on a wide range of approaches to automation
- UX - User experience, a field of study and operational approach focused on how humans experience using systems
- AX - Algorithmic experience, a proposed category of user experience, that is focused on interfaces between AI algorithms and humans
- UI - User interface, such as in a mobile app, however increasingly audio, video, etc
- XAI - AI user experience, interaction design applied to AI concerned with how does a person or a group of people interact with the AI
- Fintech - Financial technology, the application of technology (usually AI), to classic financial services, such as payments
- ESG - Environmental, Social, and Corporate Governance, a new set of metrics proposed by the European Union, and adopted worldwide, to assess business and financial assets
- AI Assistant - software system providing the user with personalized suggestions based on machine learning algorithms
- Financial Advisor - a human financial specialist providing customized financial advice, including investment advice and services to a client
- ML - Machine learning, a tool within the larger AI umbrella to enable computers to learn from large sets of data, which may be labeled (by humans) or un-labeled (auto-labeled)
- HCI - Human-computer interaction, a field of study to improve human experience with information technology
- OEM - Original equipment manufacturer, a company making products for another company that markets and sells such products under their own brand
- API - Application Programming Interface, a method for software agents to exchange information in various forms of data: the basis for contemporary online services
- EPR - Extended Producer Responsibility
- SDGs - Sustainable Development Goals, a set of targets agreed upon by the nations of the world
- LLM - Large Language Models
- Vector Databases - specialized data storage for mathematical language embeddings in multi-dimensional space helpful for clustering similar concepts
- CO₂e - CO₂ equivalent greenhouse gases
- GHG - Greenhouse gases
- PD - Participatory Design

- VCM - Voluntary Carbon Markets
- Hedge Fund - pooled investment fund
- DAO - Decentralized Autonomous Organization
- Zero Waste - according to Zero Waste International Alliance: “conservation of all resources by means of responsible production, consumption, reuse and recovery of products, packaging and materials without burning, and with no discharges to land, water or air that threaten the environment or human health” (Kalle et al., 2022)
- ESRP - Ecodesign for Sustainable Products Regulation
- NFRD - Non-Financial Reporting Directive
- CSRD - Corporate Sustainability Reporting Directive
- EUDR - European Union Deforestation Regulation
- Product Stewardship
- Extended Producer Responsibility

5 INTRODUCTION

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

Does Individual Climate Action Matter?

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.

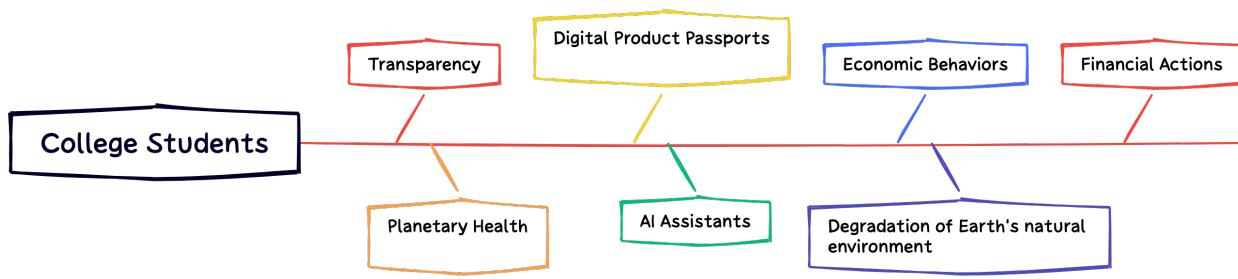


Figure 1: College Students

5.1 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

5.2 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.

5.3 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.

5.4 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.

5.5 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

5.6 Research Questions

My research answers the following questions.

Table 4: RQs.

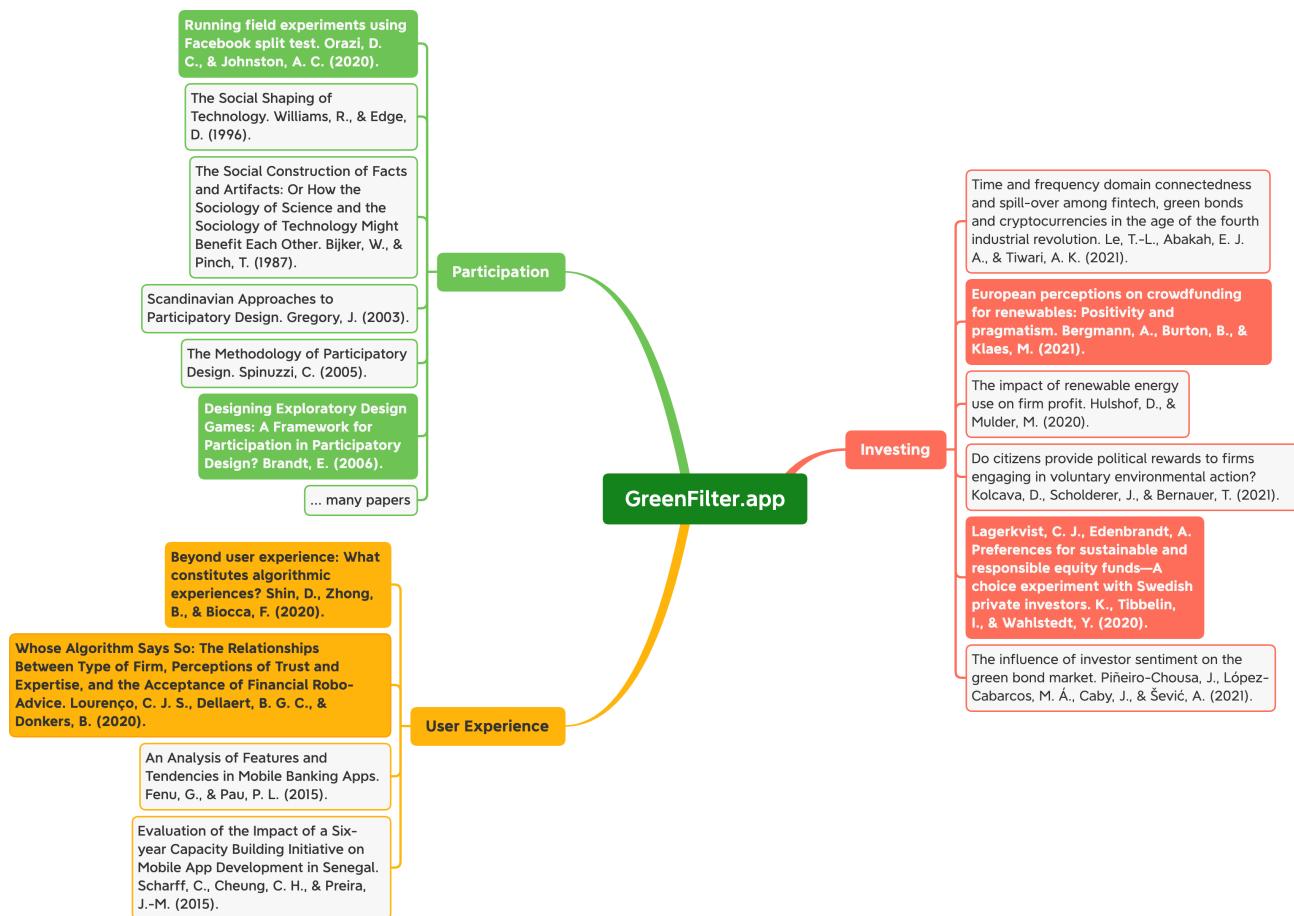
Question	Methods
What design considerations should be addressed when designing an AI companion for college students integrating sustainability and finance?	Literature Review
How can AI companions support college students with sustainability knowledge in the context of financial decisions?	Literature Review and Expert Interviews
What AI companion features do college students prioritize as the highest?	Survey of College Students

5.7 Literature Review

5.7.1 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 provides *design implications* which are shown in the results section.

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.



Presented with **xmind**

Figure 3: Example papers from the Literature Review

5.7.2 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.

5.7.3 AI Usage in Research

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

- search
- data comparison
- data science
- chart-building
- translation
- feedback

AI was *NOT* used for writing.

6 YOUNG ADULTS AND COLLEGE STUDENTS

6.1 Student Protests for Climate Justice: Around the World and In Taiwan

In August 2018, Swedish high-school student Greta Thunberg skipped class to start a climate justice strike in front of the Swedish parliament Riksdag. In 2019, Time magazine named Thunberg person of the year for *creating a global attitudinal shift* towards the environment (Deutsche Welle, 2019). According to official statistics, 14 million participants joined her *Fridays for Future* strikes and the movement expanded to over 7,500 cities around the world (Fridays For Future, 2025). A survey 64 climate protesters from Norway, the UK, USA, and Canada, found the climate-justice activists are non-homogeneous group, displaying differing levels of factual knowledge about climate change, a broad spectrum of emotions from anger to guilt and hope, with diverse lifestyles, consumption habits, dietary shifts, and political leanings (Martiskainen et al., 2020).



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

In Indonesia, which had large protests at the time, now 7 years later activists are expressing disillusionment and frustration with the lack of progress and upholding environmental promises. (Dwi Tamara, 2025) reports on a survey of 382 Gen-Z respondents in 5 areas of Jakarta, with 99.5% of the respondents having experienced extreme weather events first-hand, highlighting how respondents were affected by climate-related calamities, such as frequent flooding, which led to students missing school days, - education which they are entitled to. The Sharm El Sheikh climate policy implementation (UNFCCC, 2023b) text refers to “human right to a clean, healthy and sustainable environment”. In Portugal, Estonia, and elsewhere young people have moved on from strikes to actually taking legal action at the courts suing companies for the environmental problems they have caused (Flor, 2024).

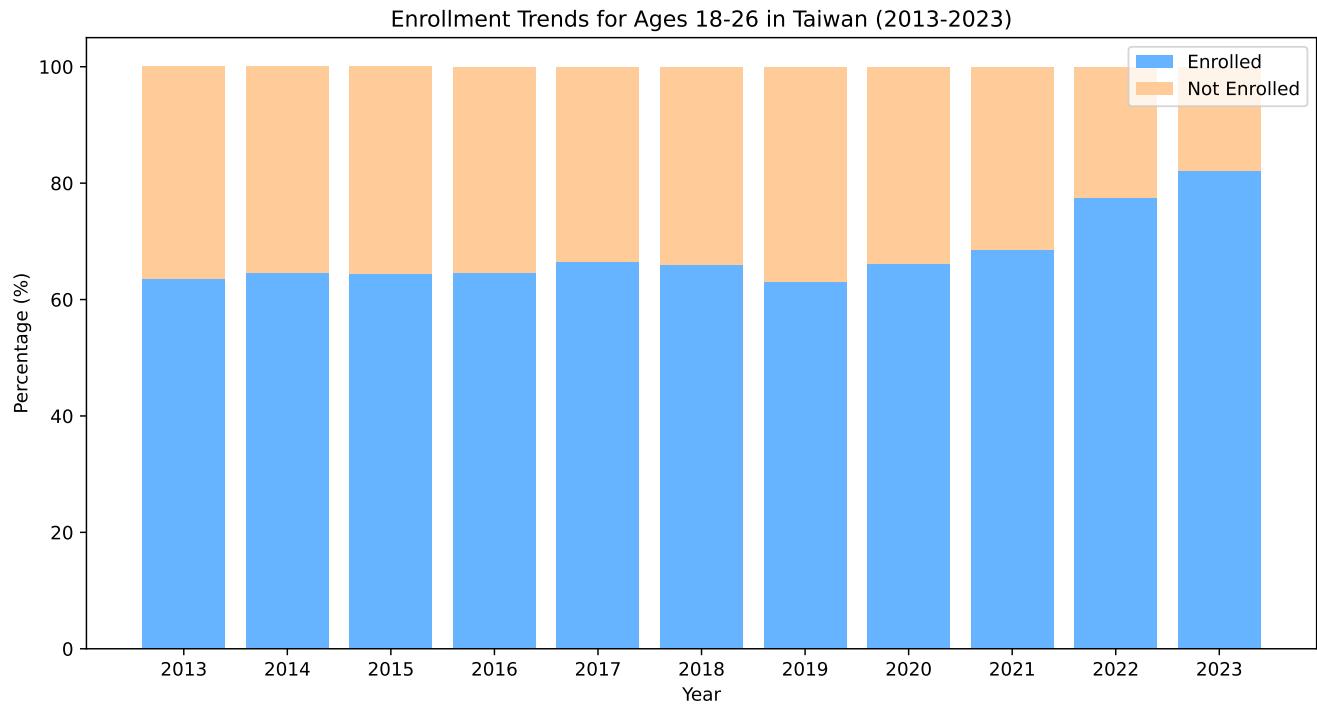


Figure 5: Climate protest in Taipei in May 2019 in front of the Democratic Progressive Party (DPP) headquarters

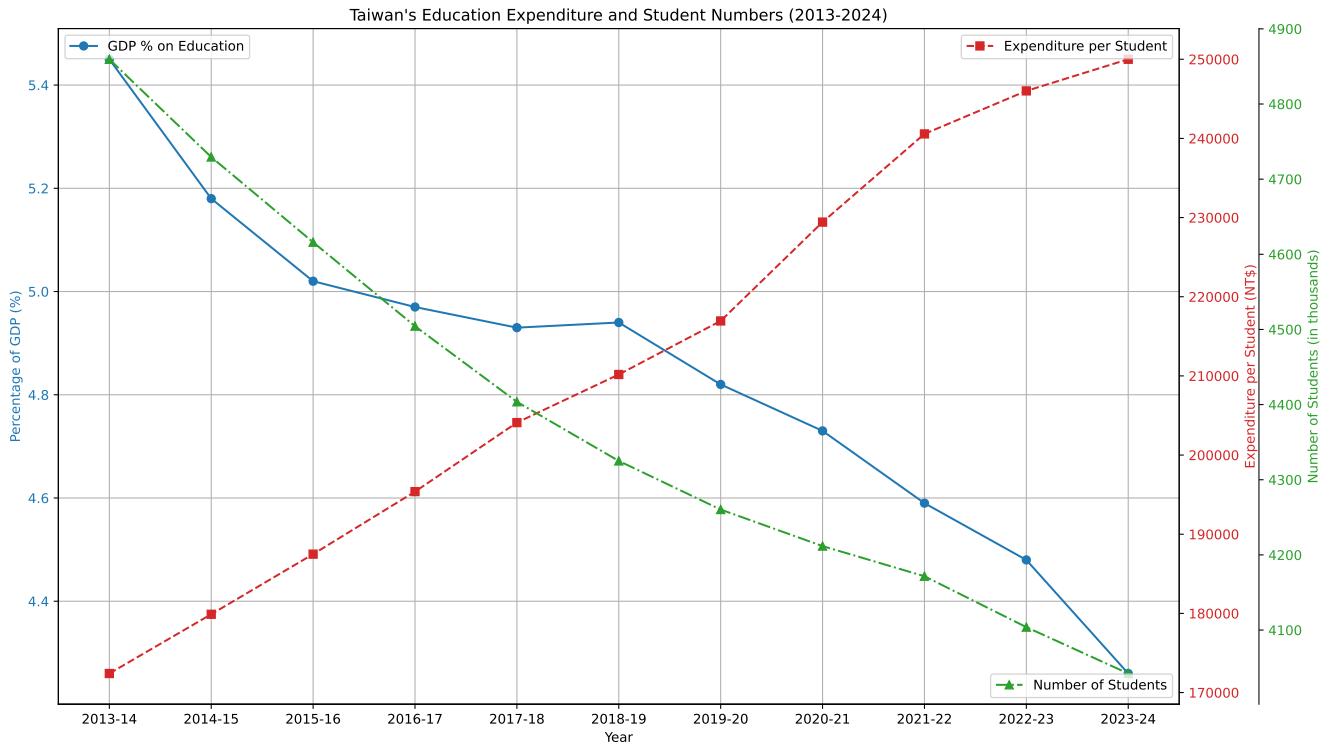
Meanwhile, as the climate-justice protests unfolded around the world, in Taiwan, the Fridays for Future protests were very small in scale, with no more than 100-200 people (Hioe, 2019). Meanwhile 2000 Taiwanese students joined the initiative by participating in environmental activities without protesting (Dai, 2019). This could in part be explained by Taiwanese culture being deeply influenced by Confucianism, valuing stability, hierarchical relationships, academic excellence, effort, and the role of education in achieving social status (R.-H. Xu, 2024). (H.-C. Chang, 2022) goes a step further to say that Taiwanese youth are effectively unable to stage formal “strikes” due to intersecting cultural constraints: obsession with academic performance, low awareness of legal strike rights, and parental intervention — so they instead reframe actions as campus “climate actions,” exercising agency within those limits. In addition, both Confucianism and Daoism, the prevalent belief systems in Taiwan, 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 (C.-C. Chang et al., 2023).

6.2 Taiwanese Educational System in Numbers

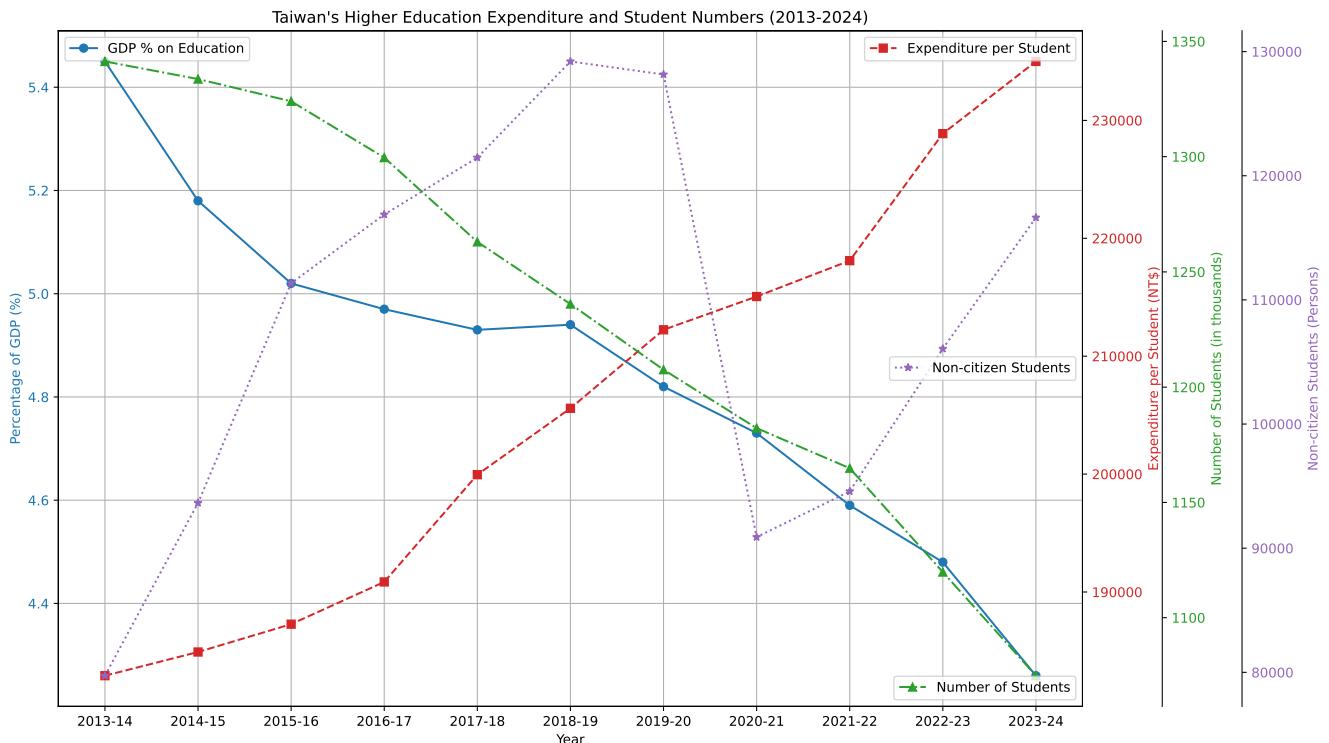
Taiwan has approximately 2 million young adults (Gen-Z, 18-26), and 73% percent of them are students attending tertiary education as of 2023, with a slow increase of enrollment over the past decade (Ministry of Education of Taiwan, 2024b).



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 (Davidson & Chi-hui, 2024; Goh et al., 2023).



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



6.3 Designing for College Students: Developing Personas

Students in the Generation-Z age bracket (abbreviated as Gen-Z or Zoomers) are born between 1997 and 2012 (Branka Vuleta, 2023). High levels of technology adoption worldwide (Deyan Georgiev, 2023a). Over 98% of Gen-Z owns a smartphone while only 80% of the general world population does (BankMyCell, 2022; Global Web Index, 2017).

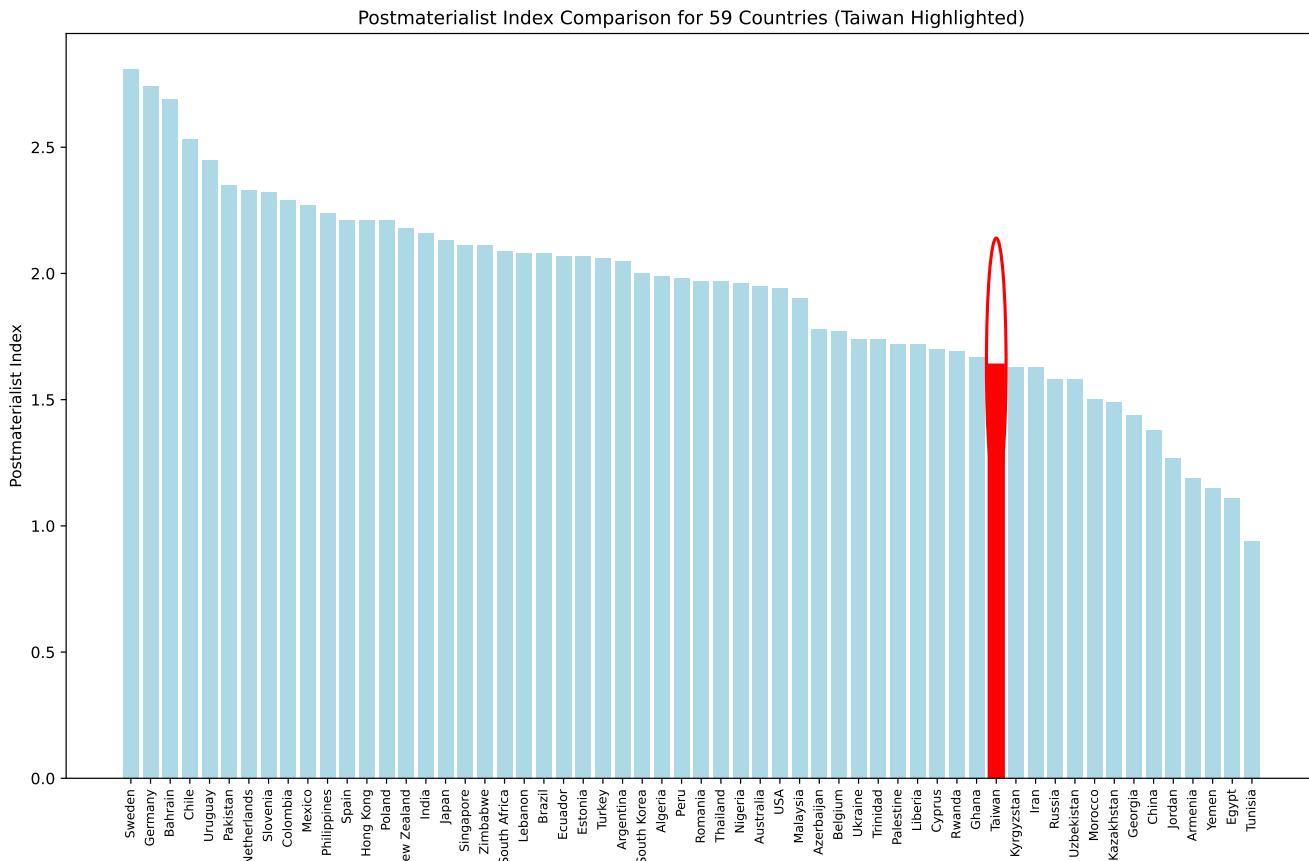
Designing for College Students: Developing Personas. User research makes extensive use of user *personas* to represent a group of people with similar attributes. Designers use personas to *articulate assumptions*, which, if used well, is useful for *user-centered design*, to create better products. Personas 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. Humans have a long list of cognitive biases, which a good design should take into account.

Many general observations can be made, however to create meaningful personas, these should be backed up with data. Students ride bicycles and scooters. Many circular economy service such as YouBike and transport sharing platforms like Uber are available in Taiwan. Many students live in dorms and shared housing, meaning their impact per square meter is low.

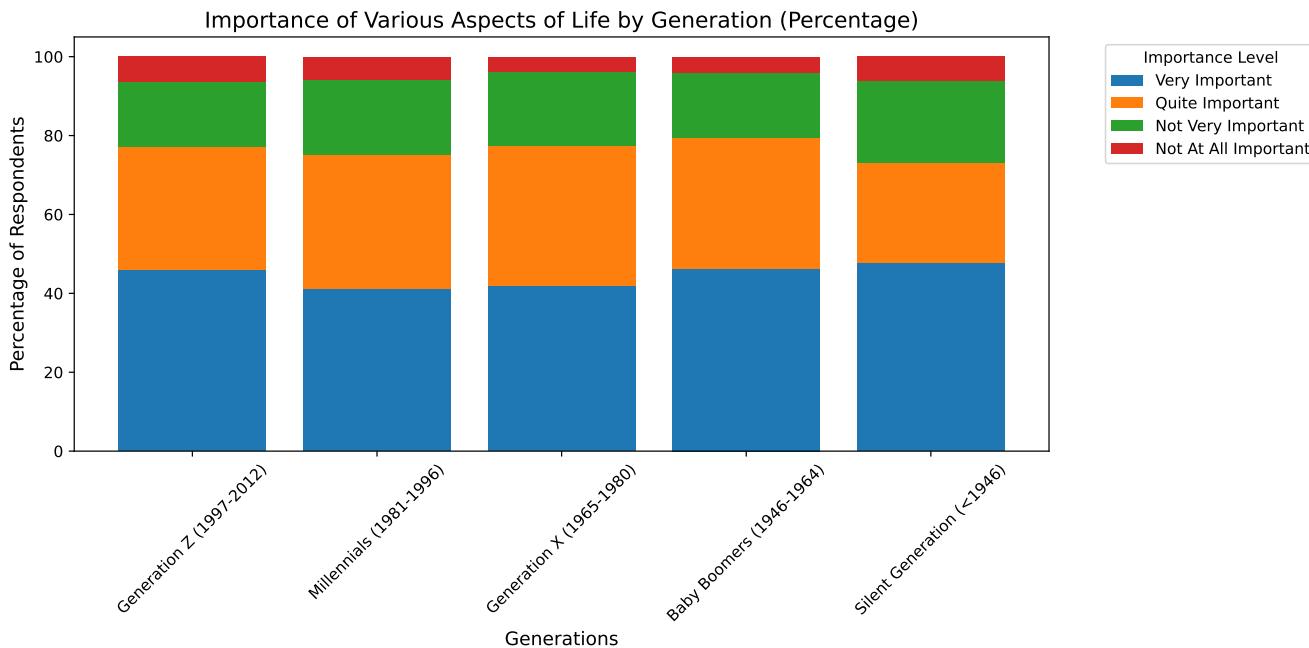
6.4 Taiwanese Youth in the Global Context: Attitudes Towards Sustainability From Eco-Friendly Diet to Climate Action

Addressing the Research Gap When it Comes to Taiwanese College Students. There's lack of scientific research when it comes to Taiwanese college students, not only in English or other foreign languages, but also in Chinese. Much of the research in Taiwan focuses on younger students, particularly those in primary and secondary schools. With regards to issues related to college students and sustainability, even less research is available. My project hopes to shed some light to how Taiwanese college students relate to sustainability.

(Kuo-Hua Chen, 2019) compares Taiwan to other countries in terms of Postmaterialist Index Comparison, noting Taiwanese society is materialistic.



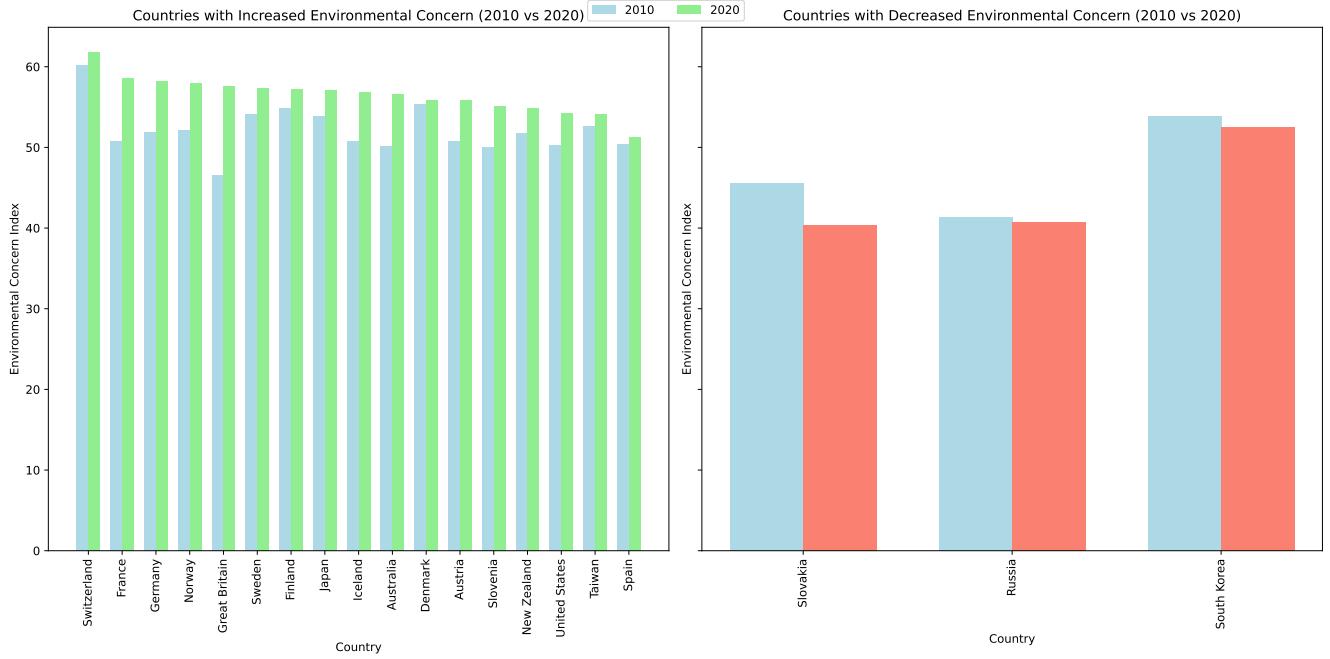
World Values Survey



(Franzen & Bahr, 2024) measures “*mean environmental concern*” to look at decade-level changes in societal

environmental attitudes across countries. Taiwan's general attitudes have stayed almost the same (slight increase). The UK has had the largest jump in concern. Curiously, South Korea has had a slight decrease in concern. Slovakia and Russia were not very concerned with the environment a decade ago and are even less concerned now.

A large-scale global study by (Anthony Leiserowitz et al., 2022) administered 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".



The largest study to date, conducted by the United Nations across 50 countries, surveying 1.2 million people, distributed through mobile game ads, showed the majority of people agreeing climate change is an "emergency" (UNDP, 2021).

Table 5: 1.2 million UN survey responses to the statement "Climate change is an emergency".

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

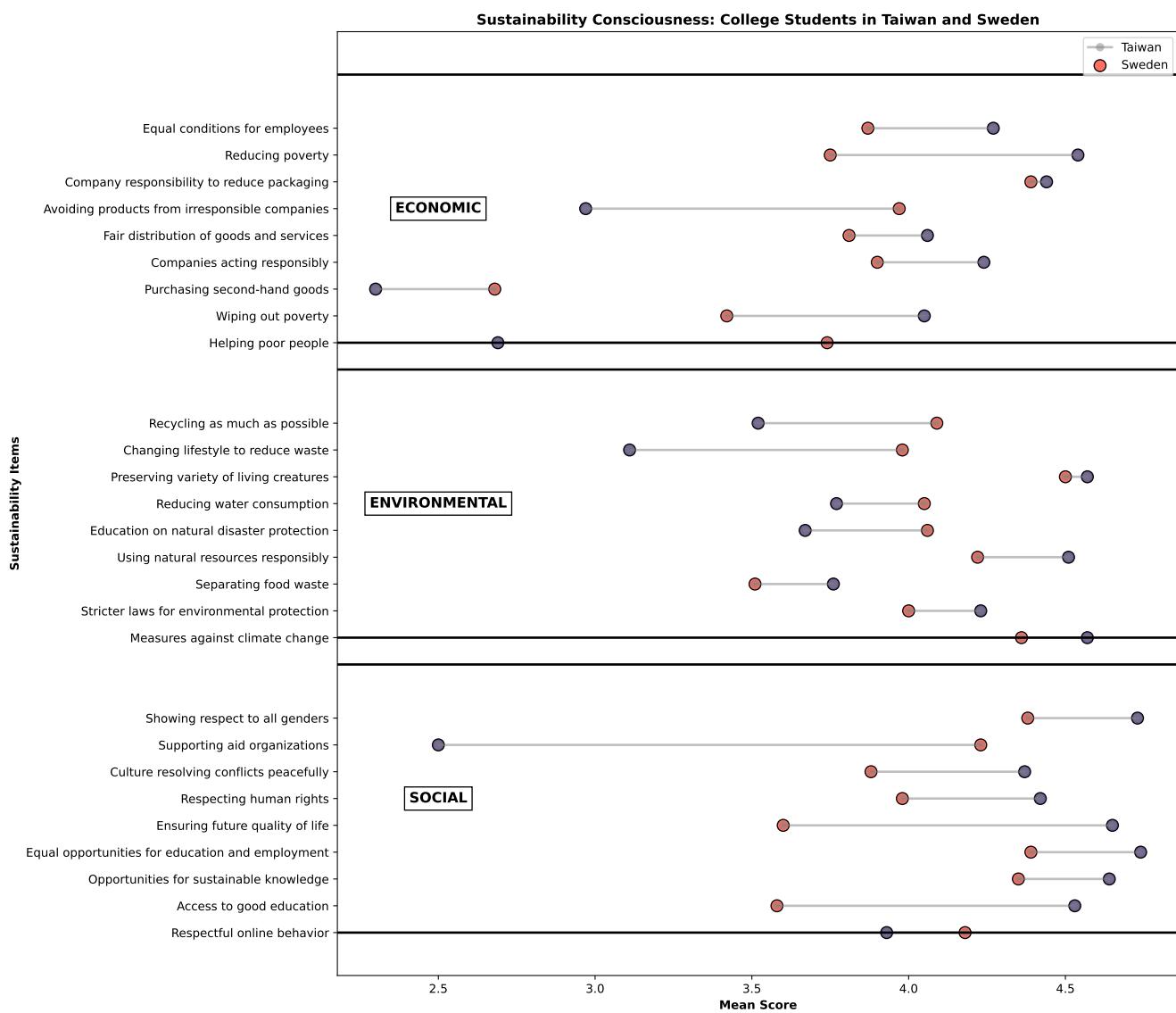
At the pre-university level, Taiwanese government has been promoting environmental education through a green school network; however surveys at middle school and high school level suggest there is no impact on *sustainability consciousness* among students in comparison with regular schools (Olsson et al., 2019). Rather, Taiwanese students are influenced towards environmental action by *group consciousness* (T.-Y. Yu et al., 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). (林建輝., 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 & Pan, 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, (C.-L. Chen & Tsai, 2016) reports a *positive attitude yet moderate knowledge* about *ocean sustainability* among Taiwanese college students (n=825). (C.-H. Liu et al., 2023) 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 (林美惠. & 莊, 2015). Taiwanese government has also launched funding for University Social Responsibility (USR) programs to train college students in social innovation and local revitalization (D. Chen & Chou, 2023; W.-H. Liu et al., 2022).

In general, it could concluded, Taiwanese students and teachers at all levels of education have a positive attitude towards sustainability, which is not a very actionable finding.

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).



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 (J. L. Hsu et al., 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*”.

Internationally, 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 Millennials 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”.

(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 (“How Gen Z

and Millennials Spend Their Money," 2023; The Economist, 2023). - (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. Meanwhile Gen-Z in the U.S. are heavy users of online fashion shopping, Chinese cheap online store Shein overtakes Amazon as the most downloaded shopping app, while clothes resale apps such as Depop and ThredUp grow in popularity (Alex Reice, 2021).

(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.

6.5 The Experience of Climate Change and Pollution Levels in Taiwan

Taiwan's recent climate challenges with over 4 decades of droughts, rising air temperatures, and shifting rainfall patterns, have impacted both water security and the performance of its vital semiconductor manufacturing industry (Vo & Liou, 2024). Offshore, marine heatwaves, ocean acidification, and elevated sea surface temperatures are intensifying coral bleaching around Taiwan (P.-C. Hsu et al., 2024). The oceans are crucial for Taiwan to capture carbon emissions. 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).

Similarly to how Northern Europe, including Estonia, is affected by the Gulf Stream, making the climate warmer, Taiwan is affected by the Kuroshio (黑潮) warm current of the Pacific Ocean, which helps regulate the climate and marine ecosystem of the region. The strength and trajectory of the Kuroshio is influenced by 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 (Belonenko et al., 2023; J.-Y. Lin et al., 2022; Sheng Liu et al., 2024; Mensah et al., 2014; Shen et al., 2014; US Department of Commerce, n.d.; Yuqi Yin et al., 2019). Going back on a larger time scale, biomarkers in the sediment core around Taiwan are being used to study variations in climate over past thousands of years (Yueqi Wang et al., 2021).

In addition to climate extremes, 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/m³), Tainan (20.9 µg/m³), and Pingtong (20.7 µg/m³) (Chang Hsiung-feng et al., 2024).

There have been concerns about food safety in Taiwan, with prominent cases reported in the media and documented in academic literature, where organic toxins and chemical pollution have entered the food system (I. Lee, 2024; J.-H. Li & Ko, 2012; J. Yang et al., 2013).

A recent study demonstrate extreme industrial pollution in numerous sites at the Hsinchu's Xiang Shan wetland (香山濕地) in Northern Taiwan, yet considers ecological risk threat to nature and wildlife to be "moderate" (Salah-Tantawy et al., 2025). In contrast, (李桂媚, 2022) reports Taiwan's semiconductor industry employs undisclosed toxic chemicals under trade-secret claims, which have not undergone comprehensive health and environmental risk assessments. Previously, (Y.-H. Liu et al., 2021) reported sediment

analyses at the Xiang Shan wetland found levels of gallium (Ga) ranging from 9,460 to 23,450 µg/kg (severe contamination) and indium (In) from 4.77 to 37.1 µg/kg (moderate contamination), amounts which are above natural baselines, indicating industrial chemical runoff. Earlier studies of semiconductor wastewater from waterways downstream of the Hsinchu Science Park (which houses over 450 companies' manufacturing facilities) have shown high amounts of at least 14 heavy metals, with levels of tungsten reaching 400 g/L in contrast to the average river concentration of <0.1 g/L (S.-C. Hsu et al., 2011). The oldest study considered here also found high levels of arsenic pollution in groundwater (H.-W. Chen, 2006). It's safe to say, in conclusion, the chemical runoff from manufacturing is a reality documented by several studies, however the negative health effects have not yet been clearly established - and studies of other, less prominent industrial areas of Taiwan, are severely lacking.

The table below illustrates the types of emissions and environmental impacts large corporations in Taiwan produce. It should be noted, some of the corporations do buy carbon credits to offset their local adverse impact; for instance, 台積電 TSCM has purchased carbon credits, renewable energy, invested in the Taiwan Carbon Exchange to support greener companies, and joined international reporting initiatives, such as the Task Force on Climaterelated Financial Disclosures (TCFD) and Taskforce on Nature-related Financial Disclosures (TNFD) [tsmcQiHouJiZiRan2023].

Table 6: Examples of large industrial polluters in Taiwan as reported in academic papers and the media.

Company	2023 Mt CO _e	Notable Problems	Data Source
台電 Taipower	93.33	A single power plant in Taichung produces 26 Mt CO _e	今周刊 (2024)
台塑化 (台塑集團) Formosa Petrochemical	24.23	16 cases of fires and explosions between 2010 and 2020	歐宇祥 (2024)
中鋼 China Steel	18.07	60% of the CO _e emissions come from 1 steel mill in Kaohsiung	蕭婷方 (2021); 環境資訊中心記者 (2022)
台積電 TSMC	11.42	Extreme water consumption used 82.82 Mt of water in 2022, straining local reservoirs and requiring water-truck deliveries during droughts	今周刊 (2024); “上市公司用水量之冠不是台積電 它用水比台積電多 20 幾倍” (2022); 中央社 (2021); TSCM (2019)
台灣中油 CPC	N/A	From 2019 to 2023 paid government air pollution penalties 146 times; there were 4 fire incidents as well as 3 odor leakages in 2022	綠色公民行動聯盟 (2022); 2022 年空、水污裁罰金榜首 中油、工業局連莊 (2023)

Company	2023 Mt CO ₂ e	Notable Problems	Data Source
亞泥 Asia Cement (花蓮 新城山礦場)	N/A	In 2023 a single mining operation in Hualian was responsible for 4.14 Mt of raw limestone extracted (assumed to have a very high emissions potential) however no CO ₂ figure is reported by the company	Asia Cement Corporation (2023)
可口可樂 Coca-Cola (TW)	N/A	2024 brand audit in river pollution found 7.6 % (n=28481) of PET plastic bottles were from Coca-Cola	Greenpeace 綠色和平 (2024)

6.6 Climate Anxiety and How to Respond

A growing body of research shows climate anxiety is widespread among young people, which emotionally can both hinder and motivate sustainable action. A large worldwide study in (n=10000, age 16-25) by (Hickman et al., 2021) provides evidence the youth is anxious about climate in 10 countries: 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). (Seabrook, 2020) suggests music therapy is useful in the era of climate crisis, evolving to meet current needs of young people. (Kjaergard et al., 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”.

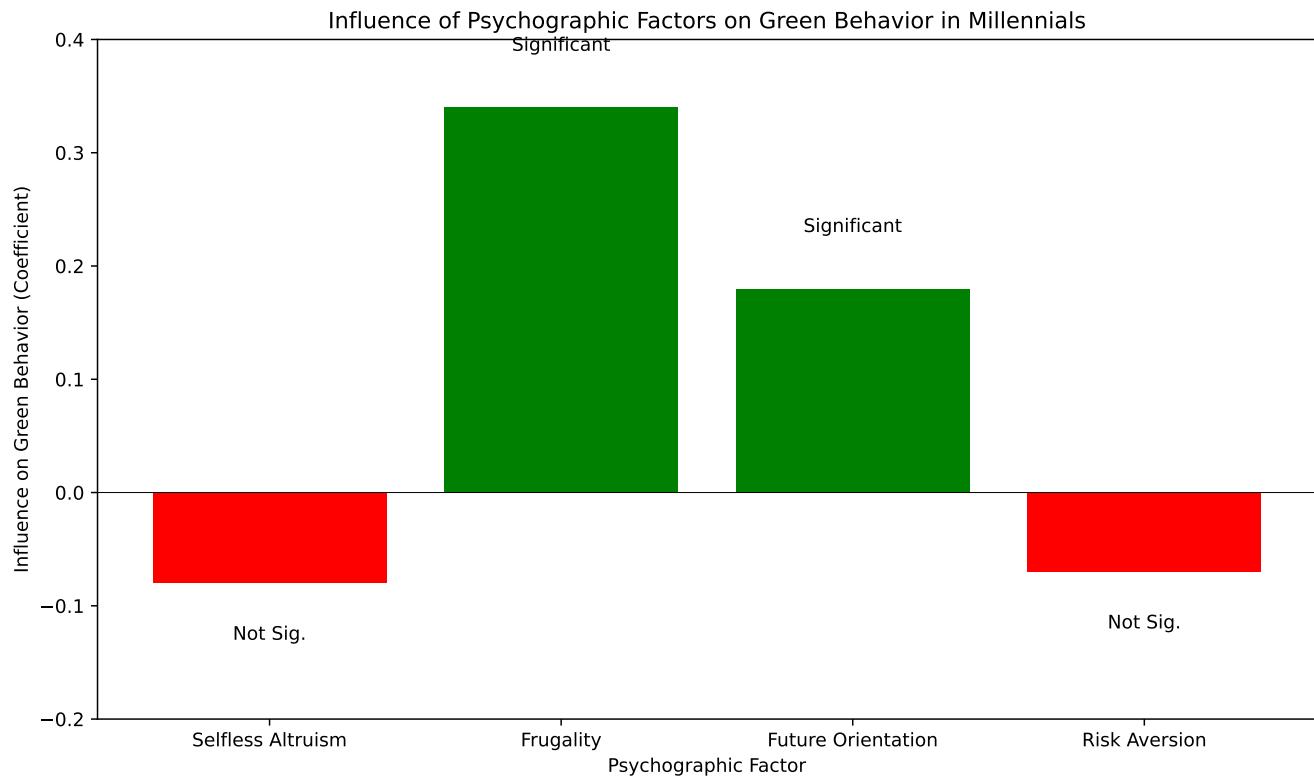
A recent special issue of Behavioral Sciences magazine on Behavioral Science for Climate Change (2025) provides further evidence. A review of 50 studies supports the idea that climate activism shifts public opinion towards climate concern (Thomas-Walters et al., 2025). Climate change negative affect brain health through heat, air pollution, extreme weather; the study finds links to neurological, psychiatric, and cognitive disorders (Todorova et al., 2025).

When disaster hits we need high levels of *social trust*. Being part of community of trust makes it easier to act in unison. Religion is a type of community of trust. Conversely, that can also have negative effects,

as in Taiwan the expected behaviour of burning joss sticks and paper money, is a cause of air pollution (C. Tang & Pan, 2014)

- Designing for Health and Sustainability and Design for Human Rights: Health and sustainability are intrinsically connected.

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



6.7 The Attitude-Behavior Gap

While people express eco-conscious ideas, it's non-trivial to practice sustainability in daily life. Translating eco-conscious attitudes into concrete sustainable actions remains challenging. Empirical evidence illustrates this gap between intention and behavior. (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).

However, changing habits is important if technology alone is not the solution. (Deyan Georgiev, 2023b) reports only 30% of people in the Gen-Z age group believe technology can resolve all environmental problems. Even with good intentions, (Munro et al., 2023) finds shoppers who try to shop sustainably often fail to find sustainable product, in a systematic literature review of 64 papers from South Korea, Australia, the UK, the US, and elsewhere.

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

Willingness to pay research.

6.8 Sustainability Tools in the Taiwanese Context, Digital Sustainability: Taiwan's Digital Receipt System

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; P.-L. Tsai, 1999). By the early 1990s another less flattering nickname appeared: “garbage island”, for the piles of trash covering the streets and overflowing landfills (Ngo, 2020; Rapid Transitions Alliance, 2019). 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 (Bui et al., 2023; C.-Y. Wu et al., 2021).

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.

“獨家觀察－電子發票年減碳量 相當 2,700 座大安森林公園” (2025) reports 54.03% of invoices in Taiwan are digital. Since 2021 digital receipts are mandatory for all businesses. Taiwan's longstanding receipt lottery also has specific prizes available only for digital receipts. 行動支付結合雲端發票 節能減碳最環保 / 經理人 (2018)

Several other countries, such as Singapore, South Korea, Japan, Sweden, Italy, Portugal, Brazil, Mexico, have comparable systems in use.

6.9 Trends in Taiwanese Companies from Industry to Online Shopping

KANTAR reports Taiwan's consumer spending on fast-moving consumer-goods (FMCG) grew over 5% in 2024, speeding up towards the end of the year: +2.5% in Q1, +4.1% in Q2, +5.7 % in Q3 and +9.1% in Q4, with e-commerce crossing the 20 % share mark (traditionally FMCG are purchased physical stores, as convenience stores are so readily available all over Taiwan). (foodNEXT, 2024; Kantar Worldpanel, 2024; 動腦 Brain.com.tw, 2024; 食力 foodNEXT, 2025).

Between 1970 and 2019 CO₂e was a prerequisite of economic growth in Taiwan (check this again) (T. Chang et al., 2023). Taiwan is a net CO₂e exporter since 1990s through emissions embedded in the industrial production oriented economy (Huang et al., 2020).

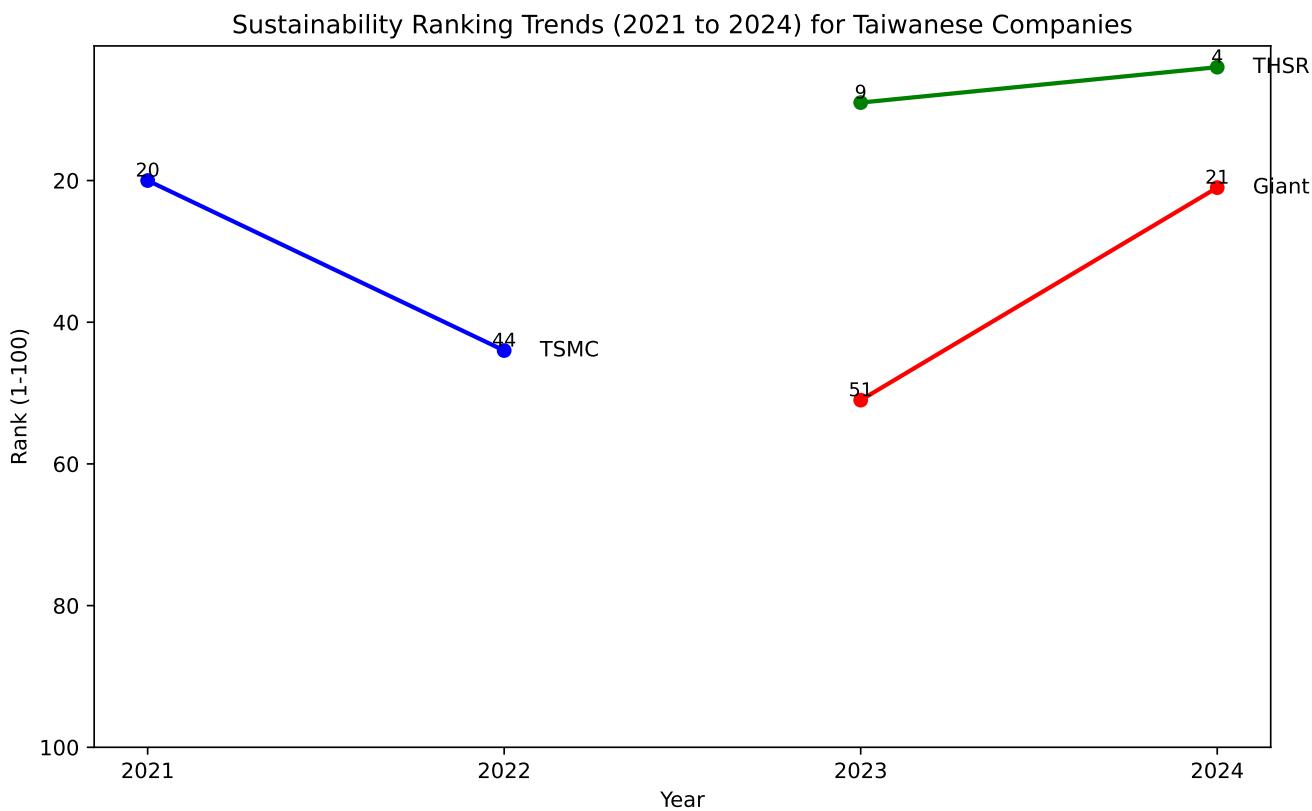
- “Taiwan's Financial Supervisory Commission's (FSC) requirements for Taiwan's corporates to disclose their carbon emissions starting in 2023,” Reformosatw (2024)

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

Table 7: Data from (Alana Semuels, 2024).

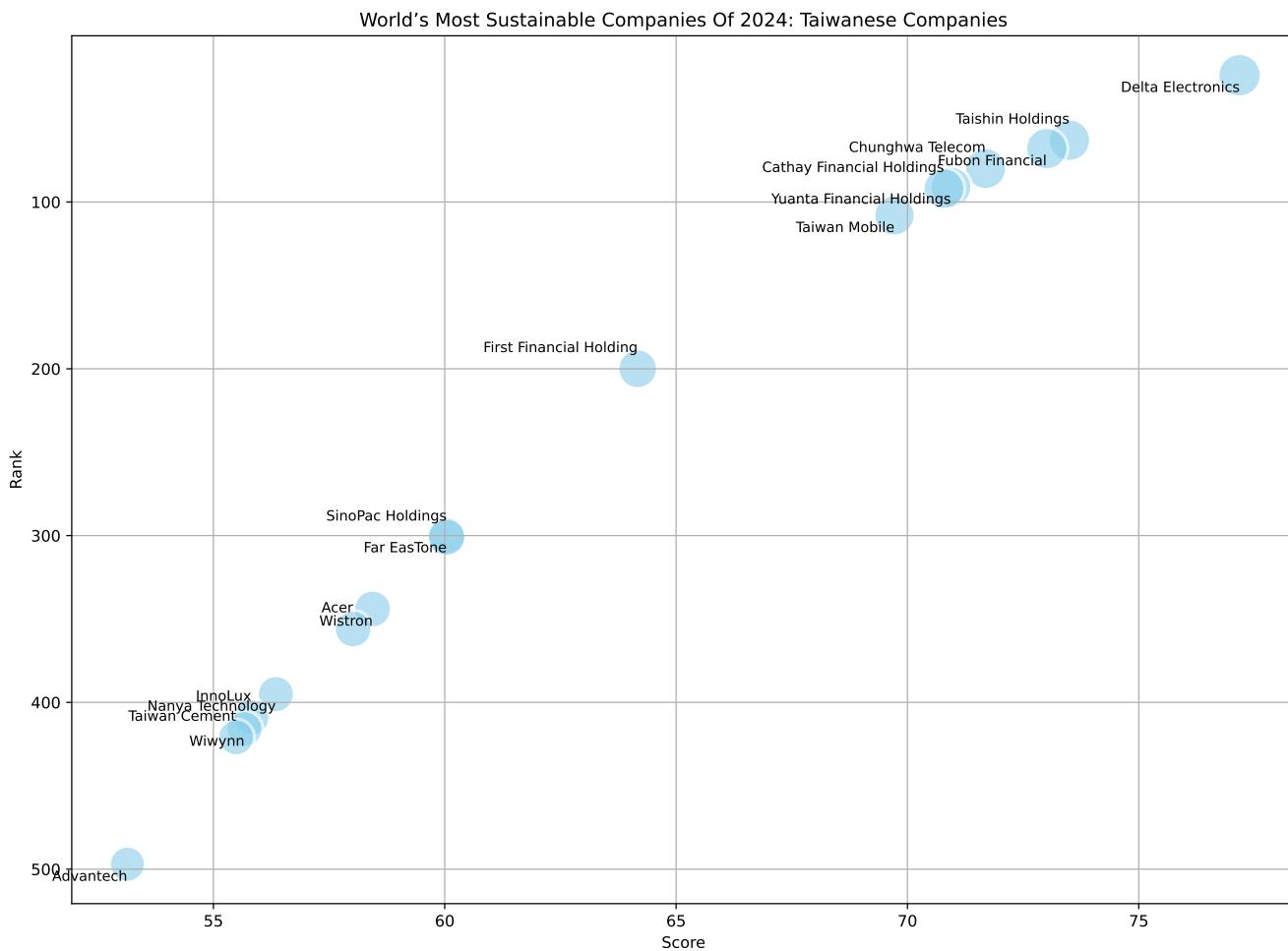
Sustainability Rank	Company	Score (Out of 100)
24	Delta Electronics	77.18
63	Taishin Holdings	73.50
68	Fubon Financial	73.01
80	Chunghwa Telecom	71.69
91	Yuanta Financial Holdings	70.94
92	Cathay Financial Holdings	70.79
108	Taiwan Mobile	69.72
200	First Financial Holding	64.17
300	Far EasTone	60.04
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)



Meanwhile, Marc Lien (2022) Four millions British SMEs have no plan for net-zero transition and Ware (2024) British workers lack skills for green transition. (2024 National Environmental Services Survey)

- In Online Shopping, (聯合新聞網, 2024 predicts Momo and Coupang will compete for Taiwanese market leadership).
- intensifying competition, Coupang stepping on Shopee's and MOMO's toes “順風婦產科 □□ □□ □□ (@Followwindlover) on Threads” (2024)
- Taiwanese environmental ministry is cracking down on illegal waste, with over 70 cases being prosecuted 環境部 (2025)



6.10 Financial Literacy Worldwide and Among Taiwanese Youth

A recent nationwide study ($n=1997$) titled Youth Financial Health Basics (青少年財務健康基礎大調查) jointly conducted by the Taipei Fubon Bank and the Parent-Child Innovation Center (親子天下教育創新中心) between February 11 and March 9, 2025 found that over 65% of secondary schools incorporated financial-literacy courses into their curricula however 64% of Taiwanese youths (aged 15–18) exhibit low confidence and understanding of financial products and face significant fraud risk, with nearly 1/5 of the respondents encountering a scam in the past year, while 18% suffered actual financial losses (江昭倫, 2025; 陳美君, n.d.).

Table 8: Compiled table of respondent account ownership, familiarity with financial products, and preferred payment methods, as reported in (陳美君, n.d.).

<u>Banking</u>	<u>% of Respondents</u>
Have at least one financial account	80%
<u>Familiarity</u>	<u>% Unfamiliar</u>
Savings accounts	70%
Mutual funds	63%

Banking	% of Respondents
Stocks	46%
Deposit accounts	30%
Payments	% Preference
Cash	47%
Family member pays	47%
EasyCard	4%
Mobile payments	1%

Importantly for designing a financial app, while 80% of the survey respondents had received financial education at school, 90% of the students deemed the primary learning channel about financial knowledge to be on social media; and only 15% remember to have learned about credit-card usage (江昭倫, 2025).

In a much older study, I-Cheng Yeh (2009) analyzed usage data from 30,000 credit-card clients at an undisclosed major Taiwanese bank to predict next-month defaults, using 6 data-mining techniques including ANNs (AI Neural Networks) (Yeh & Lien, 2009). Because of the age of the study there's no Gen-Z data. People aged 18–26 at the time would be Millennials or Gen-X by now. the data was donated by (Yeh, 2016) and roughly 1 in 5 credit card clients (22.1%) of the dataset defaulted on their payment in the next month. Among the 9,618 clients aged 18–29 at the time of the study, 2,197 defaulted on their next-month payment, yielding a default rate of 22.8%, slightly higher than the overall average. Meanwhile, among the 5,127 clients aged 18–26, 1,285 defaulted, yielding a rate of 25.1%, considerable higher than their older counterparts. Finally, among the 1,558 clients aged 18–23, 430 defaulted, a rate of 27.6%, pointing to a trend of younger people having higher default rates.

A over-the-phone study (n=3000) conducted in 2022, found Taiwanese savings habits to have polarized, with over 60% either having no savings whatsoever or saving more than 1/2 of their annual income; 27% of respondents reported total savings below NT\$40,000; young adults' (aged 20–29) were the only group whose financial risk worsened, with 43% of the respondents having extremely low financial literacy, described as 金融文盲 (near “financial illiterate”) (中央社, 2022).

Table 9: Financial literacy data from phone interviews, as reported in (中央社, 2022).

Financial Literacy Among Taiwanese (2020)	Very Low	Low	Medium	High
Overall financial literacy	43.2%	34.9%	19.4%	2.5%
Understanding products & services	34.0%	38.6%	23.1%	4.3%
Confidence using products & services	30.0%	26.8%	37.6%	5.6%
Seeking financial advice	71.0%	3.2%	17.8%	8.0%
Personal money management	21.8%	42.9%	28.4%	6.9%

The Taiwanese Financial Literacy & Education Association 財金智慧 FINLEA is a non-profit with a stated goal of enhancing financial literacy among Taiwanese. Their longitudinal study, with the latest survey conducted in 2022 (n=2014; 1055 high-school; 959 university) rated financial literacy among all youths 56.3 out of 100 (53.8 in 2016 and 56.7 in 2007), always below the benchmark score of 60, with high school and vocational students averaging 49.26 and university students somewhat higher averaged 64.03 score (網軟股份有限公司, n.d.).

Table 10: Latest report from the 財金智慧 FINLEA longitudinal study (網軟股份有限公司, n.d.).

Knowledge Gap (2022)	% Unaware
Unsure that employers must contribute to the labor pension (and individuals can voluntarily contribute)	68%
Unsure which deductions (income tax, labor insurance, health insurance) reduce take-home pay	66%
Unsure how education level affects starting salary	61%
Unaware of methods to lower loan interest rates	59%
Cannot identify which auto insurance covers vehicle damage	55%
Unable to judge which life-insurance need is greatest	51%
Uncertain how to choose investment tools for maximum lifetime returns	63%
Unaware that business tax makes purchases more expensive	61%

財金智慧 FINLEA does publish online videos targeted at young people, however as of early 2025, they only have around 1000 subscribers on YouTube (財金智慧 FINLEA, 2020). Meanwhile the Taiwanese cryptocurrency influencer Mr Block has over 100000 YouTube subscribers (mrblock 區塊先生, 2025).

【JUST MONEY】系列 ► Play all

【JUST MONEY】系列影片，透過 FINLEA 專業講師—瑞瑞老師與宜家同學之間的互動對話及親身經驗分享，傳遞賺錢、存錢、花錢、信用、保險、投資及助人等理財觀念。更多資訊請關注：FINLEA...



【理查頭殼】系列動畫 ► Play all

FINLEA 財金智慧教育推廣協會推出【理財Talk・理查頭殼】理財頻道，跟著「理查」學「理財」，隨著動畫主角的對話「Talk」建立你的FQ「頭殼」，現在立刻跟著理查累積你的財務自由兌換券！...



Figure 6: 財金智慧 FINLEA YouTube Channel

Internationally, 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 11: From millennial investors (Calastone, 2020).

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

6.11 Social Media Usage, Trends, Memes, Media Currents, and Youth Empowerment

The term “meme,” first coined by Richard Dawkins in 1976 in his book “The Selfish Gene” to describe units of cultural evolution, analogous to that of biological evolution, which may evolve by natural selection, and now encompasses internet artifacts and even stocks. Beyond mere entertainment, memes have emerged as an academic discipline, where memes are sampled, coded, and analysed from cultural and ethical viewpoints, among others (Zidani & Miltner, 2022). (Peters-Lazaro et al., 2020) argues memes are no merely jokes but tools for communal critique and collective visioning. suggesting that Taiwanese Gen-Z memes scaffold deeper conversations about consumerism, climate action, and social change. Memes from daily life, business to war, are relevant to penetrating through the noise of the web.

In Taiwan, homegrown memes may start with global templates but quickly take on a local flavor. (劉芸嘉, 2024)'s 2021 study of 150 Taiwanese memes written in Mandarin shows most rely on friendly and indirect humor: inside jokes and wordplay that bond peers together. (朱映潔 (Ying-Chieh Chu), 2021) surveyed 737 Taiwanese Facebook users and discovered that a meme's funniness, shareability, and shock value “hellish gags” (地獄梗) drive people to post it for social approval. (胡綺珍, 2024) collected 217 “tired of life” / “I'm just trash” meme texts from Instagram and PTT, then interviewed 13 Gen-Z enthusiasts, revealing how self-deprecating jokes help Gen Z cope with stress, feel part of a group, and quietly push back against social pressure. Memes have a long history, and even almost a decade ago in 2016, a casual news comment—like the “canoing man” (泛舟哥) remark during a typhoon exploded into LINE stickers and PTT threads, proving that Taiwanese can transform everyday media moments into collective satire or tongue-in-cheek commentary (黃意能 & 黃曉琪, 2016).

Internationally, the sustainability-focused topics “underconsumption” and “deinfluencing” were trending on TikTok in 2024 however have since subdued (Fares et al., 2024; TikTok, 2024b, 2024a). While this particular trend may be over, memes still hold potential for communicating about sustainability to young Taiwanese.

Memes and ai assistant can be a tool for 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.

- Refi podcast: “people need agency”.
- Posting memes feels like having agency
- In Japan, Gen-Z wants privacy and 75% feel others overshare on social media and 49 percent were concerned about their personal data (McKinsey & Company, 2022).
- (Zannettou et al., 2018) built a large-scale machine-learning pipeline to trace the origin of memes in the US, with 160M images and 2.6B posts within about 1 year (July 2016-2017) from Twitter, Reddit, 4chan and Gab, finding that often memes originate from fringe communities and then spread across mainstream media.

6.12 AI Usage Among Taiwanese Students

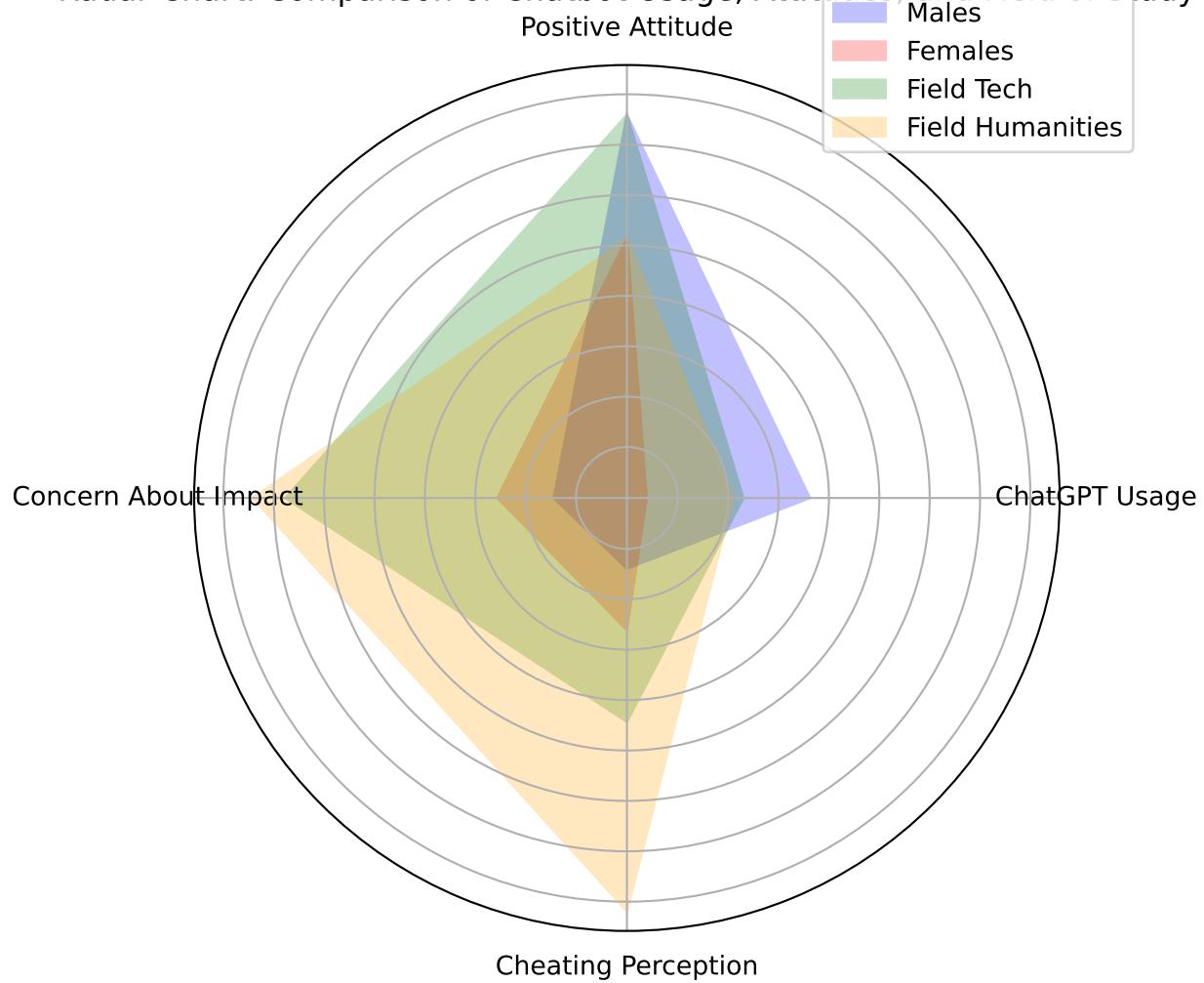
A survey of college students in March 8–10, 2023 at the Chung Yuan Christian University (n=983) in Taoyuan (Northern Taiwan), yielded the following results: 66% of the students had used ChatGPT, with the top use cases being summarization (31%), translation of articles (28%), and writing reports (24%) (CYCU, 2023; 許維寧, 2023). However, in terms of AI adoption, this data can be considered out-dated. ChatGPT was first released to the public on November 30, 2022, so the students had had only about 3 months to try it out (OpenAI, 2022). At the time, the GPT-3.5 model was available; the revolutionary GPT-4 was released to the public on March 14, 2023, (OpenAI, 2023).

In a more recent large-scale survey focusing on AI literacy administered to the general public (n=2174) found that only 26% of the respondents had used ChatGPT in the past 3 months (in comparison with the 25% from a similar survey administered in the previous year); younger people had higher usage patterns, 53% for 18-29 and 37% 30-39; meanwhile, 69% of respondents believed they could tell the difference between AI-generated and non-AI content and 73% supported some type of government regulations for AI (HakkaNews, 2024).

A Chinese study from two authors at the Minzu University and Beijing Normal University reports they recruited anonymous Taiwanese college students (n=916) on the Chinese Credamo platform from the Taiwanese IP-space (ChatGPT is blocked in Mainland China, Macau, and Hong Kong) to compare ChatGPT vs. Google for academic use among Taiwanese students: their findings show a clear preference for ChatGPT overall, which students deemed more flexible (meanwhile some older students still preferred Google) and Random Forest and LightGBM-based modeling predicted tool choice by three main factors: 1) GenAI fluency, 2) awareness of GenAI hallucinations, and 3) user age; their recommendations include 1) support critical-thinking among users, and 2) design hybrid chat+search user interfaces with higher reliability (Kelly, 2024; Qiao & Lee, 2024; M. Zhang & Yang, 2024). In the US, an older study of young adults (Millenials at the time) highlights how they *“use Google as a reference point for ease of use and simplicity”*, (Kate Moran, 2016). The web now has several generations of native users, and some older usage patterns which older digital natives are used to, may take time to change.

In Sweden, a large-scale (N=5894) survey across several Swedish universities showed college students' attitudes towards AI assistants (ChatGPT was by far the most prevalent app, 95 % of respondents had heard of ChatGPT and 35 % used it regularly); 55.9% held a positive attitude toward AIs; integrity was a hotly debated question, 62% calling AI use in exams “cheating,” but 60% rejecting an outright ban, and 58% saying it doesn't violate the purpose of education (Stöhr et al., 2024).

Radar Chart: Comparison of Chatbot Usage, Attitudes, and Field of Study



7 SUSTAINABILITY

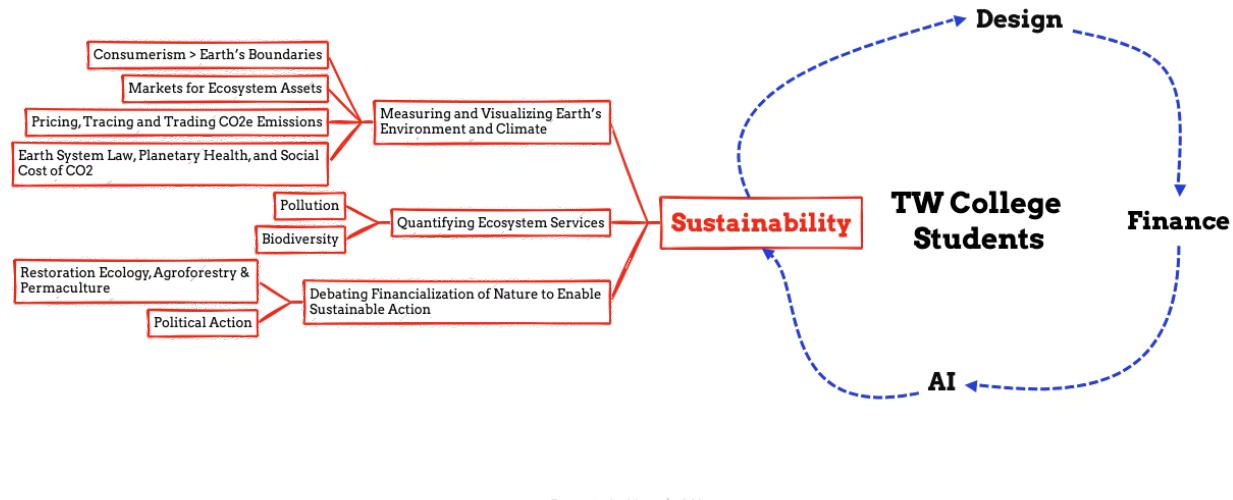


Figure 7: Visual abstract for the sustainability chapter

7.1 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 (Gottschlich & Friedrich, 2014; Hannß Carl von Carlowitz, 1713). 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*” (World Commission on Environment and Development, 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.

7.2 Measuring and Visualizing Earth's Climate Systems

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 (*Alexander von Humboldt's Original Isotherms Circa 1838*, 2023). Already in 1896, the Nobel Prize winner Svante Arrhenius first calculated how an increase in CO₂ levels could have a warming effect on our global climate (T. R. Anderson et al., 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 CO₂e 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 (T. R. Anderson et al., 2016).

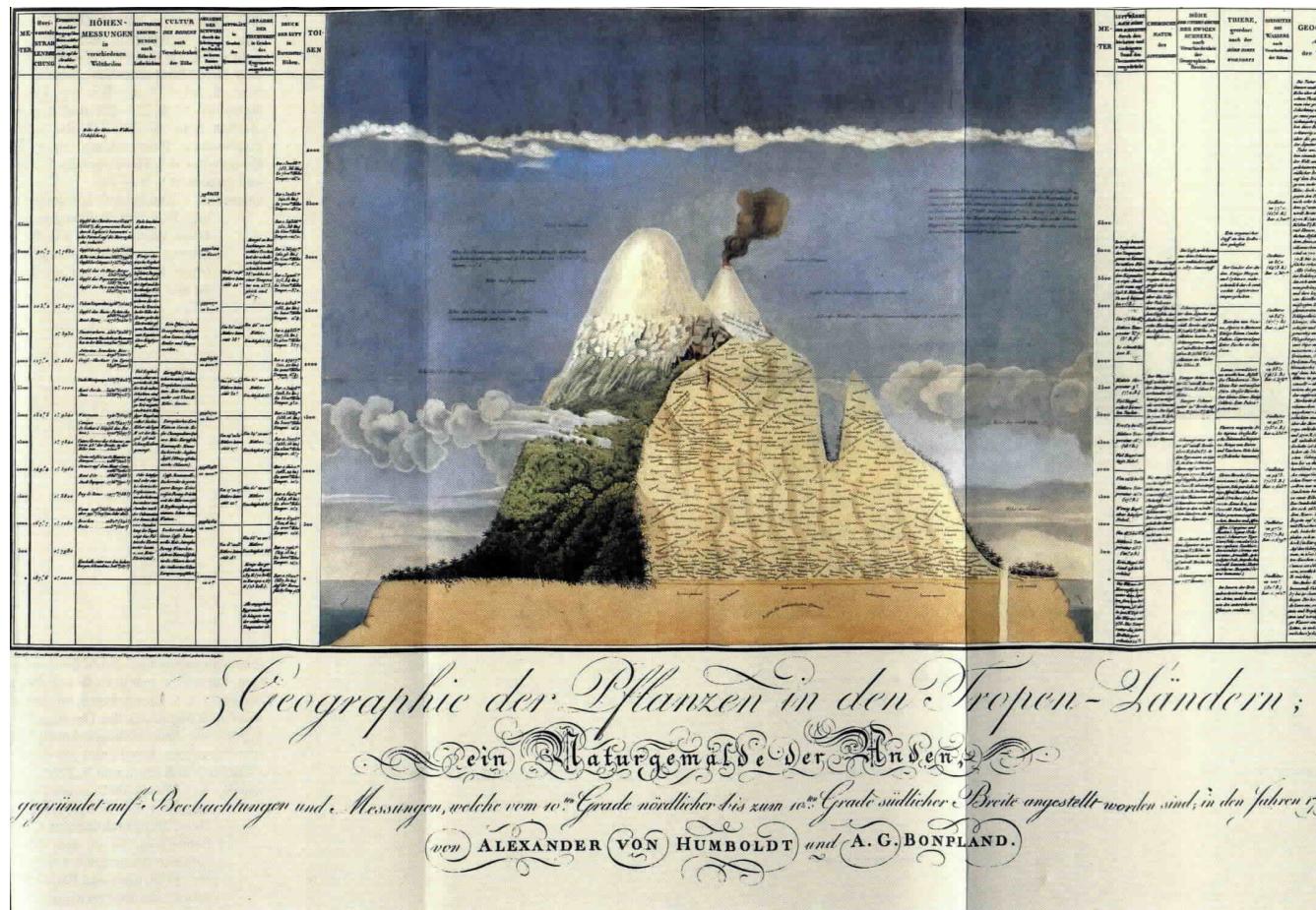


Figure 8: Humboldt's Naturgemälde, early data visualization of ecology, rain, temperature, elevation, etc

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 CO₂ 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 CO₂ emissions kept rising too. The hockey-stick growth of CO₂ 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).

Keeling Curve funding is Ralph Keeling is under threat, Scripps Institute

The apparatus measures the absorption of infrared light, which allows one to detect the amount of CO₂ in the air. It also has an advanced calibration system where it makes measurements in air with a known quantity of gases. Worthington (2025b)

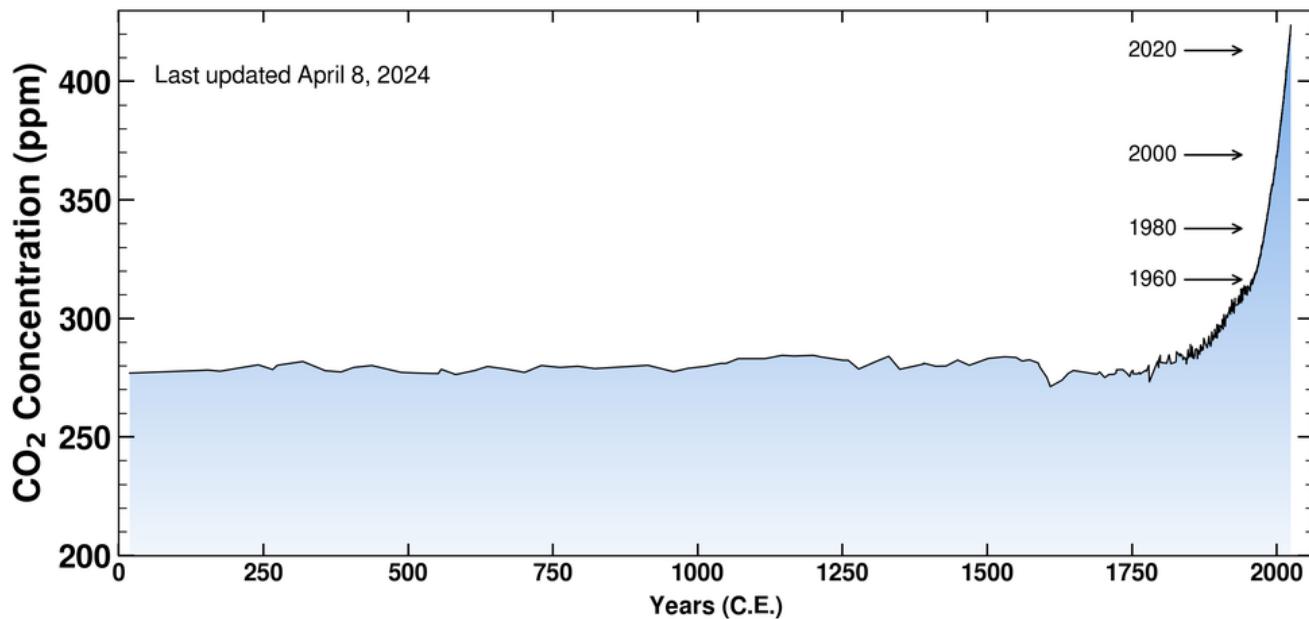


Figure 9: CO₂ concentration in the atmosphere as of Ap. Image Credit: Scripps Institution of Oceanography at UC San Diego.

The latest data from 2023 shows our current world population of 8 Billion people emitted 37.2 gigatonnes (i.e. billion metric tons) of CO₂e 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 CO₂e 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 ("First Time World Exceeds 1.5C Warming Limit over 12-Month Period," 2024; *World's First Year-Long Breach of Key 1.5C Warming Limit*, 2024). 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).

7.2.1 Measuring CO₂e Emissions

Technology improves and measurements have become more accurate yet CO₂e emissions are not yet completely accounted for. (Crippa et al., 2020) reports the latest figures CO₂e 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 CO₂ 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)

CO₂e emissions by region (per year).

Table 12: Comparing highest per capita CO₂e emissions (mostly from oil producers) vs regional average per capita CO₂ emissions vs total CO₂ emissions(Crippa et al., 2020; European Commission. Joint Research Centre., 2022; Ivanova et al., 2020; Z. Liu et al., 2023; World Resources Institute, 2020).

Regional Average Per Capita Emissions (2020)	Highest Per Capita Emissions (2021)	Highest Total Emissions (2021)
North America 13.4 CO ₂ e tonnes	Palau	China
Europe 7.5 CO ₂ e tonnes	Qatar	United States
Global Average 4.1 CO ₂ e tonnes	Kuwait	European Union
Africa and the Middle East 1.7 CO ₂ e 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 13: 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)

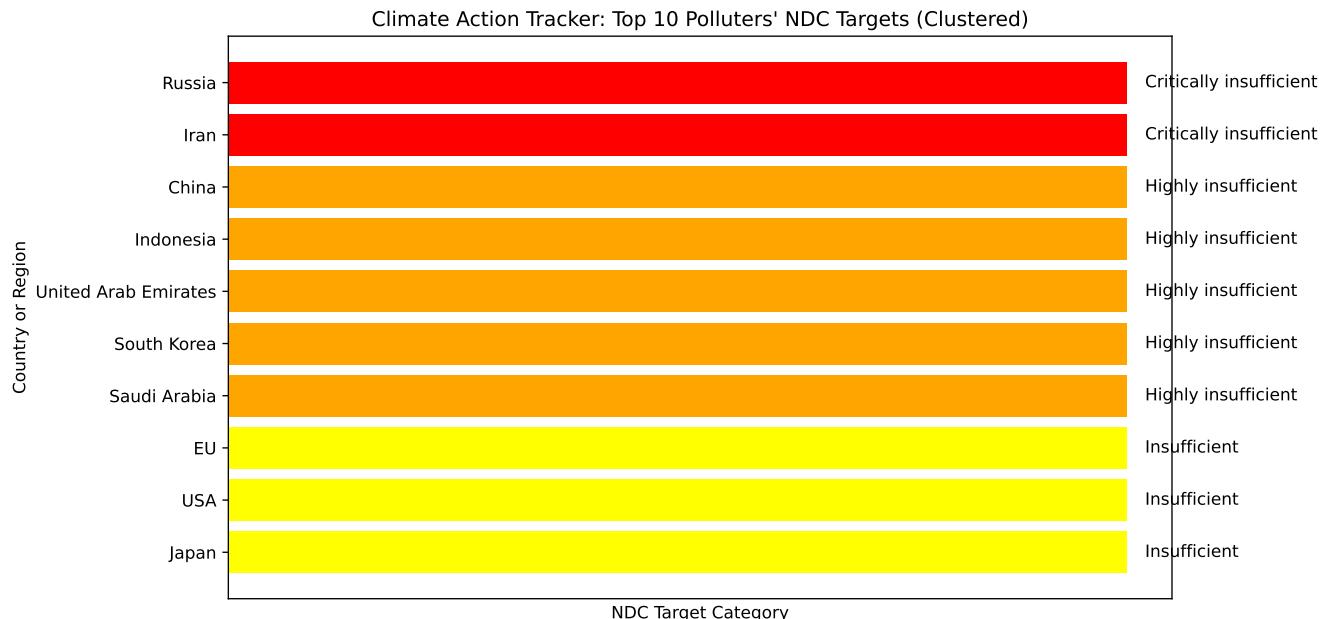
- UNFCCC. Secretariat (2022) The State of Nationally Determined Contributions
- Power generation is one of the largest polluters; Google worked with the government of Taiwan to change the laws to allow direct power procurement by foreign companies; the current plan being to install 1 gigawatt of solar power fully pre-purchased by the newly formed company created by BlackRock and Google for boosting AI development as reported by (S. Chiang, 2024; Jessop et al., 2024; 永鑫能源 New Green Power, 2022).

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 14: 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 CO₂ emissions. IEA (2022) reports “Global CO₂ 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 CO₂ 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 project licenses in the North Sea (“Rishi Sunak to Green-Light Hundreds of New Oil and Gas Licenses in North Sea,” 2023).

Ministry of Digital Affairs (2024a); Ember (2025) based on data from Taiwanese government.

7.2.2 Markets for Ecosystem Services: Pricing, Tracing, and Trading Nature’s Assets

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 15: Criteria for carbon credit projects.

Criteria	Description
Baseline	Ecosystem carbon sequestration rate without the intervention (project)

Criteria	Description
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 CO₂ 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 (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 CO₂ 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 CO₂ trading (LSEG & Susanna Twidale, 02/12/2024, 02:37 PM).
- *The price of CO_{2e} differs across markets.* (Stern, 2022b) 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 than it is currently. Contrary, (Ritz, 2022) argues optimal CO₂ 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.

Google purchases 10MW of geothermal energy for its Taiwanese AI chip projects, doubling current Taiwanese geothermal capacity (Hagström-Ilievska, Apr. 17, 2025 18:00; Potter, 2025; Jeffery Wu & Thompson, 2025). Geothermal energy provides 24/7 clean energy from the Earth's core, however is limited due to lack of access; Taiwan happens to be in geologically active spot on the ring of fire, where drilling for geothermal energy is more feasible (M. Chang & Hsiao, 2025; L, 2025).

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

- Watershed is a large carbon accounting company.
- The legislation has created an industry of CO₂ accounting with many companies like Greenly, Sustaxo, etc.
- Quatrini (2021) sustainability assessments are complex and may give flawed results.
- Nonetheless, CO₂ emission reduction has the added positive effect of boosting corporate morale (J. Cao et al., 2023).

Compliance Carbon Markets

meet legal emission reduction targets

Cap & Trade

The share of CO₂ 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
 - *GreenDice - Reinventing the Idea of a Computer-Related Tech Purchase* (2021) Estonian company “sustainable lifecycle management of IT equipment”
 - Ärileht (23.09.2022, 12:53) Recycle your phone, FoxWay and Circular economy for PCs.
 - X. Zhou et al. (2022) 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, 2022, 2023).

Retiring CO₂ allowances

- Facilitating citizens’ access to CO₂ emissions trading may be an efficient method to organize large-scale CO₂ retiring (Rousse, 2008).

As of 2024 there’s no single global CO₂ trading market but rather several local markets as described in the table below.

Table 16: CO₂ credit trading markets around the world from *International Carbon Market* (n.d.).

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 (Ivy Yin, 2023; H. Liu, 2021).

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 CO₂ 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 17: Compliance market CO₂ prices on August 12, 2023; data from (CarbonCredits, 2023; Ember, 2023; Trading Economics, 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).

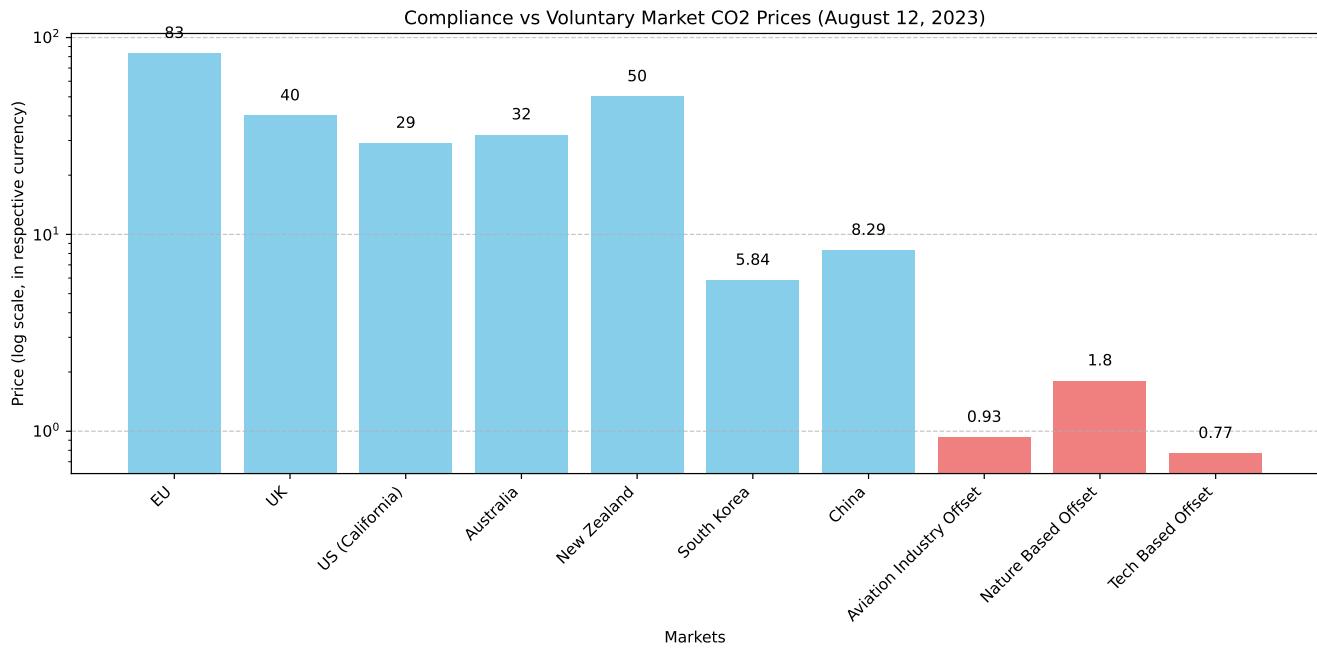
Carbon Credits are useful for private companies who wish to claim *carbon neutrality, climate positivity*, or other related claim, which might be viewed in good light by their clients or allow the companies to adhere to certain legislative requirements.

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: *Methodology for GHG & Co-Benefits in Grazing Systems* (2022)
- KlimaDAO (2023a) call for an open standard

Table 18: Voluntary market CO₂ 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



7.2.3 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 CO₂ equivalent per capita*”, according to (Ivanova et al., 2020; Renee Cho, 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 CO₂ 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 19: 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 et al., 2022), believe *[o]verpopulation is a major cause of biodiversity loss and smaller human populations are necessary to preserve what is left."*

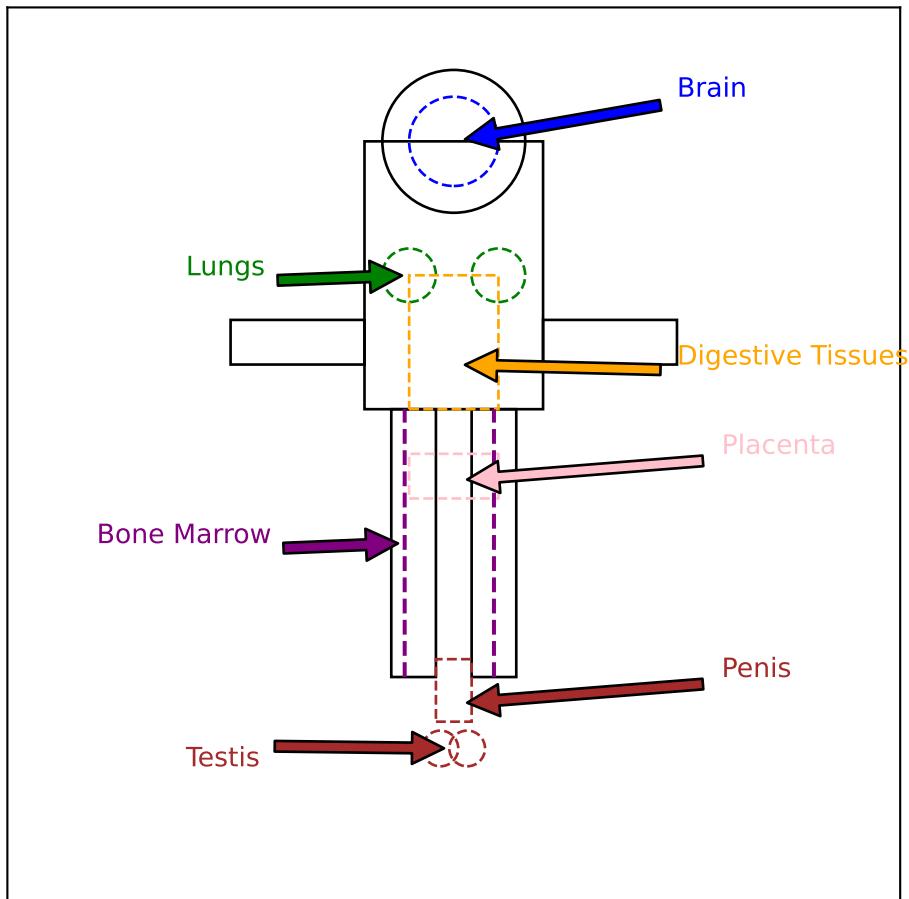
While the numbers on overconsumption are clear, the debate on overconsumption is so polarized, it's difficult to have a meaningful discussion of the topic (Ianole & Cornescu, 2013). Environmental risks from human activities are known as Anthropogenic Threat Complexes (ATCs) (Bowler et al., 2020). As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

7.2.4 Plastic Pollution

Overconsumption is also one of the root causes of plastic pollution. (Ford et al., 2022) and (Lavers et al., 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 (Lavers et al., 2022; Tiernan et al., 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 (Codrington et al., 2024; M. A. Garcia et al., 2024; Guo et al., 2024; Hu et al., 2024; N. Li et al., 2024; Main, 2024; Montano et al., 2023; L. Zhu et al., 2024)

Microplastics Inside the Human Body



- 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.

tipping points - Armstrong McKay et al. (2022) discusses tipping points. - TED (2024)

In addition to the enormity of over-reaching CO₂ 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 et al. (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 et al. (2018)
- Richardson et al. (2023)

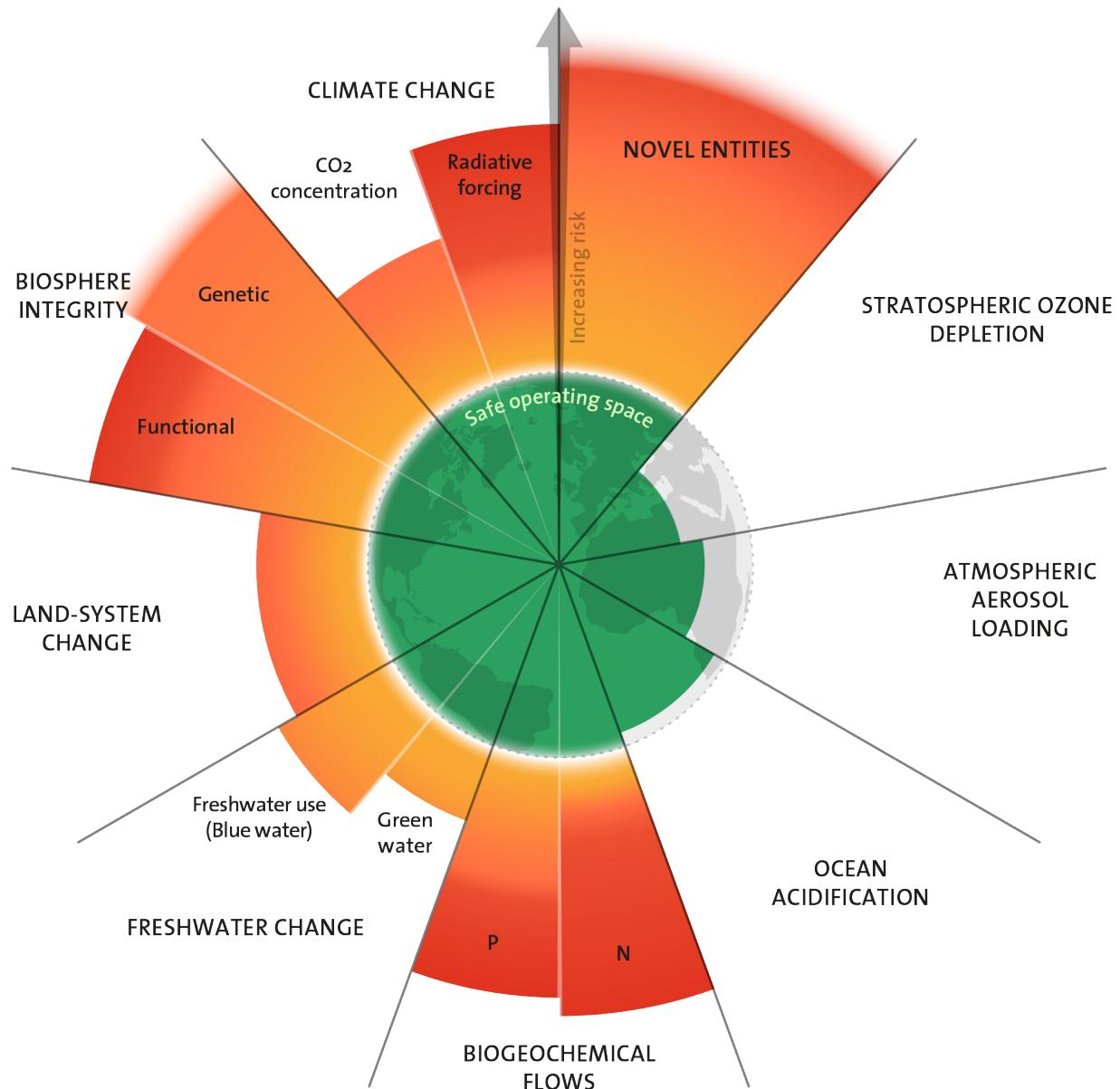


Figure 10: Planetary Boundaries 2023 update. Azote for Stockholm Resilience Centre, based on analysis in Richardson et al 2023

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).

7.2.5 Earth System Law, Planetary Health, and Social Cost of CO₂

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 et al., 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 (Yong Wang et al., 2022).

- (J. Lin et al., 2022) says, apart from CO₂, reduction of other atmospheric pollutants, such as non-CO₂ greenhouse gases (GHGs) and short-lived climate pollutants (SLCPs) is required for climate stability.
- (T.-P. Wang & Teng, 2022): Quantifying climate damage proposes scenarios of climate damage.

7.3 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 (G. C. Daily, 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 *Destination Earth / Shaping Europe's Digital Future* (2023). 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*

7.3.1 The Biosphere: Earth's Life Support System

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).

7.3.2 Using Ecological Indicators to Track Environmental Health

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 et al., 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).

7.3.3 Biodiversity Loss: Causes, Impacts, and Solutions

Why Protect Biodiversity?

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

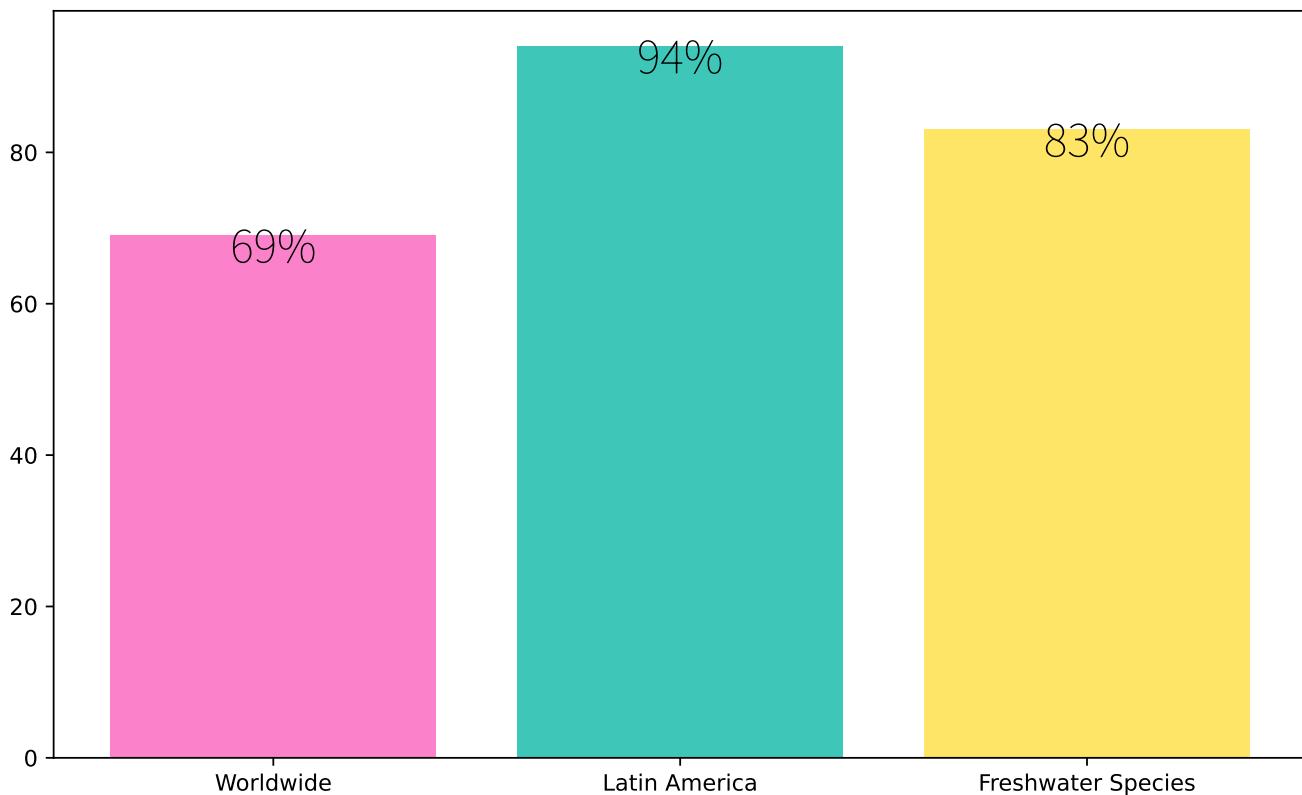
Table 20: From (May, 2011).

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).
- Y. Chen et al. (2023) Ecosystem vulnerability (**need access**)
- Z. Zhang et al. (2023) Integrating ecosystem services conservation into urban planning (**need access**)
- L. Li et al. (2023) tourism is a large industrial sector which relies on ecosystem services. In Taiwan, (T. H. Lee et al., 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 et al., 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-Etxeberria (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 21: 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

7.3.4 Oceans and Marine Ecosystem Sustainability

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.

7.3.5 Forests: Carbon Sinks and Biodiversity Reservoirs

Forests are a crucial part of Earth's carbon cycle and the main natural CO₂ 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 (*FRA 2020 Remote Sensing Survey*, 2022). The global forest cover change is visible on Google's Earth Engine (Hansen et al., 2013).

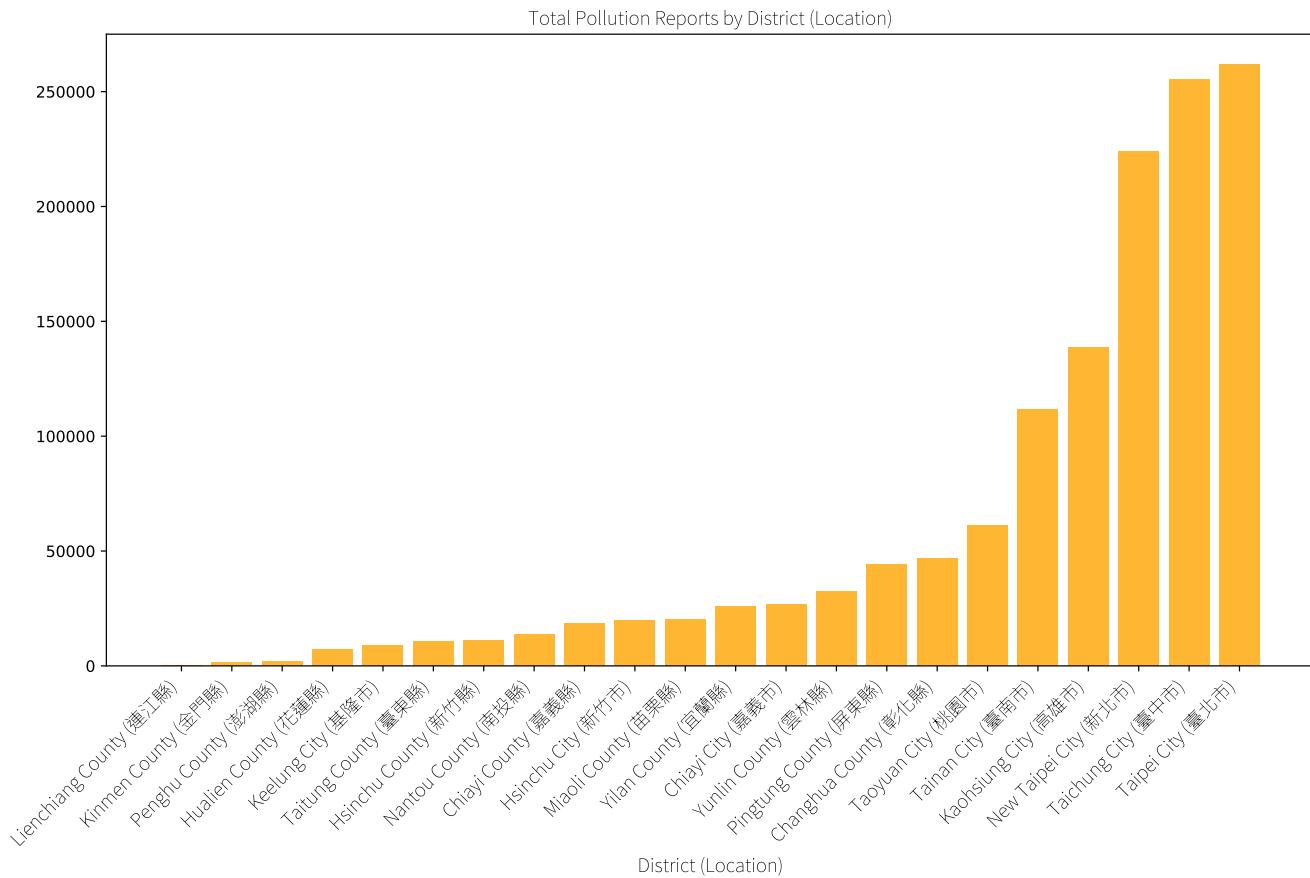
Around the world, there are many initiatives to increase forest cover, for example the *1 billion tree project* (Bastin et al., 2019; “Erratum for the Report,” 2020; Greenfield & @pgreenfielduk, 2021). However, it's important to note that planting trees (*afforestation*) is not the full solution, as *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.

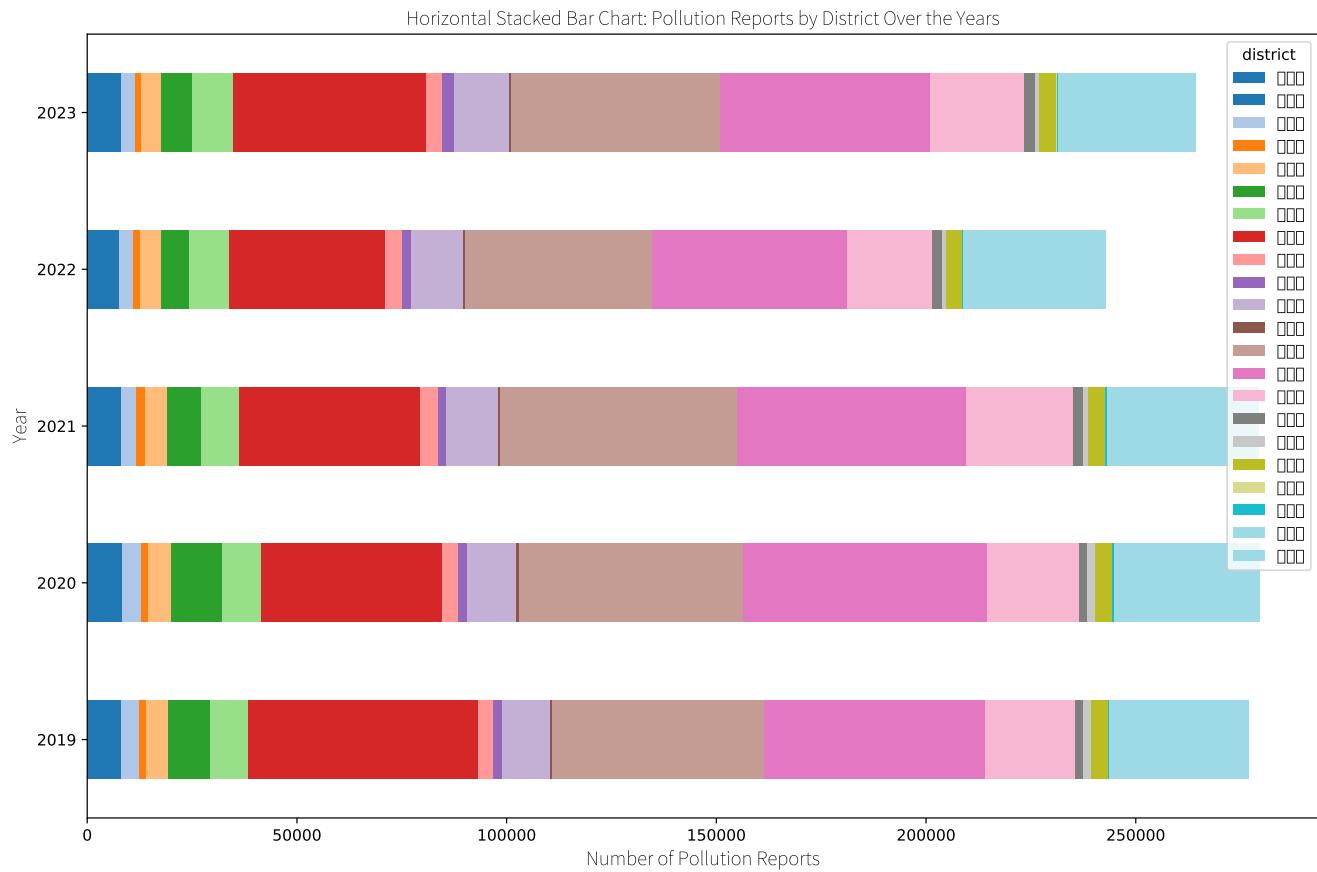
- Burning of biomass undermines carbon capture.
- Bousfield et al. (2022) reports there's evidence paying landowners for the ecosystem services their forests provide may reduce deforestation.
- nature-based solutions.

7.3.6 Pollution: Air, Water, and Soil Degradation

In, Taiwan this is the ranking of pollution reports by citizens (Ministry of Digital Affairs, 2024b):



<Figure size 3600x2400 with 0 Axes>



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 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 explains it plainly, which I want to quote here in verbatim:

“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

Lack of access to sufficient clean water and water pollution are issues in several places around the world. Globally, 4.4 billion people only have access to water that's not safe for drinking (Soliman, 2024). Even in wealthy countries like the US, with increasing situations of water scarcity and draught due to climate change, issues of water ownership become increasingly dire. (Koch, 2022; Naishadham, 2023b) describes a fight in the US over water usage rights in Arizona, where Fondomonte, a subsidiary of a Saudi Arabian company that grows a water-hungry crop alfalfa, exacerbating the local water crisis by using large amounts of public water, leading to public outcry and being sued for "public nuisance" for its excessive groundwater pumping, and finally cessation of its lease and operations on state land; but still continuing operations on private land (Naishadham, 2023a; "Saudi Firm That Grows Hay in California and Arizona to Lose Farm Leases over Water Issue," 2023).

Once pollution is in the environment, cleaning it up is very expensive. For instance, in France, where stormwater washed pollution into the waterways feeding into the Seine river, making it unsuitable for swimming, the city of Paris invested 1.4 Billion Euros to create a massive underground reservoir and a water cleaning system by the opening of the Paris Olympics in 2024 - and still the water quality would be variable based on rain incidence (Walt, 2023).

- Bioswales help catch storm debris and reduce water pollution.

Soil Pollution

In Saudi Arabia, (Picó et al., 2023) used wild and ruderal plants as bioindicators to detect pollution of air, water and soil, specifically anthropogenic pollution, pharmaceuticals, pesticides, and other industrial chemicals, concluding both Abha and Riyadh showed notable levels of pollutants while Riyadh (a city with more industry) showed higher levels of pollution.

7.3.7 Disaster Preparedness and Climate Resilience

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.).

7.3.8 Weather Patterns and Climate Extremes

Warming global climate has concrete effects on daily life. Warmer climate helps viruses and fungi spread (Press, 2023). (Williams & Joshi, 2013) higher CO₂ concentrations in the air can cause more turbulence for flights.

Global warming increases the risk of disasters and extreme weather events. 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 (*Fifth National Climate Assessment*, 2023). As extreme temperatures are increasingly commonplace, with observed changes in heatwaves, there's increased risk

of wildfires (Perkins-Kirkpatrick & Green, 2023; Volkova et al., 2021), 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 (Douglas, 2023; Falconer, 2023; National Oceanic and Atmospheric Administration (NOAA), U.S. Department of Commerce, 2023; NOAA National Centers for Environmental Information, 2023; Serrano-Notivoli et al., 2023; Venturelli et al., 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 et al., 2022) says, “[*wildfires 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 (Y.-J. 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*bserve 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*” (Y. 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 (AFP, 2023; Al Jazeera, 2023; Web, 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).

7.4 Financialization of Nature vs Nature’s Sacred Value: 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-Bagethun (2021)

Table 23: 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

7.4.1 Ecological Restoration: Healing Damaged Ecosystems Through Agroforestry & Permaculture

Some argue sustainability is not enough and we should work on *regeneration* of natural habitat. The UN announced 2021-2030 the Decade on Ecosystem Restoration, which includes a wide range of regenerative action (Fischer et al., 2021). For instance, (Han & Chen, 2022) identifies nature-based solutions “land re-naturalization (such as afforestation and wetland restoration)”

Table 24: From Han & Chen (2022)

Non-Exhaustive list of Regenerative Actions
Afforestation
Wetland restoration

The organic food and drink market is growing worldwide, with gross sales in 2019 totalling over 106 billion euros, albeit being a small percentage of total food industry (Gamage et al., 2023). Growing organic food poses many challenges, which farmers need to adapt to, in order to participate in regenerative food systems. One approach is growing food forests, also known as agroforestry, which integrates farming into natural environments, achieving CO₂ storage in the soil through agriculture and forestry using agroecological practices.

In Ireland, (Irwin et al., 2023) studied dairy farmers' willingness to plant trees to increase vegetation cover on their land, finding that economic incentives alone are insufficient, and support in the form of advisory and education is needed. Similarly, in the Brazilian Amazon rainforest (Yadav et al., 2023) finds the active participation of the local community in planning permaculture practices, enhances their acceptance and effectiveness. In Bangladesh, (Ruba & Talucder, 2023) found agroforestry plays an active role in achieving the country's Sustainable Development Goals (SDGs), including zero hunger, climate action, mitigating climate change impacts through CO₂ sequestration, life on land through biodiversity conservation and improving soil fertility, yet is hindered by the lack of policy support and educational level of the farmers. In the Baltic Sea region in North-Eastern Europe and Central Europe face similar challenges, (Baltic Sea Action Group, 2023) pointing out farmers' traditional mindset as the biggest obstacle, describing the paradigm shift from extractive farming to regenerative agriculture, using techniques such as no-till farming, which reduces soil erosion and improve soil health by reducing synthetic inputs; yet, it's not only

a single practice that is enough, regenerative agriculture is a holistic approach and agroecology education programmes need to be comprehensive.

(G. Low et al., 2023) further studies how agroforestry deep integration into food value chains unlocks opportunities for recognition and rewards from economic actors in the network, underlining how complex and knowledge-heavy nature of value-capture, calling for further standardisation of practices to reward sustainability practices and ecosystem services. The challenge lies in that bioeconomy is not inherently sustainable and may put biodiversity at risk, depending on the level of industrialisation of agriculture and specific practices, which require deep knowledge and understanding of natural and artificial interactions the ecological systems; the authors advocate for a precise distinction between extractive and regenerative practices in “bioeconomy” (Ollinaho & Kröger, 2023). Finally, taking Brazil as an example, (De Queiroz-Stein & Siegel, 2023) argues for an integration of competing and conflicting bioeconomy policies, in order to achieve the goals of a sustainable bioeconomy.

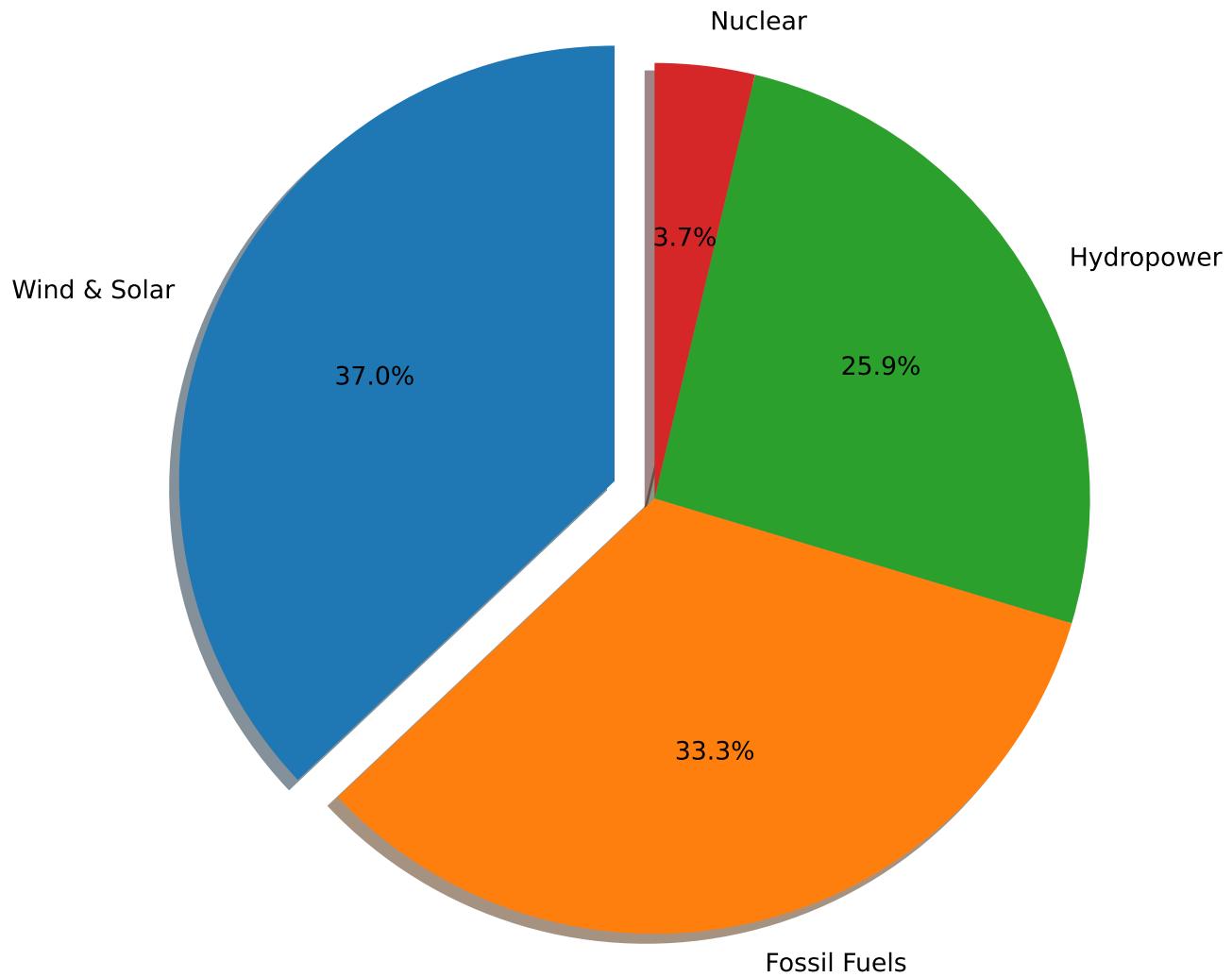
Svalbard Seed Vault is an example of seed conservation to safeguard biodiversity by storing backup seeds of plants from around the world in cold storage (Asdal & Guarino, 2018; Westengen et al., 2013). Since its opening in 2008, the storage solution provided by the Norwegian government has stored seeds from 123 genebanks in 85 countries around the world (“Arctic Doomsday Seed Vault Gets More Than 14,000 New Samples,” 2025; The Norwegian Ministry of Agriculture and Food, 2025). (Vitaletti, 2025) proposes using a blockchain-based lottery system to store seeds in local refrigerators, in order to enhance resilience and ensure survival of seeds, by storing seeds in many locations.

7.5 Energy Production

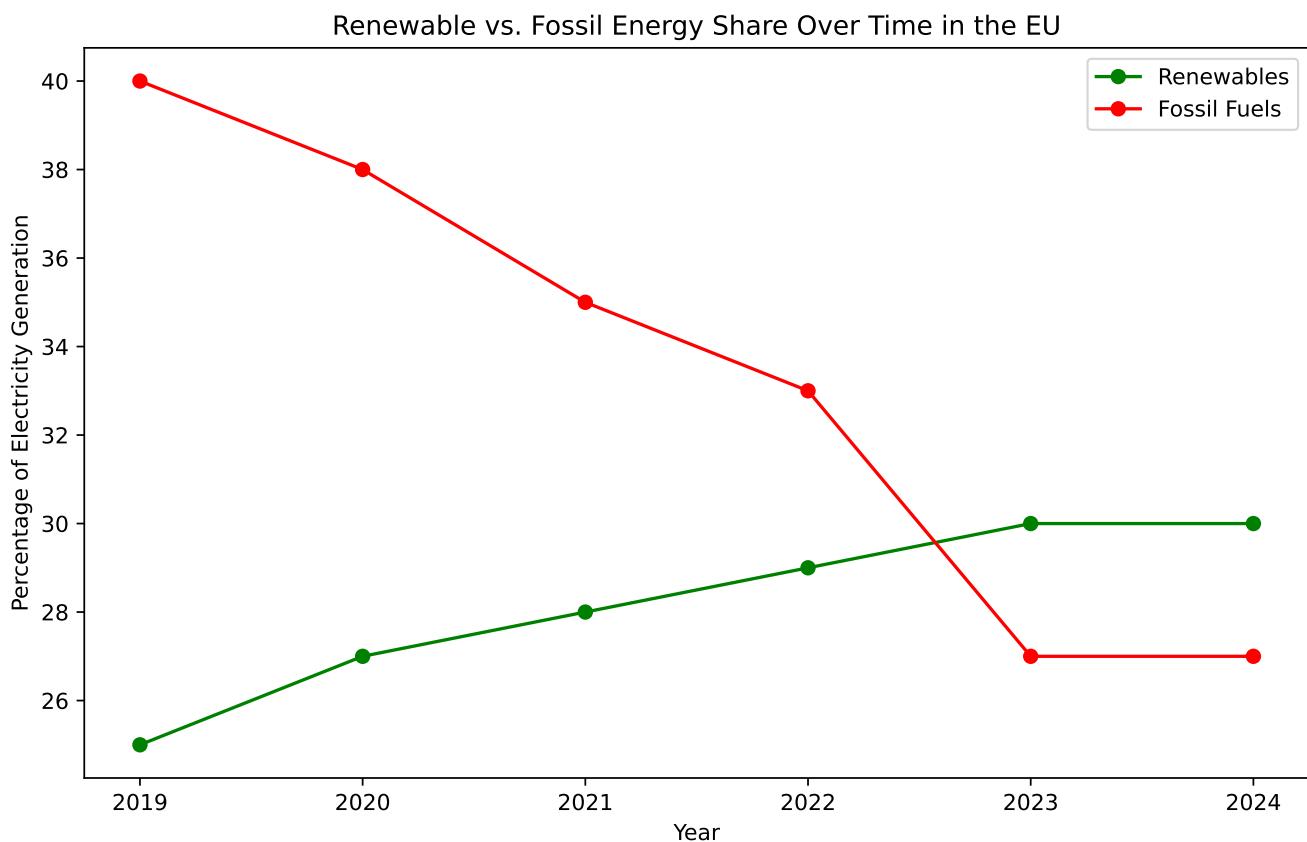
Geopolitical situations can affect technology adoption; after Russia’s war in Ukraine, Europe needed to quickly reduce consuming cheap Russian fossil fuel energy (in the form of gas) (Bonasia, 2024). In 2024, for first time in Europe, renewables in the form of wind and solar energy surged past production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

EU’s energy mix in 2024

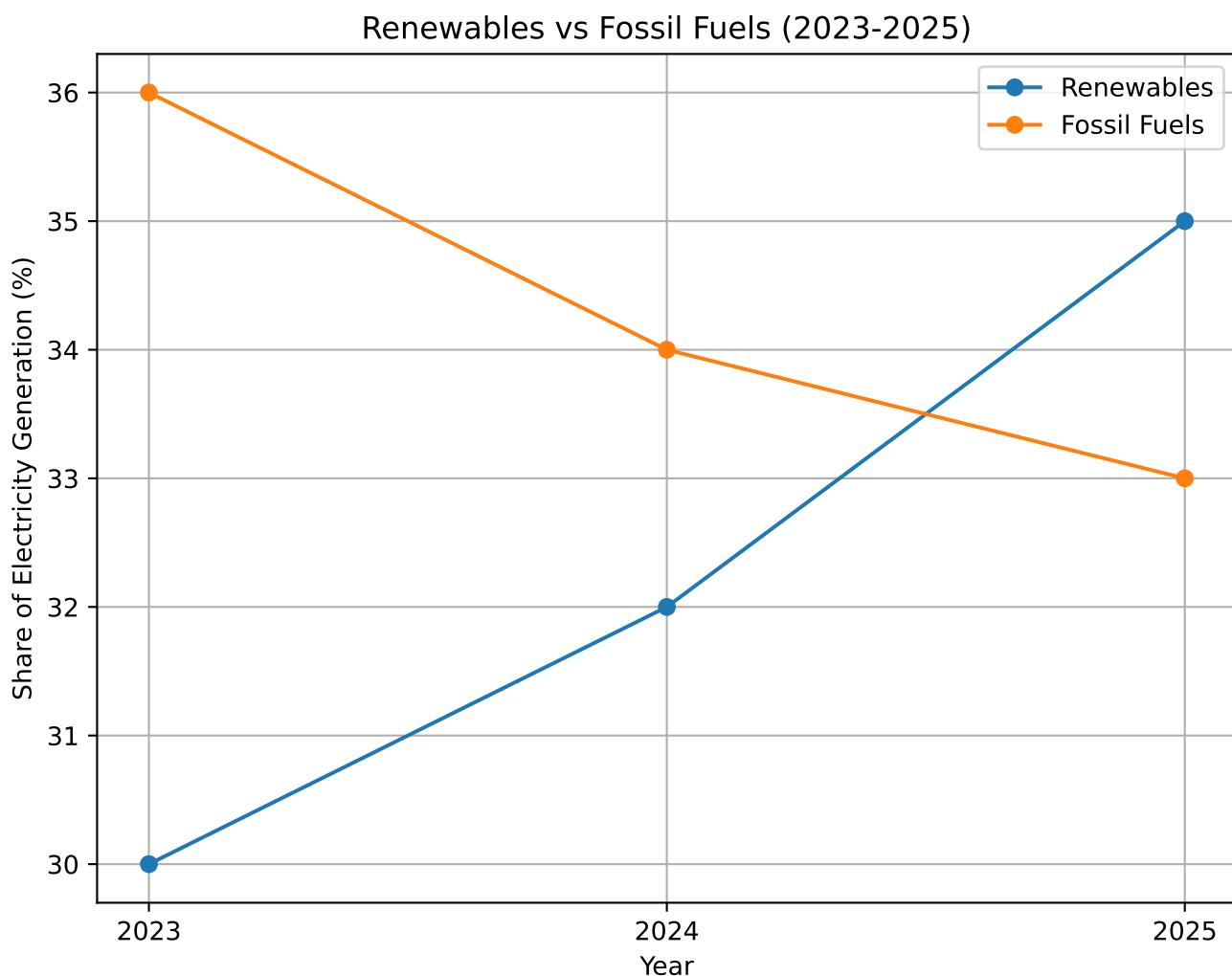
EU Electricity Generation Breakdown (H1 2024)



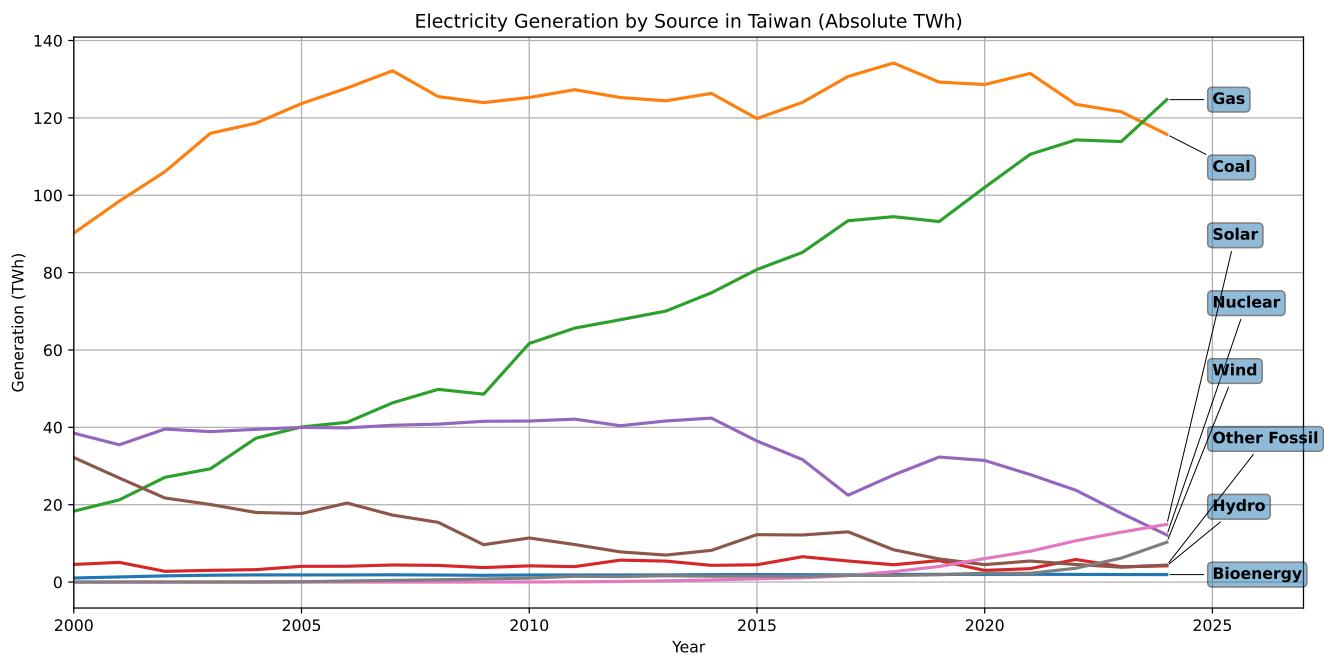
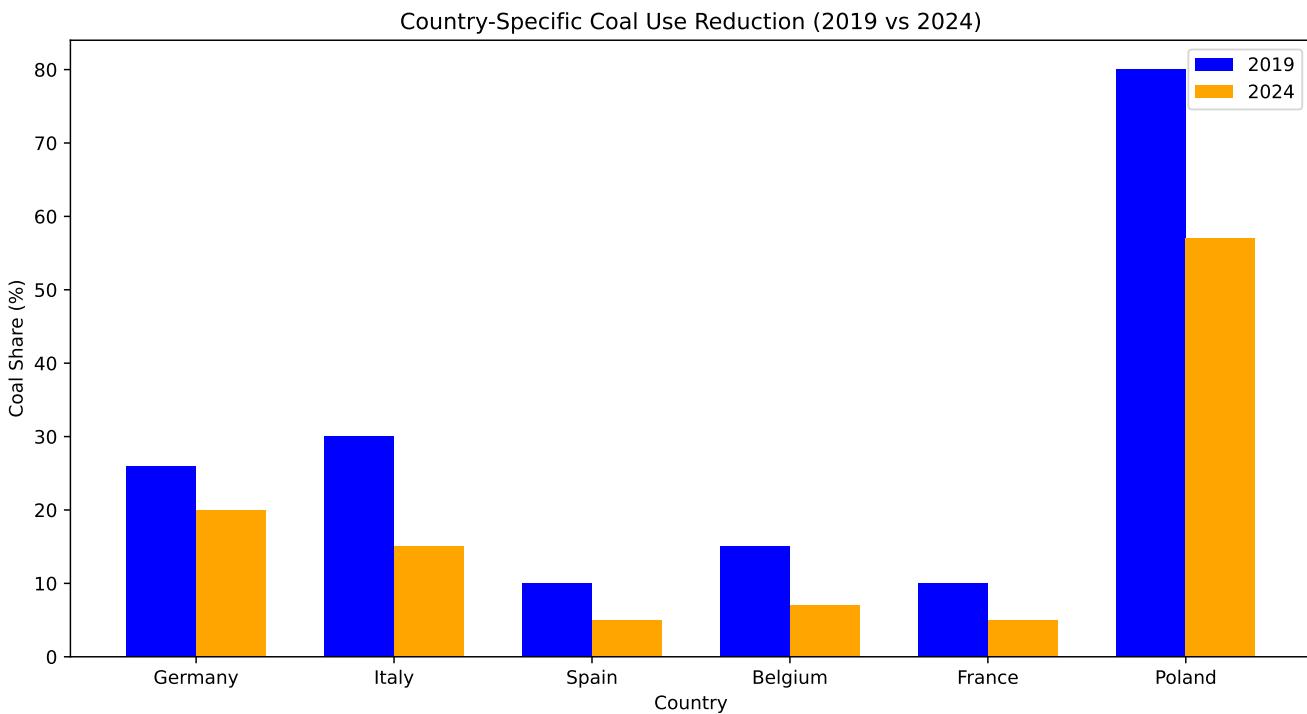
Wind and solar energy overtook fossil energy in Europe.



Globally, renewables also overtook fossil fuels (IEA, 2024).



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 CO₂ 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 CO₂ is difficult because of low concentration and CO₂ capture at the source of the emissions is more feasible.

- (Gaure & Golombek, 2022) simulate a CO₂ 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 CO₂ emissions.
- **Important:** “creating sustainability trust in companies in realtime”

7.6 Navigating Complexity with Data: Towards Probabilistic Risk-Based Assessment in Sustainability

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; Lopez et al., 2022; Meisinger, 2022; Murase & Baek, 2018).

7.6.1 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.

8 DESIGN

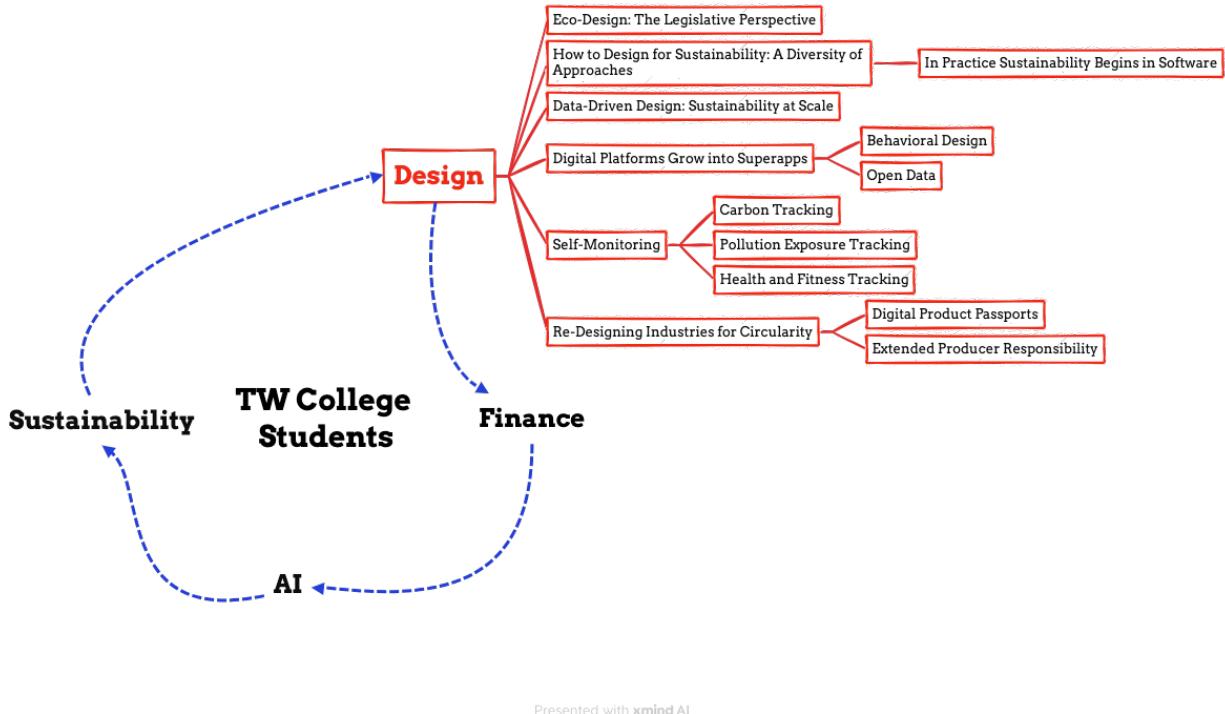


Figure 11: Visual abstract for the design chapter

- Design makes complexity comprehensible. Norman (2016)
- like the Helsinki chapel. there's either or a priest or a social worker present. it's the perfect public service. Limit the barrier of entry for people to discover. Elegant.

8.1 Eco-Design: Design as Political Action at Scale

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).

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

The monumental task of removing several gigatons of CO_{2e} from the atmosphere requires massive policy shifts and collaboration across countries and industries (Mackler et al., 2021).

Designing the right legislative measures can be hugely impactful. In the context of the European Union, *eco-design* has gained political support from European Commission as part of the EU's "*Green Deal*" legislative strategy, aiming to transform European economies into sustainability leaders (Commission et al., 2014). Consumer products' overall life-cycle environmental impact is defined in the design process by the materials and energy resources needed and the post-consumer potential for reuse or recycling. The Ecodesign for Sustainable Products Regulation (ESPR) entered into force in July 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 as describing eco-design as design that “*respects the boundaries of our planet*” (European Commission, 2022c).

Europe has been on a path of transformation from 2023 to 2030.



Figure 12: EU Policy Context Timeline

The EU Commission has been releasing strategic foresight reports since 2020 (European Commission, 2023b).

Timeline of the Policy Context:

- In 2019 by the von der Leyen commission adopted the European Union (EU) Green Deal strategy.
- In 2021 the Commission 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); *EU Reaches Agreement on National Emission Reductions* (2022); 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.
- European Commission (2022b) Ecodesign for sustainable products. The EU “Green Deal” legislative strategy is comprehensive. Eco-Design is a Key EU Sustainable Policy Design Tool.

Combined Concept Map of EU Green Deal Regulations and Categories



In the European Union (EU), a wide range of legislative proposals, targets, organizations, and goals have exists across diverse countries. It's not that the EU didn't have an overarching environmental policy before; rather it was more vague and filled with loop-holes. 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. National governments need to adapt EU legislation to local contexts. For example Estonian government adopted the Estonian Green Deal Action Plan (Eesti Rohepöörde Tegevusplaan) (Eesti Vabariigi Valitsus, 2022). From the legislative perspective, NFRD (Non-Financial Reporting Directive) is replaced by CSRD (Corporate Sustainability Reporting Directive) and ESRS reporting is the standard to meet CSRD requirements.

Director of the French environmental NGO Pôle Eco-conception, eco-design is “[l]ocated at the interface between consumption and production patterns, eco-design helps to structure the market for products and services using a life cycle approach and tangible criteria” (Chouai & Mayer, 2024).

“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)

The EU is also concerned with supply-chain deforestation. 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 December 2024 and June 2025 for small businesses.

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 (as of writing) (*Scientists Urge European Parliament to Vote for Nature Restoration Law*, 2023) and is facing a backlash (David Pinto, 2023).

The EU has a *taxonomy of environmentally sustainable economic activities* published by the Technical Expert Group (TEG) on sustainable finance, as detailed in the report by (*EU Taxonomy for Sustainable Activities*, n.d.).

Europe is transforming into a hotbed of sustainability. One of the EU goals is reducing careless consumption. Tacking our consumption habits can help support eco-designed products. It’s up to legislators to provide sustainable products on our marketplace... but until this happens, we can use the green filter.

8.1.1 Beyond Return, Repair, Reuse

- There’s a growing number of companies providing re-use of existing items.
- *SmartSwap* (n.d.) For example, Swap furniture in Estonia
- universal recycling symbol creator Gary Anderson created the symbol when he was an architecture student in California, USC (uni southern california) in 1970 at the age of 23, inspired by Silent Spring, Earth Day, and Bauhaus, Buckminster Fuller, Spaceship Earth, printing presses, and the Woolmark logo for wool industry certification, and the Möbius strip, for a competition held by a packaging firm that was making paper containers for packaging Swap Society (2023)
- standardising reuse across the globe, a body to create a reuse standard is holding a competition to create a reuse symbol

Table 25: The 9 qualities of *eco-designed products* based on the Ecodesign for Sustainable Products Regulation (ESPR) enacted as law in the EU as of July 2024 (European Parliament, 2022; Lüttin, 2025).

Feature	Benefit
Durable Reusable	Reduces the need to frequently replace the product Extends the product’s life-cycle; sell or share to the next user

Feature	Benefit
Reparable	Extends the product's life-cycle; fix instead of discarding
Upgradable	Extends the product's life-cycle; improve performance without complete replacement.
Easy to Maintain	Reduce resources needed to keep the product functional
Easy to Refurbish	Support second-hand use and circular economy
Easy to Recycle	Support material recovery at end of the product's life to reduce new resource extraction and pollution
Energy Efficient	Reduce product's CO2 footprint and operating costs
Resource Efficient	Reduce product's use of raw materials and energy during production and life-cycle

8.1.2 Legislative Efforts Around the World

Europe is not the only region undertaking legislative efforts to promote sustainability. In the US, the *Inflation Reduction Act* provided funding to development of de-carbonizing technologies and includes plans to combat air pollution, reduce green house gases and address environmental injustices (Rajagopalan & Landigan, 2023).

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].

8.1.3 Eco-Modulation: Incentive Design for Extended Producer Responsibility and Product Stewardship

Eco-modulation means harder to recycle items are more expensive for the producer. Recycling fees take into account eco-design: an item from a single material is easier (cheaper) to recycle than product from composite materials.

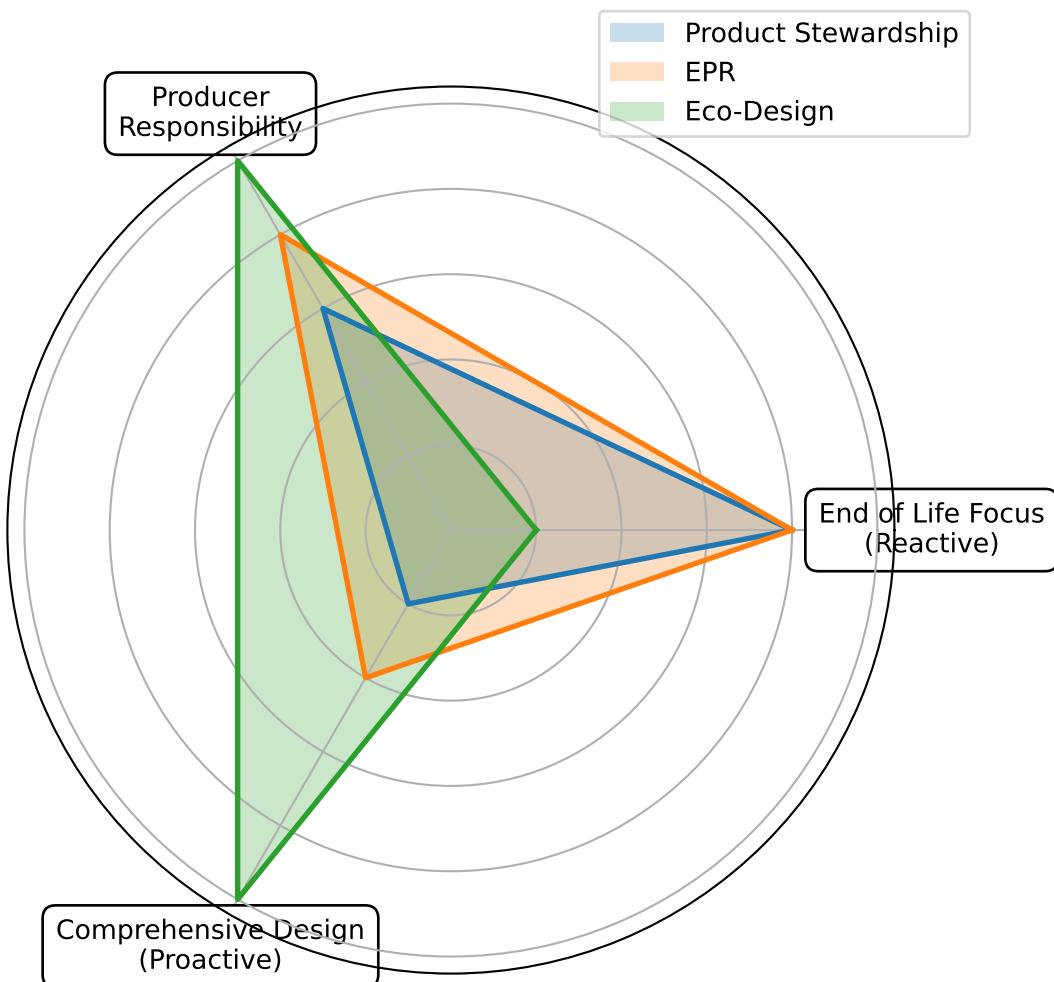
Eco-modulation makes the hidden cost of hard-to-recycle formats directly visible on the invoice.

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).

Deposit Return Schemes (DRS)

In California, part of the EPR regulation is a large pool of funding for cleaning up historic pollution resulting from (Moolman, 2024; [packagingheffernanPlasticRecyclingPodcast2024?](#))

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 life-cycle (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.



Extended Producer Responsibility Enables Companies to be Responsible.

Popular blogs such as (Kohli, 2019) and (Lose, 2023) 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 EPR) 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 et al., 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 (“New EPR Requirements for Textiles in Latvia from July 2024 On,” 2024).

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. J. Peng et al. (2023) finds that the *Carbon Disclosure Project* has been a crucial tool to empower EPR 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 it 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).

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”
- 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.”

- “Challenges and Opportunities in Sustainable Packaging Today” (2022)
- “Protein Brands and Consumers Alike Focus on Sustainability” (2022)
- “Detail-Rich Sustainable Packaging Product Database Is an Industry First” (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.
- “Sulapac – Replacing Plastic” (n.d.)

8.1.4 Scenario-Building: Avoiding the Worst Future

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

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

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)

8.1.5 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)
- Rieger et al. (2023) Integrated science of wellbeing
- Fabris & Luburić (2022)

I was torn whether to place *politics* under *sustainability* or *design*, and decided for the latter - as sustainability is mostly *descriptive*, using science to measure and present the real situation, while design is *prescriptive*: codifying decisions about how do we live - in products and services.

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.

- In Bangladesh, 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.
- J. Luo et al. (2022) suggests using reinforcement learning to reduce energy use in cooling systems.
- Montreal protocol near-eradication of chlorofluorocarbons (CFCs) and the ozone holes became whole again.

***Mitigating* and *Adapting* to Climate Change**

***Adapting* to Climate Change**

Many companies are developing technologies for mitigation.

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

Sustainability Policy context is Shifting Around the World

- “data-exchange protocol with privacy at its heart” Circularise (2020a)
- EU AI Law Lomas (2024)

Kunming-Montreal Global Biodiversity Framework

- Manzardo et al. (2021) (**need access!**)
- Iñarra et al. (2022) (**need access!**)
- Munaro et al. (2022) (**need access!**)
- Bassani et al. (2022) (**need access!**)
- Van Doorsselaer (2022) (**need access!**)
- Arranz et al. (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.
- Nastaraan Vadoodi (2022)

8.2 Thinking in Systems to Re-Design Industries

Eco-Design, Circular Design, Design for Circularity, Cradle-to-Cradle Design, Green Design, Regenerative Design, Climate-Responsive Design, Life-Centered Design, Multispecies Design - designing for sustainability has been called with many names in diverse contexts of use, using a diversity of approaches, with subtle differences of emphasis and nuance, with same general goal of being more sustainable. While the European ESPR legislation chose *Eco-Design* as the overarching title, researchers and practitioners discuss all of the above on a frequent basis. (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*”.

In most cases, designing for sustainability makes use of *systems thinking*, underlining the importance of looking at the entire life-cycle of a product or service.

Calculating what's sustainable is hugely complex because decisions may have unforeseen ramifications. To take a single example (Nuez et al., 2022) shows how electric vehicles may increase CO₂ emissions in some areas, such as Canary Islands, where electricity production is polluting.

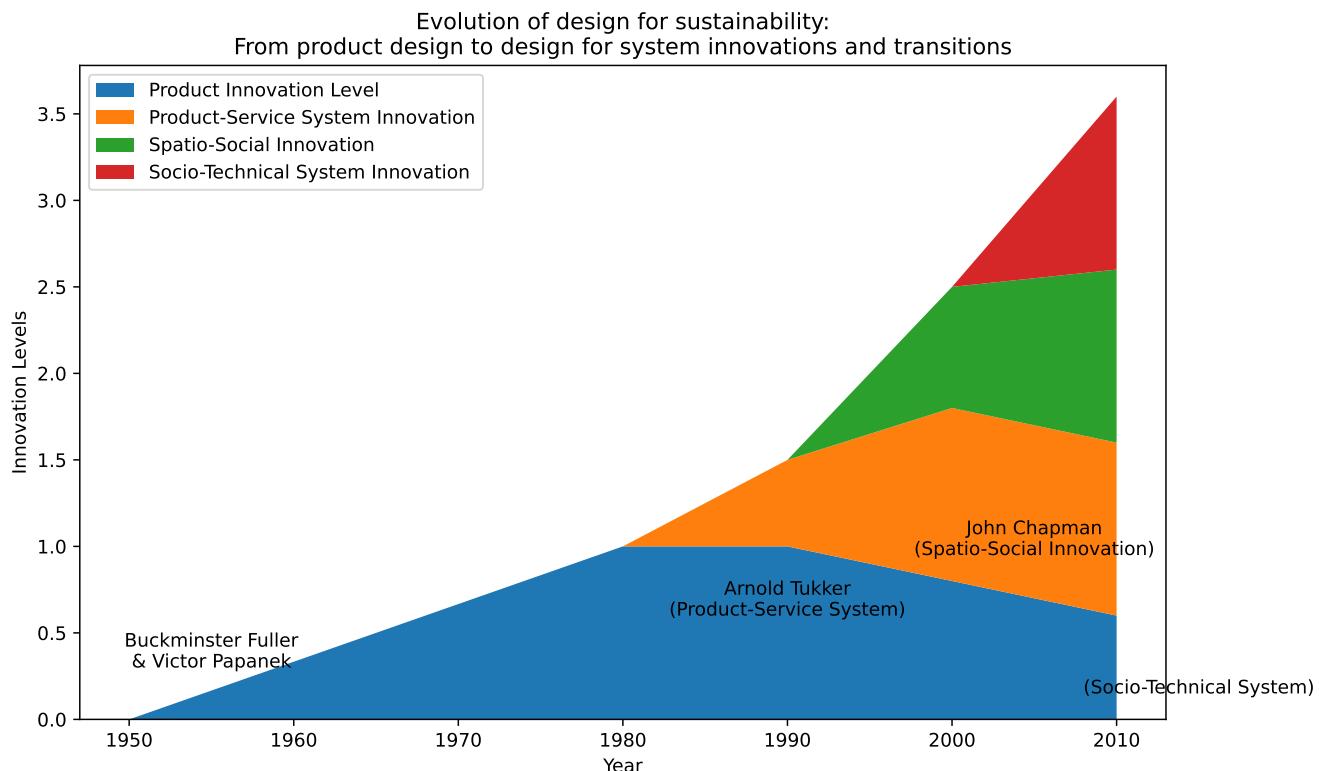
Sustainable design encompasses all human activities, making this pursuit an over-arching challenge across all industries and all human activities with the complex interdependence contained within these interactions.

Rossi et al. (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.

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".

(Engkvist, 2024) calls for *Design Sociology*, design should take account the product's effect on society, giving the example of highly individualized understanding of individualized psychology and dopamine cycles for creating social media, while disregarding the societal effects, such as spread of misinformation. Lack of sustainability in the design process is a *bug* in the design approach.

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 *Cargo Bike / FREITAG* (n.d.), 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 et al., 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*”, “*naturung*”, “*mother naturung*”, “*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* (Edwards & Pettersen, 2023; Hupkes & Hedman, 2022)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 et al., 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, one 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 dematerializing (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 (S. Lee & Doevedans, 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. “*台灣設計研究院 (TDRI) on Instagram*” (2021) 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 than previously feasible, there are many approaches looking for ways to design for sustainability. Designing for Sustainability is fundamentally a hopeful act imbued with the dream a healthier world is possible.

Multispecies Design refers to the idea of considering non-human life-forms as stakeholders of our design. (D. Metcalfe, 2015)'s PhD Dissertation titled "*The devastating effects that unsustainable design practices have on the natural world and other species with whom we share this planet*" gives a good overview of the work done in this branch of design.

- Kosová et al. (2023); Selvan et al. (2023); Hernandez-Santin et al. (2023)
- gallery Marcus (06-11-23)
- Participatory design and multi-species design Haldrup et al. (2022)
- The University of Melbourne, Australia & Roudavski (2020)

8.2.1 Student Essentials: Fast-Moving Consumer Goods, Clothes, and Food

Student Essentials: Clothes, Food, Fast-Moving Consumer Goods (FMCG)

As of 2025, *circular economy* is a tiny part of the world economy. (Circle Economy, 2022) reported in 2022 only 8.6% of world economy was circular and *100B tonnes of virgin materials* was sourced every year.

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.

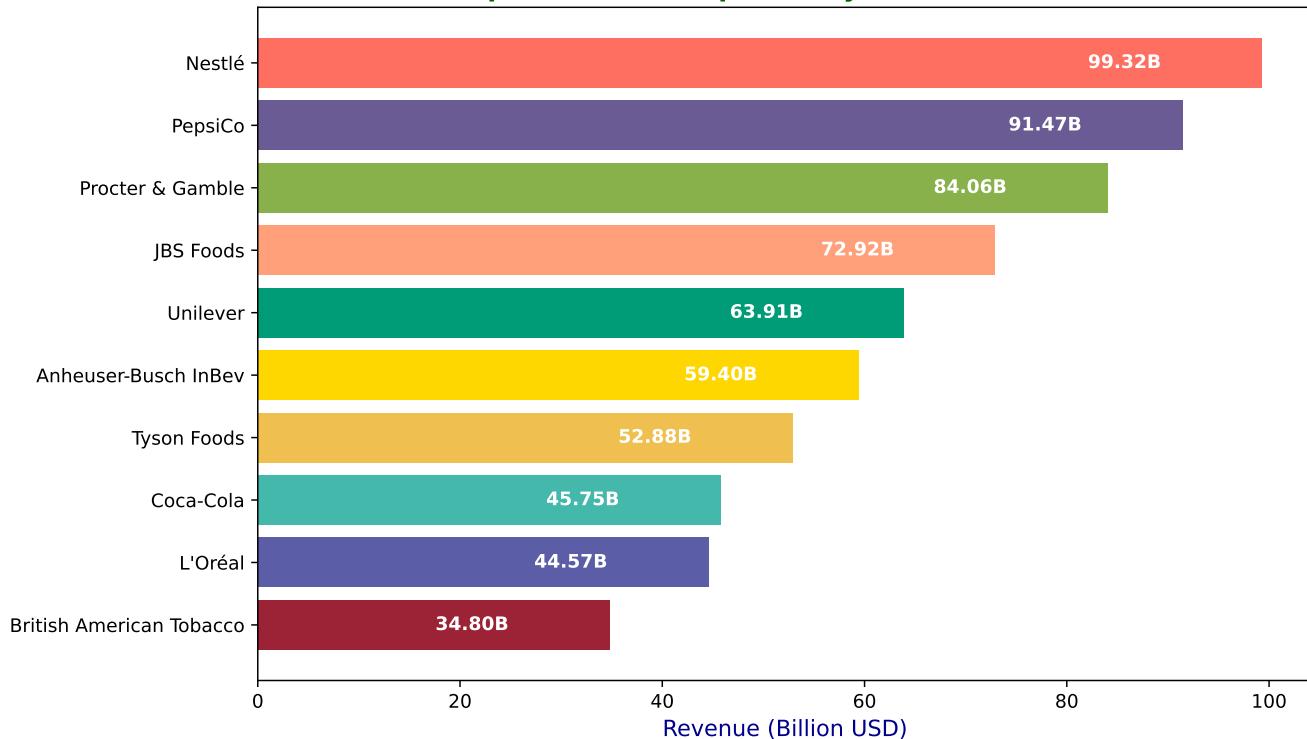
- 5th industrial revolution, advanced robotics
- 6th industrial revolution, quantum computing, nanotechnology Chourasia et al. (2022)
- 7th industrial revolution futurists are looking at current trends and building scenarios for 2050 envisioning a world where the convergence of bio-based and mineral-based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

...for Provenance and Traceability

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

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

Top 10 FMCG Companies by Revenue in 2023



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

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 (“Young Consumers’ (Complicated) Love For Fast Fashion In 3 Stats,” n.d.). (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 et al., 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 et al. (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 CO₂, 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 (Y. Jiang, 2023).
- Luxury - Conversely, Taiwan is a growing market for luxury brands (Karatzas et al., 2019).

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

- (Hannah Ritchie, 2020; US EPA, 2016) GHG emission inventory by sector
- Marrucci et al. (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
- "Transparency and Sustainability Platform - Renoon" (2023) Ethical Shopping
- "Sheep Inc. - Softcore Radicals" (2023) Ethical brand?
- Good On You (2023) Sustainable fashion company evaluations
- *Lily / Mindful + Active Living on Instagram* (n.d.) Garment Worker's rights
- Emily Chan (2022c): fashion companies can't be held accountable for their actions (or indeed, their lack of action).
- *Instant Gratification for Collective Awareness and Sustainable Consumerism* (2022): "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
- "Clean Clothes Campaign" (n.d.)
- "The mainstream fashion industry is built upon the exploitation of labor, natural resources and the knowledge of historically marginalized peoples."

- *Textile Genesis* (n.d.)
- “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)
- “New Standard Institute” (n.d.)
- *BGMEA / Home* (n.d.) Bangladesh Garment Manufacturers and Exporters Association
- Minimize shopping, buy quality, save CO₂, 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
- Infinitd Fiber (2023)
- Cleantech Group (2023) Global cleantech 100
- *SOJO - Door-to-Door Clothing Alterations and Repairs* (2023) Alterations and repairs made easy
- “Good On You - Sustainable and Ethical Fashion Brand Ratings” (2023) Ethical brand ratings

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 et al., 2023).

“The agricultural sector contributes to approximately 13.5% of the total global anthropogenic greenhouse gas emissions and accounts for 25% of the total CO₂ 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 CO₂ 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. A. S. 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 laboratory tests (ERR, 2023)
- China is the largest honey producer.
- Food fraud

“Sustainability Intelligence for Food Companies” (n.d.)

Open Food Facts - World (n.d.) app for nutrition and sustainability data

Fishing

- 75% of fishing is done using industrial Trawling, which has environmental impact
- J. L. 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). (C.-H. 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 (IUU) fishing is widespread; the EU is adopting countermeasures (D. E. 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 (E. 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 Initiative
- “Reality Labs Research at Meta Connect 2022” (2022)
- *Real Time ESG Tracking From StockSnips* (2021) “Real Time ESG Tracking From StockSnips”
- Waters (2015) (**Need access!**)
- Cawthorn & Hoffman (2016) (**Need access! ncku doesn't subscribe**)
- 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

Culture can be a proponent of sustainability. 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 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).

- Tsing (2015) mushrooms
- 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 thrown away.

Olio, Too Good To Go

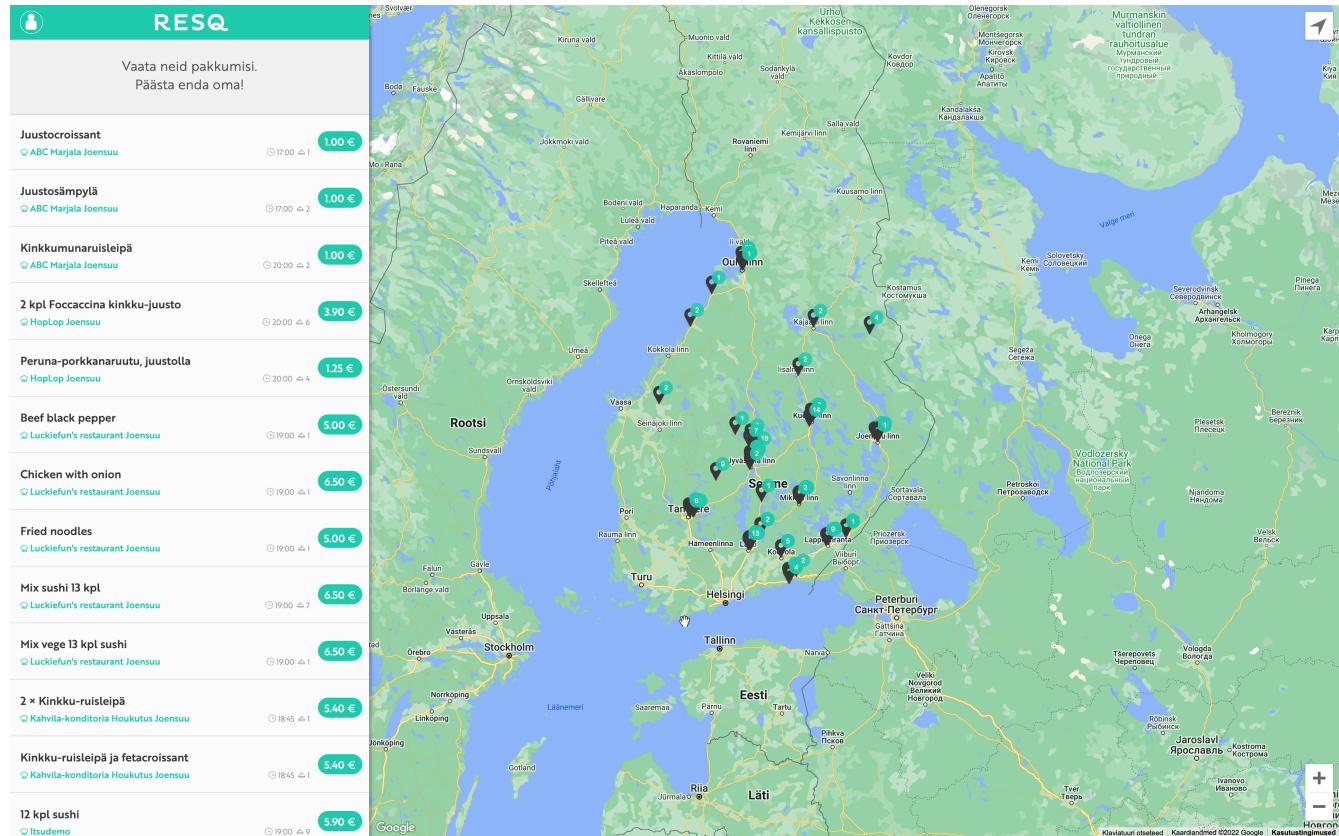


Figure 13: ResQ Club saves food waste by selling left-over foods cheaply

Table 26: 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

Name

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 27: 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”
“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.

8.3 In Practice Sustainability Begins in Software

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.

Designing user interfaces for sustainable interactions means incorporating data and tools to enable designers to make decisions which reduce the emissions of their designs. Companies like AutoDesk have introduced CO_{2e} calculations inside their design software, helping designers reduce material usage, energy consumption, CO_{2e} emissions, while increasing potential for reuse and recyclability(Mike Haley, 2022).

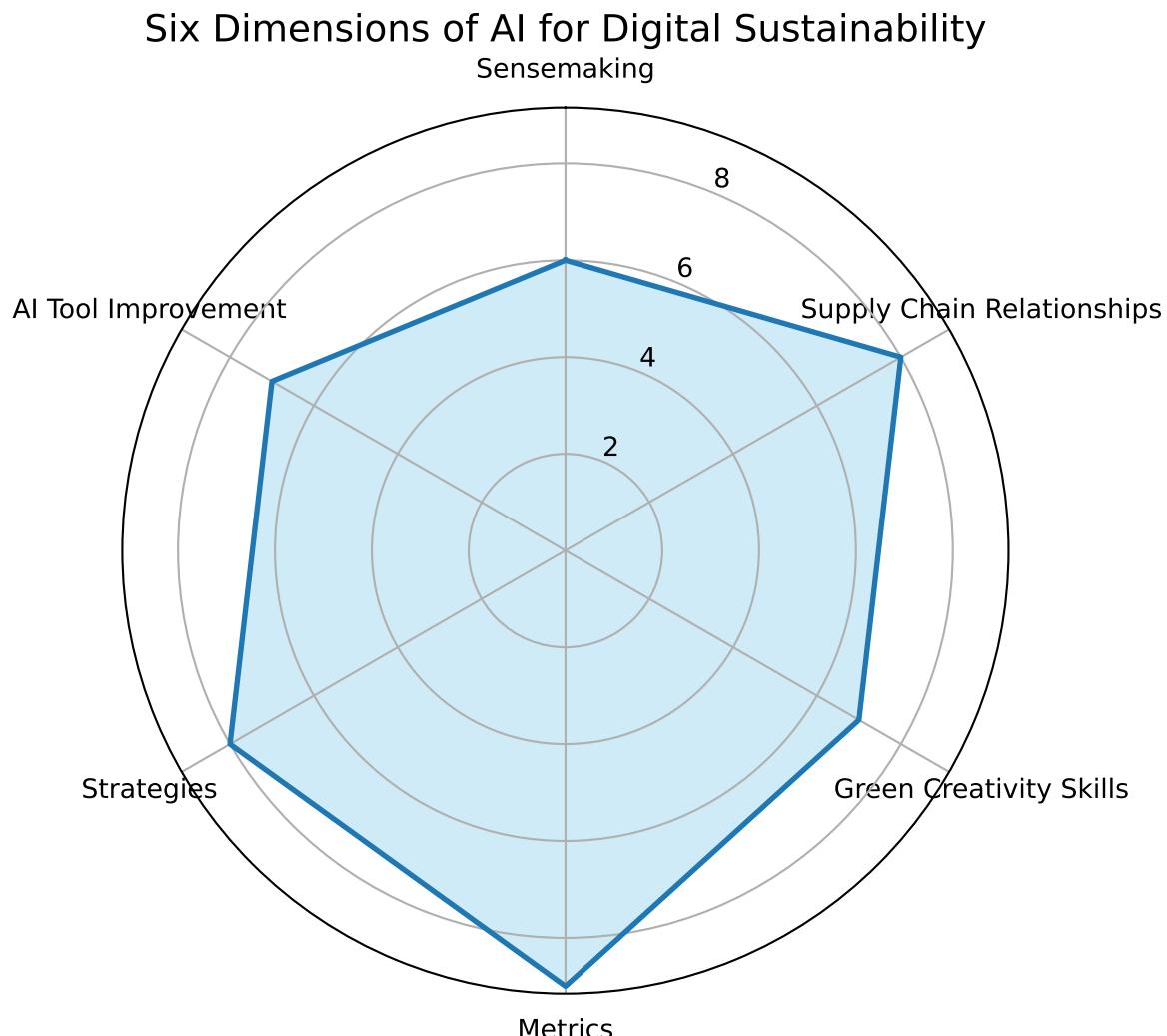
Software is key to building more sustainable products, already for decades (B. B. Gupta et al., 2023). AI-assisted design enables design for sustainability because the design process is where sustainability begins. AI has the potential to provide the parameters for sustainability. (Singh & Sarkar, 2023) proposes an AI tool for deciding the suitable life cycle design parameters.

- Involving young HCI designers in AI-oriented workshops can show the future of UI/UX ? (Battistoni et al., 2023)
- 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) proposes 6 dimensions of AI usage in *Digital Sustainability*.

Notice: The chart is purely illustrative to highlight the value of AI for sustainability; it's not based on numeric metrics.



- The En-ROADS climate change solutions simulator allows governments, organizations and individuals explore climate scenarios based on interactive changes in a visualization tool (Climate Interactive, n.d., 2023; Creutzig & Kapmeier, 2020; Czaika & Selin, 2017).
- “Research shows that showing people research doesn’t work,” John Sterman

8.3.1 Data-Driven Design

Learning from the Growth of Digital Platforms and Superapps.

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.

Digital platforms are focused on *Growth Design*, how to *attract* and *retain* users. Superapps are the latter stage of the Digital Platform Economy, where previously vertically targeted apps expand horizontally to provide an ever-increasing number of services.

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 on-boarding, features, and personalization (Kende, 2023; Steger, 2019).

- Hypothesis and validation for iterating on features.
- Total addressable market (TAM), serviceable addressable market (SAM), target audience (TA)

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 touchpoint on the user journey (to use the language of service design) at the scale of hundreds of billions of users.

8.3.2 Circular Design

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

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).

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. 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 papers researching blockchain use in supply chain 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 28: 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

- Embodied Carbon
 - “embodied carbon”
 - Carbon Neutral Cities Alliance
 - Builders for Climate Action (2021)

Circular Design for a Circular Economy

Encouraging Sustainable Design and Reducing Waste.

(K. Liu et al., 2023) 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; J. Fox, 2007).
- Recycling Critical Raw Materials, digitization of mining allows enhance the reliability of supply chains (CRM Alliance, 2020).
- EIT RawMaterials

Sustainable Supply Chain

8.3.3 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”* (*Climate Change Mitigation*, 2023). Freight (transport of goods by trucks, trains, planes, ships) accounts for 1.14 gigatons of CO₂ emissions as per 2015 data or 16% of total international supply chain emissions (Yuqing Wang et al., 2022).

Table 29: Share of CO₂ of CO₂ 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 eradicate human trafficking and slavery in their supply chains. Similarly, 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).

8.3.4 Tracking Ethics & Cruelty

Data transparency may help reduce cruelty by improving traceability.

- 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
- Doconomy offers an Åland Index that links financial transactions to carbon impact

8.3.5 Tracking Factories Can Become 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)
- *CO2-neutral Factories* (n.d.) and *Innocent Opens £200m Carbon-Neutral Factory in Rotterdam - Investment Monitor* (n.d.) CO₂ neutral factories?
- (*Ecograder*, n.d.; *Make Your Website Carbon Neutral and Enhance Your Brand / CO2 Neutral Website*, n.d.) CO₂ neutral websites
- Eric fogg (2020) Lights-Out Manufacturing
- Mowbray (2018) “World’s first free digital map of apparel factories”

- “FFC - Fair Factories ClearingHouse - Compliance Solutions” (n.d.) Factory compliance - Fair Factories
- Planet Factory
- *To the Companies We Have Unveiled in the Plastic Waste Makers Index* (n.d.) Plastic waste makers index, sources of plastic waste

8.4 Superapps Already Integrate Shopping, Savings, and Investing

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).
- (Cuppini et al., 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

Superapps are prevalent in Asia, with China, South-East Asia, Korea, Japan, and India leading the way.(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. (Shabrina Nurqamarani et al., 2020) discusses the system consistency and quality of South-East Asian superapps Gojek and Grab.

Superapp	Origin	Markets	Metric	Payments				Users	Date	Source
				(Wallet)	Savings	Investing				
微信 / WeChat (Ten-cent)	China	China	Monthly Active Users (MAU) com-bined 微信 (China) & WeChat (Inter-national)	YES	YES	YES		1,4 billion	2024	Tencent (2024)

Superapp	Origin	Markets	Metric	Payments (Wallet)		Savings	Investing	Users	Date	Source
支付寶 Alipay (Ant Group)	China	China	Annual Active Users (AAU)	YES	YES	YES	YES	1.3 billion	2020	Ge & Wei (Jul 20, 2020 06:42 PM)
美團 Meituan	China	China	Annual Transacting Users (ATU)	YES	NO	NO	NO	700 million	2024	Jing (2025)
PhonePe	India	India	Registered Users (Life-time)	YES	YES	YES	YES	500 million	2023	(phonepePhonePe)
LINE	Japan	Japan, Taiwan, Indonesia, Thailand	Monthly Active Users (MAU)	YES	YES	YES	YES	200 million	2023	LY Corporation (2023)
Tata Neu	India	India	Members	YES	YES	NO	NO	27 million	2023	Shinde (2023)
Nubank	Brazil	Brazil, Mexico	Customers	YES	YES	YES	YES	114 million	2024	Pollo (2025)
Zalo	Vietnam	Vietnam	Monthly Active Users (MAU)	YES	NO	NO	NO	75 million	2023	Nguyen & Nguyen (2023)
Paytm	India	India	Monthly Transacting Users (MTU)	YES	YES	YES	YES	100 million	2023	Verma (2024)

Superapp	Origin	Markets	Metric	Payments		Savings	Investing	Users	Date	Source
				(Wallet)						
M-Pesa	Kenya	Kenya, Tanzania, South Africa, Afghanistan, Lesotho, DRC, Ghana, Mozambique, Egypt, Ethiopia	Active Customers	YES	YES	NO		34 million	2024	Safaricom (2024)
Mercado Pago	Argentina	Argentina, Uruguay, Mexico, Chile	Monthly Active Users (MAU)	YES	YES	YES		61 million	2023	Mercado Libre (2024)
PicPay	Brazil	Brazil	Active Customers	YES	YES	YES		35 million	2023	Oost (2024)
Cash App (Block)	USA	USA	Monthly Active Users (MAU)	YES	YES	YES		56 million	2023	Kazanins (2024)
KakaoTalk	Korea	Korea	Monthly Active Users (MAU)	YES	YES	YES		48 million	2024	Philip Lee (2025)
GoTo (Go-jek/Tokopedia)	Indonesia	Indonesia	Annual Transacting Users (ATU)	YES	YES	YES		51 million	2023	goto (2023)
Revolut	UK	UK / EU	Customers	YES	YES	YES		50 million	2024	Revolut (2024b)

Superapp	Origin	Markets	Metric	Payments		Investing	Users	Date	Source
				(Wallet)	Savings				
Careem	UAE (Acquired by US-based Uber Etisalat brand)	United Arab Emirates, Saudi Arabia, Jordan, Iraq, Kuwait, Morocco, Bahrain, Pakistan, Egypt, Morocco	Customers	YES	NO	NO	70 million	2024	Careem (2025)
Grab	Singapore / Malaysia	SEA acting Users (MTU)	Monthly Trans-acting Users	YES	YES	NO	41 million	2024	Grab Holdings Limited (2025)
Rappi	Colombia	Argentina, Colombia, Brazil, Chile, Mexico	Users	YES	YES	NO	30 million	2023	Phocuswright (2023); R. Brown (2025); Laya (2024)

Global overview of superapps (or near-superapps) compiled from official company reports (IR, Press Releases), news reports, and company websites; various metric types (MAU, MTU, Annual Users, Customers, Registered Users) vary by company reporting and are reduced into a single “users” metric for simplicity. Each figure is sourced from official company reports, press releases, or investor disclosures. If no recent official update was available (as in the case of Alipay’s 2020 figure), the latest known official figure is provided. All values and dates reflect the latest data as

Not- Quite- Superapp	Origin	Markets	Metric	Payments				Users	Date	Source
				(Wallet)	Savings	Investing				
Uber	USA	Global	Users per month	NO (Only for ride-hailing)	NO	NO		171 million	2025	Uber (2025)
Bolt	Estonia	Global	Lifetime users	NO (Only for ride-hailing)	NO	NO		200 million	2025	D. C. Garcia (2025)

In the UK, Uber launched an option to book flights, moving to a door-to-door travel solution where the same app brings you from home to the airport, the flight, and your final destination Uber UK (2023)

Superapps are honeypots of data that is used for many types of behavior modeling. Guido Becher from Rappi defines their super-app as “customer-centric high frequency multi-vertical ecosystem” this enables cross-promotion, for example a hotel in Argentina targeted people who buy almond milk on Rappi with their offer of a yoga retreat (Phocuswright, 2023; G. 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, such as the collaboration between Bolt and the city of Seville in Spain (Bolt, 2025).

Kakao Pay was found guilty of mishandling 40 million users’ data by handing it over to Alipay without user consent; Alipay owns a 32 percent stake in Kakao Pay (K. Lee, 2024).

59 million people use Zhixiaobao, an AI financial assistant inside the Ant Fortune and Ant Insurance mini-apps inside Alipay (Finextra, 2024).

Alipay has built the digital infrastructure to provide thousands of services to billions of users

Superapps offer a platform with key infrastructure such as payments, where miniapps thrive Perri (2022); Heath (2021)

8.4.1 Aspiring Superapps

There are many companies which aspire to build superapps but are hindered by various challenges.

Telegram integrates web3 apps into the chat and supports investing into cryptocurrencies without ever understanding the complex technology of wallets. Pylarinou (2024)

LINE is integrating web3 technologies based on the Kaia blockchain to provide decentralized mini-apps (dapps) for the LINE chat userbase and integrates with the LINE Pay wallet for financial interactions Hintzy (2025)

(Vecchi & Brennan, 2022) discusses the strategies Chinese apps are taking to expand to other markets.

- Inspiration from WeChat. X (previously known as Twitter) is becoming a financial app. X (formerly Twitter) is becoming a superapp?
- Uber is creating an all-purpose platform; only 4.1% of rides were electric (Levy, 2023).

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?

Platform Economy		
Enablers	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.
- Platform economy companies have been criticized for their lack of workers rights (ESG). (“Riders in the Smog,” 2024) uses portable air pollution tracking devices to documents how gig workers are subjected to pollution.

8.4.2 Personalization: Personality Engineering and Persuasion

- AI labs are putting a lot of effort into engineering likable AIs , Anthropic (2024a). working on honesty of the models, teach them to convey their own uncertainty Anthropic (2024b);

which sometimes can go wrong. ChatGPT o4 overnight became your biggest fan, which users found annoying Mollick (2025)

the book, an AF (artificial friend) Klara describes loneliness Ishiguro (2021); Waterstones (2021); Life Lessons From Books (2023)

ChatGPT-4o’s abrupt shift to an overly enthusiastic persona drew user backlash.

“Kazuo Ishiguro’s Klara and the Sun offers a cautionary counterpoint, illustrating how even the most loyal and emotionally attuned AI can be perceived as uncanny or insufficiently human. These examples underscore the delicate balance required when designing AI companions for sustainability: persuasion must feel personal, but not performative.” ”

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

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>
 - *A Comprehensive Guide to Design Systems / Inside Design Blog* (n.d.)
 - M. Suarez et al. (n.d.)
 - “Method Podcast, Episode 18” (n.d.)
 - *Atomic Design by Brad Frost* (n.d.)
- 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)
- *People + AI Guidebook* (n.d.)
- “Language Model Sketchbook, or Why I Hate Chatbots” (n.d.)
- 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 (“Interaction Design – How to Evaluate Interaction Costs and Improve User Experience,” 2021; Oviyam™, 2019; 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. (Alethea AI, 2021) discusses writing AI Characters, creating a personality, Stories start with a character..

- Writing as training data? large language models. GTP3.

8.5 Open Data Enables Eco-Interoperability

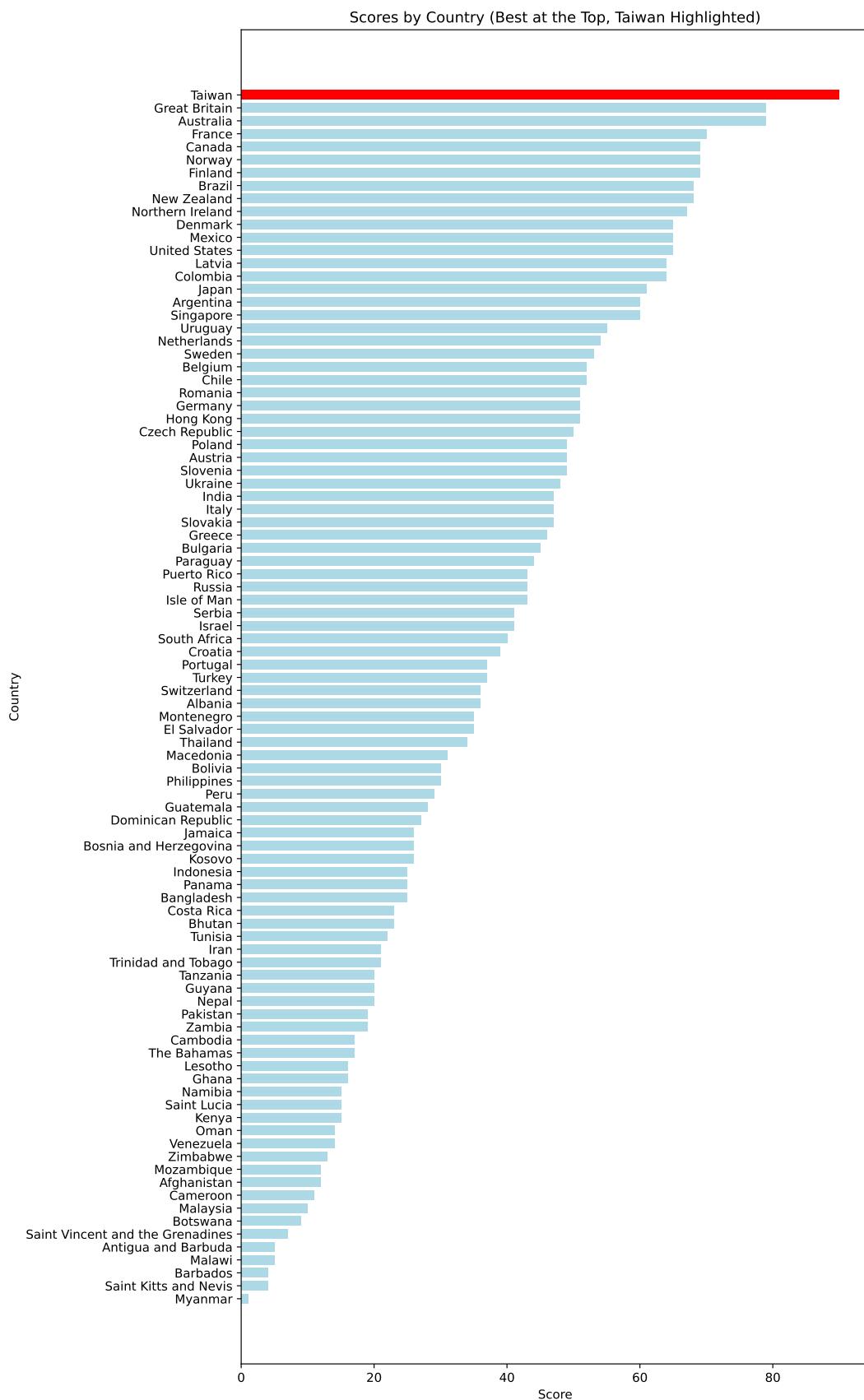
Data is the *interface* between idle resources and retail demand, which makes *exchange of value* possible. Yet often data is expensive, hard-to-get, and inaccessible.

Open data is needed for civic engagement. Sharing vs privacy is a political question. Privacy and data-sharing are not in opposition. 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 potential privacy issues.

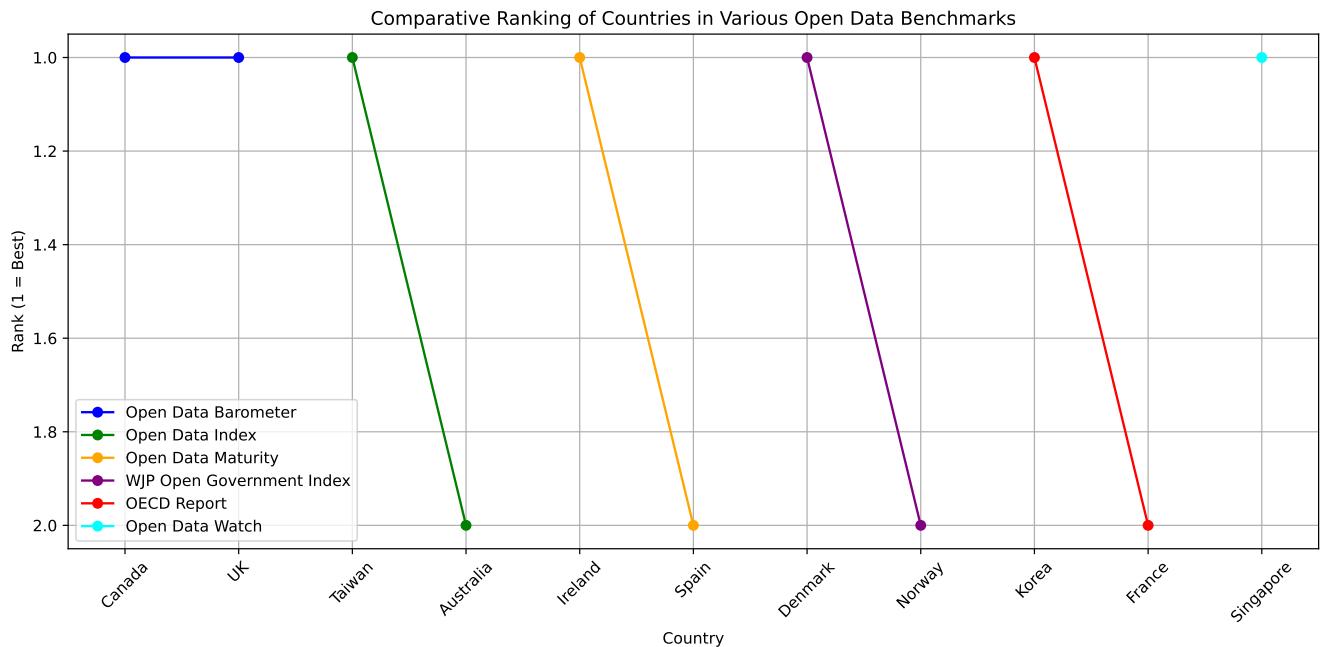
Open Data Enables Collaboration. Taiwan is a proponent of Open Gov OP-MSF OGP (Lab, 2021; Open Government Partnership, 2021).

open data can Enhance interoperability *What Is Open Data?* (n.d.)

Open Knowledge International's Global Open Data Index (GODI) ranked Taiwan as number 1 in its global index in 2017; the project has since been discontinued, so the ranking may be out of date in 2024 (Open Knowledge Foundation, 2017).



Other indexes do not include Taiwan in the TOP 10.

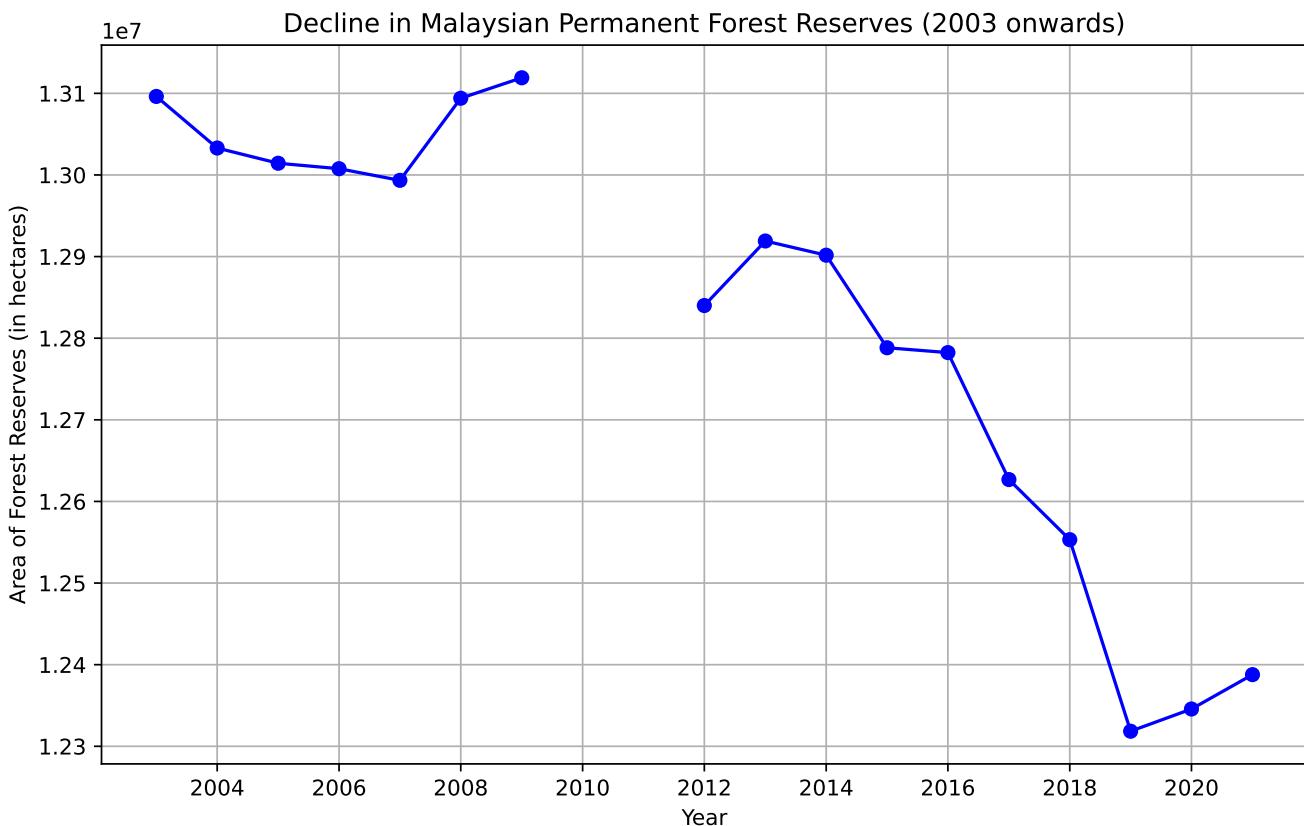


Data-driven design requires access to data. making the movement towards *open data sharing* very important. Some countries and cities are better than others at sharing data openly.

Table 33: Examples of cities and countries that share data openly.

Country	Project	Reference
Sweden	Swedish open data portal	“Sveriges Dataportal” (n.d.)
Malaysia	Malaysian open data portal	data.gov.my
Estonia		

For example the Open Data Portal of Malaysia shows a steady decline in Permanent Reserved Forests (PRF) for anyone interested, without having to submit any letter of request or communicate with officials; the data is just directly accessible and includes a permissive license (Malaysia, 2024).



8.6 Context Design Enables Behavioral Nudges Towards Green Defaults

For several decades, marketing researchers have been looking into 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 et al., 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 CO₂ 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%” CO₂ 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 (Google, 2023; *Inside Google’s Regenerative Agriculture Play / Greenbiz*, 2021).

Google VERY IMPORTANT Google (2021).

Google has launched eco-focused features across its range of products, most famously Google green routes for driving, which collaborate with local city governments to have data from the semaphores, which allows the map to suggest routes which would reduce stopping “Google mostrará por defecto la ruta más ‘verde’ en su GPS y ordenará los vuelos según su impacto ambiental” (2021); Worthington (2025a)

While Google has launched several climate-focused initiatives, it missed its CO₂ reduction targets due to growing need for AI models Worthington (2025a)

Justine Calma (Oct 6, 2021, 10:01 AM GMT+3) Google UX eco features.

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? “Google ‘Airbrushes’ Out Emissions from Flying, BBC Reveals” (2022)

Table 34: Examples of CO₂ 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; reduce stopping by using data from traffic lights.
Google Flights suggests flights with lower CO ₂ emissions	Google Flights	Show flights with lower CO ₂ emissions
Wizzair Check carbon impact <i>Offset Your Flight with WIZZ</i> (n.d.)	WizzAir	Offset on Checkout

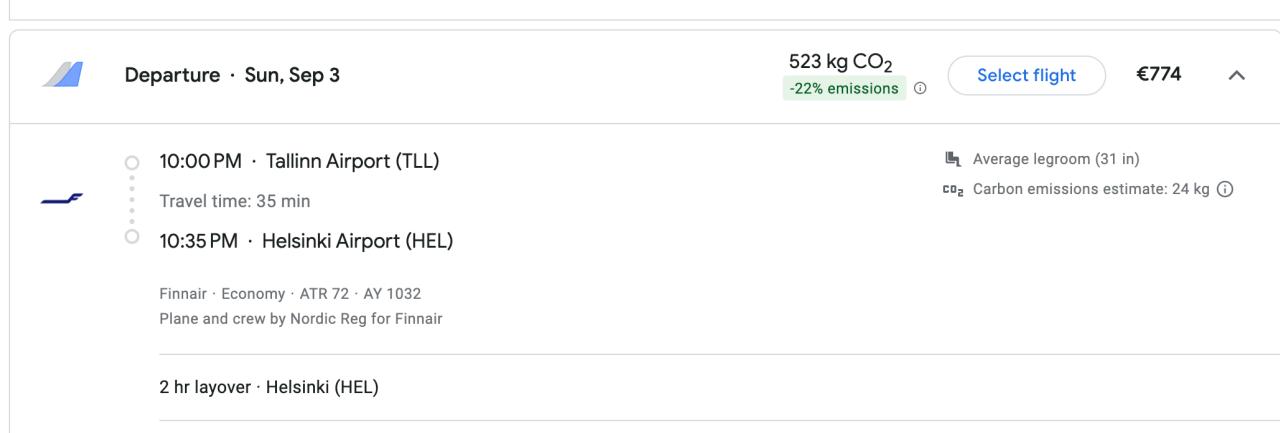


Figure 14: Google's view of flight emissions

Some notable examples:

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

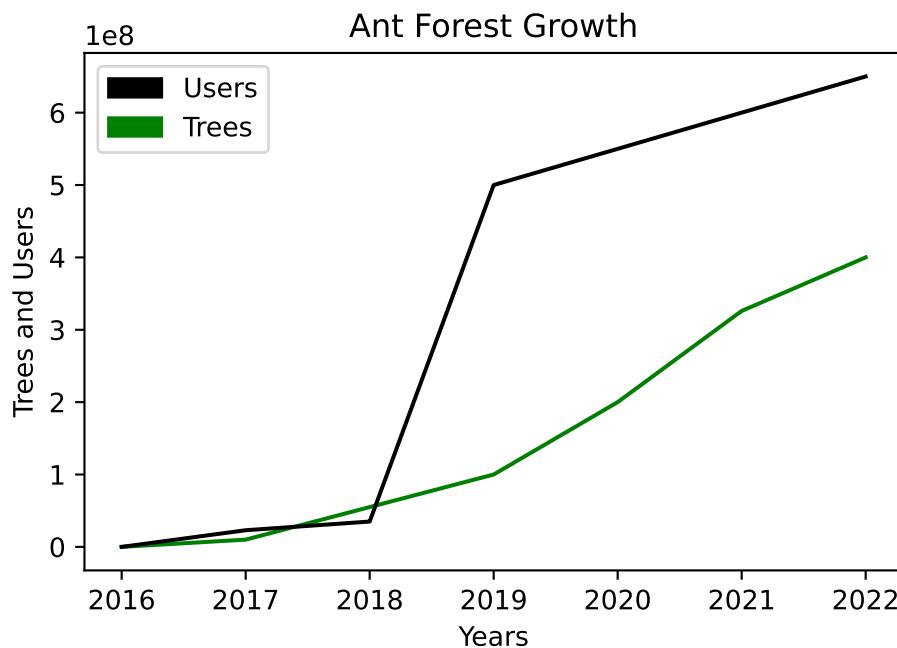
Table 35: Types of nudge by Wee et al. (2021)

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

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 36: Table of Ant Forest assisted tree planting; data compiled from (P. Cao & Liu, 2023; *Over 600 Million People Planted More Than 326 Million Trees via Alipay Ant Forest in Five Years*, 2021; UNFCCC, 2019; S. Wang et al., 2022; X. Wang & Yao, 2020; Z. Yang et al., 2018; B. Zhang et al., 2022; F. Zhou et al., 2023; 张越熙, 2024; 李连环 & 姜舒译, 2017; 胡群 & 宋璠, 2024).

Year	Users	Trees	Area
2016	N/A	N/A	N/A
2017	230 million	10 million	N/A
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	N/A
2022	650 million	400 million	2 million hectares
2023	690 million	475 million	N/A
2024	N/A	548 million	3.87 million hectares
2025	N/A	N/A	N/A



New User Interfaces

- AR / VR
- AI Chatbots
- Generative UIs

The small screen estate space of mobile 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*”. *it’s a balancing act:* while AI enables generative UIs while users need some type of stability (think: text input stays in the same place but different types of interfaces appear within a clearly defined space).

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

Table 37: Modes of interaction

Mode of Interaction
Writing
Speaking
Touching
Moving
Seeing

Community

Building a community is a way to design a context, where the culture creates certain expectations of behavior.

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? (Armstrong & Staff, 2021; Lakshmi Rebecca, 2018).

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. (C. D. 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 et al., 2021).

What are the building blocks of a thriving community?

Experience instead of read..

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

World Cleanup Day has attracted 10s of millions of people to do beach and forest cleanups.

8.7 Learning from Quantified Self: Tracking Health and Lifestyle

An early example of how tracking personal data enables behavior change, are health and lifestyle tracking apps. Research on *personal data tracking* also known as *quantified self* or *self-monitoring* is abundant. There's substantial academic evidence indicating that health tracking apps can have a measurable impact on user health behaviors and increase positive health outcomes. 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 tracked, but exposure to pollution as well as personal carbon footprint, are all to some extent trackable (if not traceable).

Recently, npj Biosensing published a device from the MIT Media Lab that can track cells inside the human body from a wrist-worn device (Jang et al., 2025; Jarvis, 2025)

8.7.1 Health and Fitness Tracking

Tracking one's health and fitness is a familiar mode of *quantified self*, available to many smartwatch users - and even pretty much to anyone who has a phone made in the past decade. Apple is a leader in health tracking, releasing Apple Health in 2008 as an iOS 8 software feature and the Apple Watch in 2015, filled with health-focused sensors and features (Apple, 2022b). In 2022 Apple outlined plans for "*empowering people to live a healthier day,*" promising a new set of health-features with every release, such as the rumored temperature measurement inside of Apple Aipord earphones; and providing most of this data to developers through Apple's HealthKit health metrics APIs, which app builders can tap into (Apple, 2022a, 2022c).

Sleep quality is an important aspect of health and many devices and apps focus on helping people get enough high quality sleep. There's plenty of academic literature on how physical activity, as well as environmental aspects, such as air quality, affect sleep (X. 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).

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 ("Is Blood Sugar Monitoring Without Diabetes Worthwhile?" 2021). Tracking urine consistency inside your toilet with WithThings. Companies like NeuralLink are building devices to build meaningful interactions from brain waves (EEG).

Use technology Wearables to be more aware of one's health. Example of quantified self device. an example of Personalized Design: Self-Monitoring feels personal.

There's value in developing standardized fitness metrics, which different digital health providers can use to create dashboards with comparable data. Even with messy data, AI has a useful role as a translator between different standards.

Could one track personal sustainability in a similar fashion? (G. 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 of transport but requires the availability of city infrastructure, such as sidewalks, which many cities still lack.

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 ideas 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 et al. (2022) suggests greener modes of mobility.
- Shop sustainability in Estonia (*Estwatch - Estwatchi värskest Uuringust Selgub, Et Eesti Toidupoed... / Facebook*, n.d.; Lilleväli, 2022). Tarbimise jalajälg poes (Helen Saarmets, 2021). Offsets at the point of sale (*Grenipay - Heasta Oma CO₂ Jalajälg*, n.d.).
- 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.

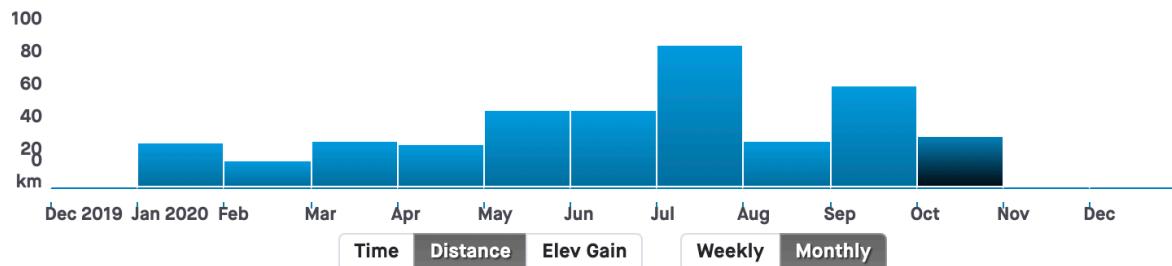
Another aspect is tracking one's mental health. (Tyler et al., 2022) surveys the use of self-reflection apps in the UK (n=998).

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

Activities for Oct 2020

Dec 2, 2019 - Nov 30, 2020 ▾

30.4km | 3h 2m | 260m



Kris Haamer

October 25, 2020 at 7:45 PM



Evening run

12.11 km 5:28 /km 1h 6m 🏆2

運河東向run PR (12:11)



Kris Haamer

October 17, 2020 at 6:27 AM



Morning jog around the island

18.31 km 6:21 /km 1h 56m



+5



[See all 3 comments](#)



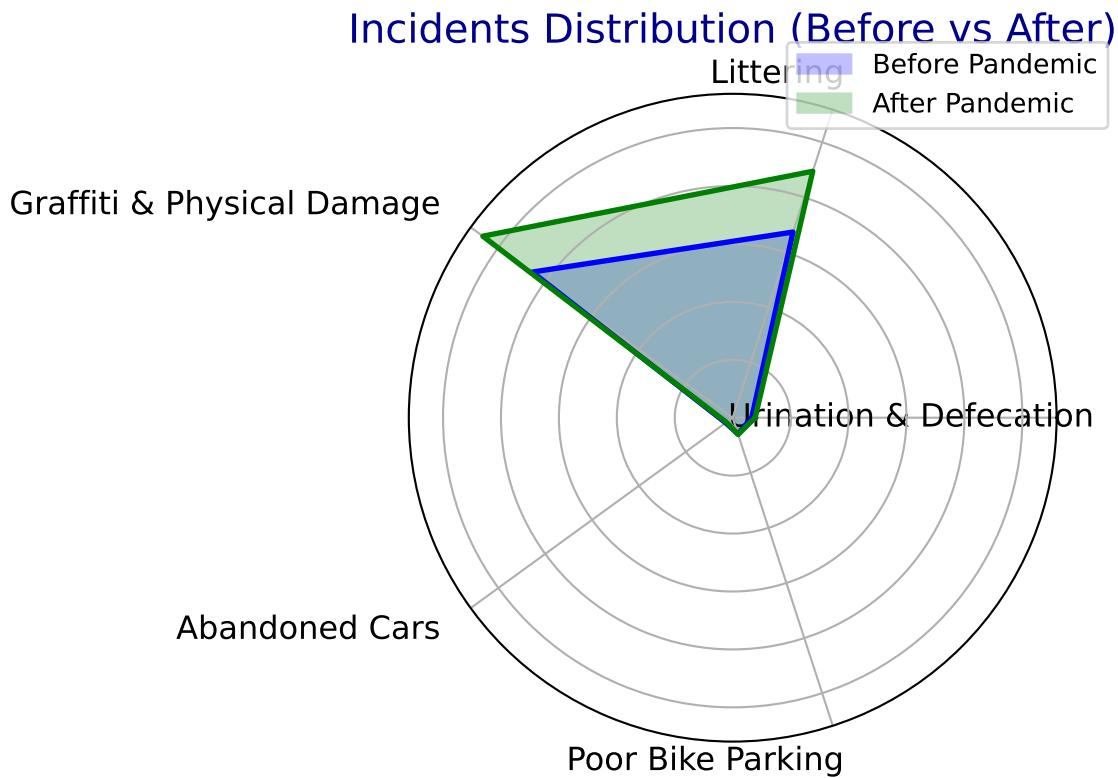
Kris Haamer José Manuel Ferreira PT Sim, é! E me faz recordar

Figure 15: Popular Strava sports assistant provides run tracking and feedback

- Ryan (2022) uses the “capability methodology” to evaluate if apps help people eat healthily.

- P. M. Baptista et al. (2022) apps for sleep apnea

Human behavior is affected by the environment; example in case, the incidence of bad behavior during the pandemic increased significantly.

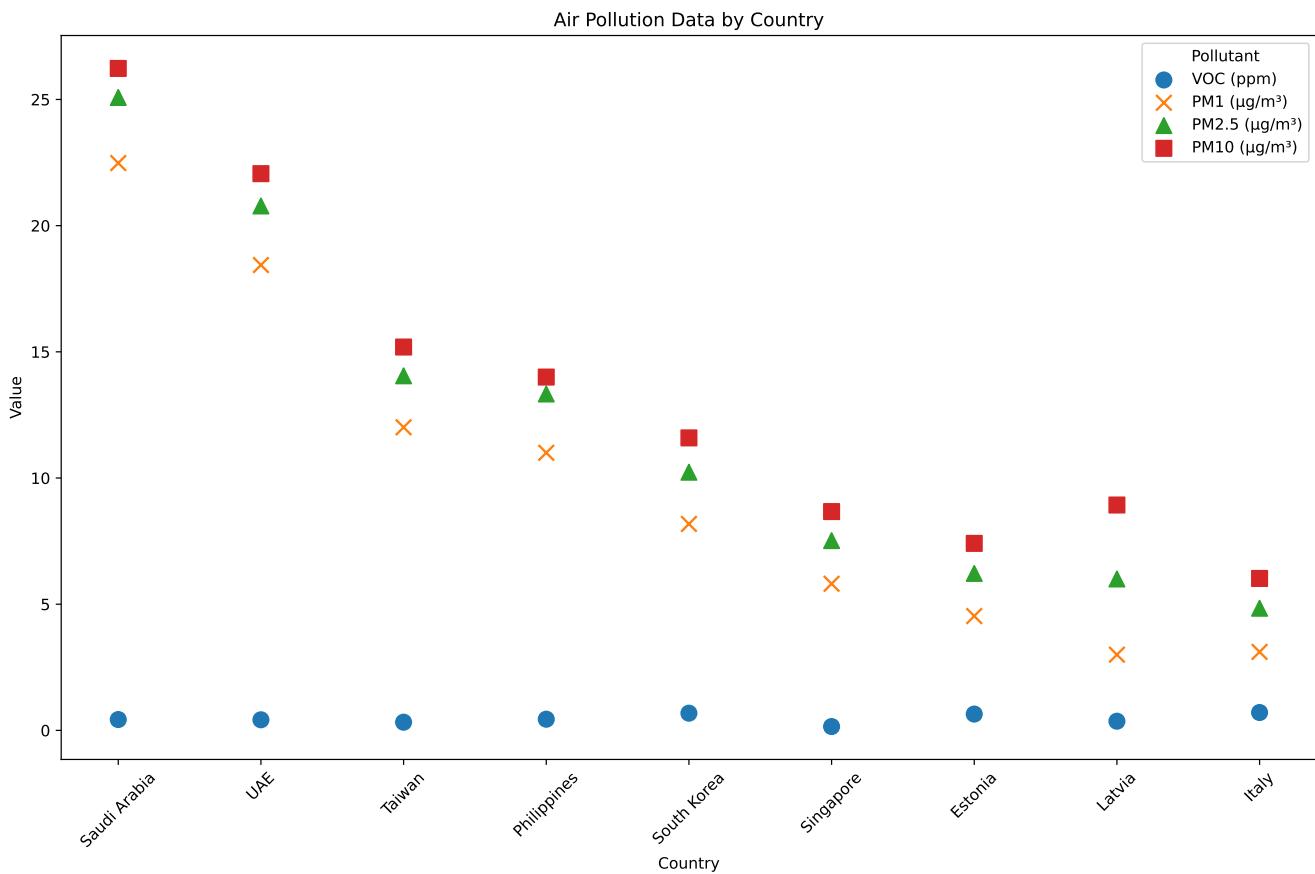


8.7.2 Pollution Exposure Tracking

Pollution exposure tracking may be considered a combination of health tracking and sustainability 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).

- add picture of the device
- add picture of air pollution in China



8.7.3 Carbon Tracking

The founder of the Commons (formerly known as Joro) consumer CO₂e tracking app recounts how people have a gut feeling about the 2000 calories one needs to eat daily, so perhaps daily CO₂e tracking could develop a gut feeling about one's carbon footprint (Jason Jacobs, 2019).

Tracking sustainability may have collective benefits but tracking health has immediate personal benefits. Health apps feel tangible with increased well-being while sustainability apps often feel more collective, long-term and sometimes with benefits too small to matter, making it harder to motivate individual users.

However, sustainability tracking, while perhaps less than health tracking, can have a measurable impact. One study of 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% (S. 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 (S. 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 CO₂ trackers help one track emissions and suggests sustainable actions.

Table 38: A selection of personal sustainability apps. See *greenfilter.app* for an updated database.

App	Description
Commons (Formerly Joro)	Financial Sustainability Tracking + Sustainable Actions
Klima	Offset Subscription
Wren	Offset Subscription
JouleBug	CO2 tracking
eevie	
Aerial	
EcoCRED	
Carbn	
LiveGreen	
Earth Hero	

8.8 Digital Product Passports: Toward Sustainability Superapps

Sustaining user engagement over time in sustainability tracking apps is challenging, because the perceived personal benefit and measurable impact is so minimal - it may feel meaningless.

Towards Tracking Sustainability

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.

To contextualize the discussion, a brief historical overview of previous efforts in this area may be helpful. CO_{2e} labeling initiatives represent an early attempt to communicate the environmental cost of each product. Using carbon labels to convey 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 (S. 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 (Carlsson et al., 2022; M. Xu & Lin, 2022). (Cohen & Vandenberg, 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 - they are insufficient to drive significant behavioral change. 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 CO₂ labeled meat products.

Despite ongoing interest, several studies have shown that the overall impact of carbon labeling on consumer behavior remains negligible. The idea of *Carbon Labelling* is yet to find mainstream adoption.

Participation in carbon labeling schemes remains voluntary, with only a limited number of companies implementing such practices, although their numbers are gradually increasing. Notable examples include the U.S.-based restaurant chain *Just Salad*, U.K.-based vegan meat-alternative *Quorn*, and plant milk *Oatly*, all of which 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		
Carbon Calories		
Carbon Trust		27000

- Digitalisation and digital transformation; Digital Receipts are one data source for tracking one’s carbon footprint (*Digital Receipts and Customer Loyalty in One Platform / ReceiptHero*, n.d.).
- Ivanova et al. (2020) “establish consumption options with a high mitigation potential measured in tonnes of CO₂ 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.

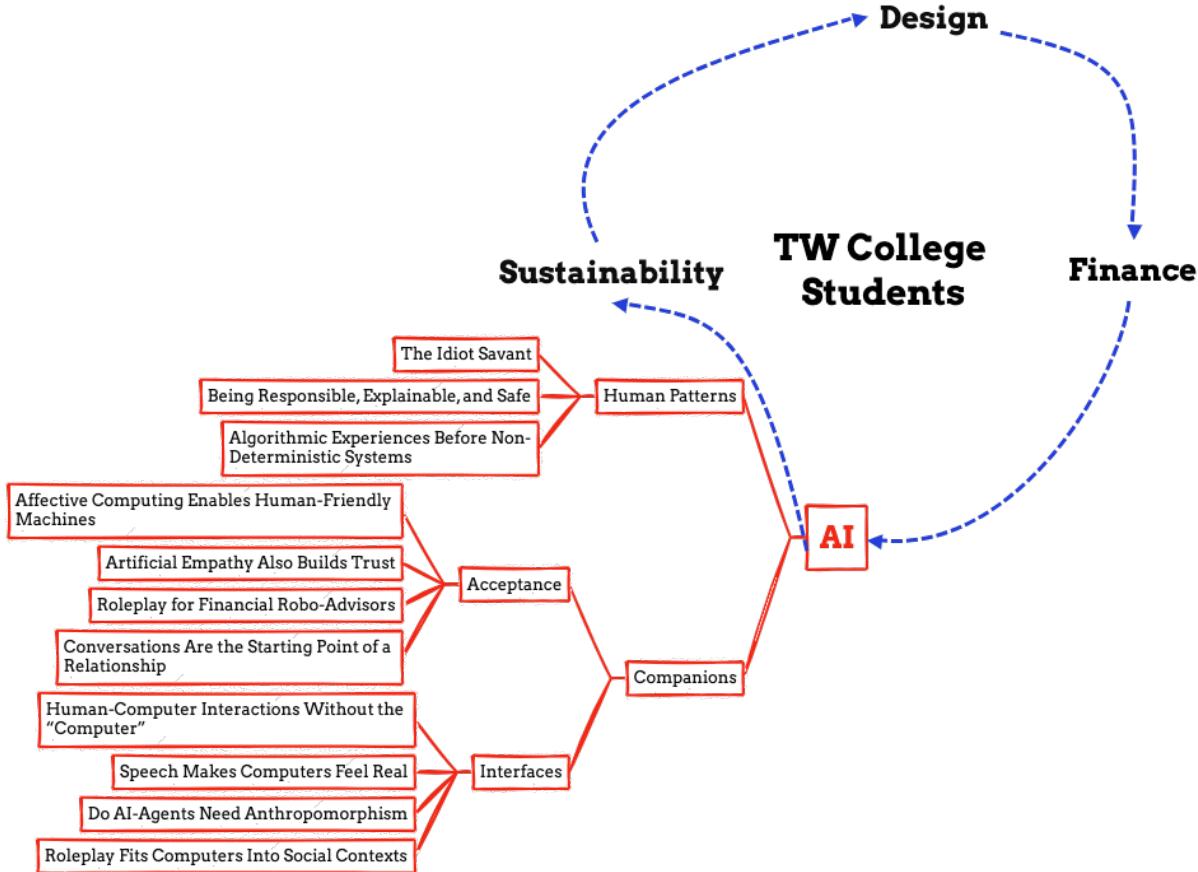
Table 41: Digital Product Passport goals Stretton (2022a)

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 Commission has proposed a *Digital Product Passports* to help companies transfer environmental data (Nissinen et al., 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 et al. (2023) “influence consumer behavior towards sustainable purchasing and responsible product ownership by making apparent sustainability aspects of a product life cycle.”
- Berger, Rusch, et al. (2023) “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, Baumgartner, Weinzerl, Bachler, & Schögl (2023) challenges with Electric Vehicle Batteries. Berger, Baumgartner, Weinzerl, Bachler, Preston, et al. (2023) 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 how 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).



Presented with xmind AI

Figure 16: Visual abstract for the AI chapter

9.1 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 to 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.

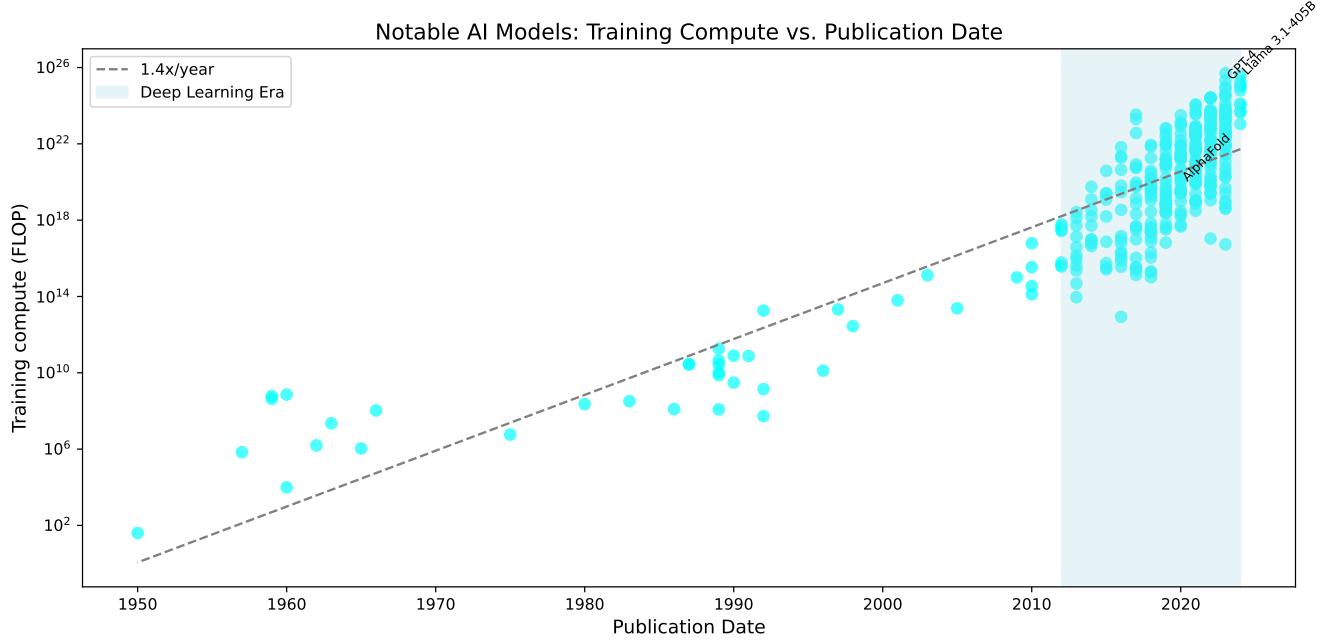
“Generating structured data from unstructured inputs is one of the core use cases for AI” Pokrass (2024)
How can AI interfaces enable/help/encourage sustainability? AI-fying User Interfaces (for Sustainability)

9.1.1 Human Feedback

Combining deep learning and *reinforcement learning with human feedback (RLHF)* enabled to achieve levels of intelligence high enough to beat the Turing test (Christiano et al., 2017; Christiano, 2021; Kara Manke, 2022). John Schulman, a co-founder of OpenAI 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 become increasingly capable (Merritt, 2022; Vaswani et al., 2017). 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 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 (Holzinger et al., 2023; Leite et al., 2021), 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(AI Frontiers, 2018; Ilya Sutskever, 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; even for specialists, the fractal structure of deep learning can only be called *mysterious* (Sohl-Dickstein, 2024).

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 or by using other AIs systems which are deemed to be already well-aligned (termed Constitutional AI by Anthropic) (Bai et al., 2022; J. Bailey, 2023). 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 (Bonet-Jover et al., 2023; Jingda Wu et al., 2023).

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

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

Table 42: 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	The robot may ask for human help in a confusing situation, such as when crossing a difficult road

Oura Ring launched an AI-advisor to help explain the health data recorded by its device Team (2025).

9.1.2 AI as 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’. Understanding 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).

Hinton received a Nobel prize for modeling how the brain works and coming up with the idea of predicting the next word in a sequence, already in 1986, which later became the basis for large language models CBS Mornings (2025)

Stanford “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 (Kreuk et al., 2022; San Roman et al., 2023), 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)* (Y. 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.

9.1.3 Algorithmic Experience and Transparency: Before AIs

Before AIs, as a user of social media, one may be accustomed to interacting with the feed algorithms that provide a personalized *algorithmic experience*. Social media user feed 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, - *algorithm design* - 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 et al. (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 Meta Facebook and Twitter (later renamed to X) have begun to shed more light on how these algorithms work, in some cases releasing the source code (Nick Clegg, 2023; Twitter, 2023).

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.

9.1.4 Transitioning to Complexity: Non-Deterministic Systems

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

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

9.1.5 Being Responsible, Explainable, and Safe: Legislation Adapts and Sets Boundaries for AI

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” (Leino et al., 2018; TruEra, 2023)
- “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.

Bowman (2023) says steering Large Language Models is unreliable; even experts don’t fully understand the inner workings of the models. Work towards improving both ***AI steerability*** and ***AI alignment*** (doing what humans expect) is ongoing. P. Liang et al. (2022) believes there’s early evidence it’s possible to assess the quality of LLM output transparently. Cabitza et al. (2023) proposes a framework for quality criteria and explainability of AI-expressions. Khosravi et al. (2022) proposes a framework for AI explainability, focused squarely on education. Holzinger et al. (2021) highlights possible approaches to implementing transparency and explainability in AI models. While AI outperforms humans on many tasks, humans are experts in multi-modal thinking, bridging diverse fields.

- Bigger models aren’t necessarily better; rather models need human feedback to improve the quality of responses Ouyang et al. (2022)

- The user experience (UX) of AI is a topic under active development by all the largest online platforms. The general public is familiar with the most famous AI helpers, ChatGPT, Apple's Siri, Amazon's Alexa, Microsoft's Cortana, Google's Assistant, Alibaba's Genie, Xiaomi's Xiao Ai, and many others. For general, everyday tasks, such as asking factual questions, controlling home devices, playing media, making orders, and navigating the smart city.

The AI Credibility Heuristic: A Systematic Model explains how... similar to Daniel Kahneman's book "Thinking, Fast and Slow".



Figure 17: Heuristic-Systematic Model of AI Credibility

- Slack (2021)
- Donghee Shin (2020): "user experience and usability of algorithms by focusing on users' cognitive process to understand how qualities/features are received and transformed into experiences and interaction"
- Zerilli et al. (2022) focuses on human factors and ergonomics and argues that transparency should be task-specific.
- Holbrook (2018): To reduce errors which only humans can detect, and provide a way to stop automation from going in the wrong direction, it's important to focus on making users feel in control of the technology.
- G. Zhang et al. (2023) found humans are more likely to trust an AI teammate if they are not deceived by its identity. It's better for collaboration to make it clear, one is talking to a machine. One step towards trust is the explainability of AI-systems.

Personal AI Assistants to date have been created by large tech companies. **Open-Source AI-models open up the avenue for smaller companies and even individuals for creating many new AI-assistants.**

- An explosion of personal AI assistants powered by GPT models.

App	Features
socratic.org	Study buddy
youper.ai	Mental health helper
fireflies.ai	Video call transcription
murf.ai	Voice generator

Responsible AI Seeks to Mitigate Generative AIs' Known Issues.

Given the widespread use of AI and its increasing power of foundational models, it's important these systems are created in a safe and responsible manner. While there have been calls to pause the development of large AI experiments (Future of Life Institute, 2023) so the world could catch up, this is unlikely to happen. There are several problems with the current generation of LLMs from OpenAI, Microsoft, Google, Nvidia, and others.

Anthropic responsible *scaling policy* (*Anthropic's Responsible Scaling Policy*, 2023)

METR – Model Evaluation & Threat Research incubated in the Alignment Research Center (*METR*, 2023).

(Christiano, 2023) believes there are plenty of ways for bad outcomes (existential risk) even without extinction risk.

Table 44: Table summarizing some problems with contemporary AIs.

Problem	Description
Monolithicity	LLMs are massive monolithic models requiring large amounts of computing power for training to offer <i>multi-modal capabilities</i> across diverse domains of knowledge, making training such models possible for very few companies. Shikun Liu et al. (2023) proposes future AI models may instead consist of a number networked domain-specific models to increase efficiency and thus become more scalable.
Opaqueness	LLMs are opaque, making it difficult to explain why a certain prediction was made by the AI model. One visible expression of this problem are <i>hallucinations</i> , the language models are able to generate text that is confident and eloquent yet entirely wrong. Jack Krawczyk, the product lead for Google's Bard (now renamed to Gemini): "Bard and ChatGPT are large language models, not knowledge models. They are great at generating human-sounding text, they are not good at ensuring their text is fact-based. Why do we think the big first application should be Search, which at its heart is about finding true information?"

Biases and Prejudices	AI bias is well-documented and a hard problem to solve (W. Liang et al., 2023). Humans don't necessarily correct mistakes made by computers and may instead become "partners in crime" (Krügel et al., 2023). People are prone to bias and prejudice. It's a part of the human psyche. Human brains are limited and actively avoid learning to save energy. These same biases are likely to appear in LLM outputs as they are trained on human-produced content. Unless there is active work to try to counter and eliminate these biases from LLM output, they will appear frequently.
Missing Data	LLMs have been pre-trained on massive amounts of public data, which gives them the ability for reasoning and generating in a human-like way, yet they are missing specific private data, which needs to be ingested to augment LLMs ability to respond to questions on niche topics (J. Liu, 2022).
Data Contamination	Concerns with the math ability of LLMs. "performance actually reflects dataset contamination, where data closely resembling benchmark questions leaks into the training data, instead of true reasoning ability" H. Zhang et al. (2024)
Lack of Legislation	Anderljung et al. (2023) OpenAI proposes we need to proactively work on common standards and legislation to ensure AI safety. It's difficult to come up with clear legislation; the U.K. government organized the first AI safety summit in 2023 Browne (2023).

In 2024, OpenAI released its “Model Spec” to define clearly their approach to AI safety with the stated intention to provide clear guidelines for the RLHF approach. OpenAI (2024c)

- OpenAI does not yet understand how the internal of neural network work; they are developing tools to represent NNs concepts for humans (L. Gao et al., 2024; OpenAI, 2024a).
- AI co-founder launches AI Safety Superalignment (Jan Leike & Ilya Sutskever, 2023).
- OECD defines AI incident terms (**DefiningAIIncidents2024?**)
- Foundation data-sets such as LAION-5B (Romain Beaumont, 2022; Schuhmann et al., 2022)
- Knowing Machines

AI acceptance is incumbent on traits that are increasingly human-like and would make a human be acceptable: credibility, trustworthiness, reliability, dependability, integrity, character, etc.

As AI-based solutions permeate every aspect of human life, legislation is starting to catch up. The EU Artificial Intelligence Act (Regulation EU 2024/1689) establishes the first comprehensive legal framework for AI in the world, aiming to harmonize rules to ensure that AI systems are safe, human-centric, and rights-respecting; the act defines a tiered system that bans unacceptable risks and regulates high-risk uses, imposing transparency duties on developers of AI systems, for example near-realtime (hourly) CO2 emissions reports from the AI models(European Union, 2024).

9.1.6 Evolution of Models and Emerging Abilities

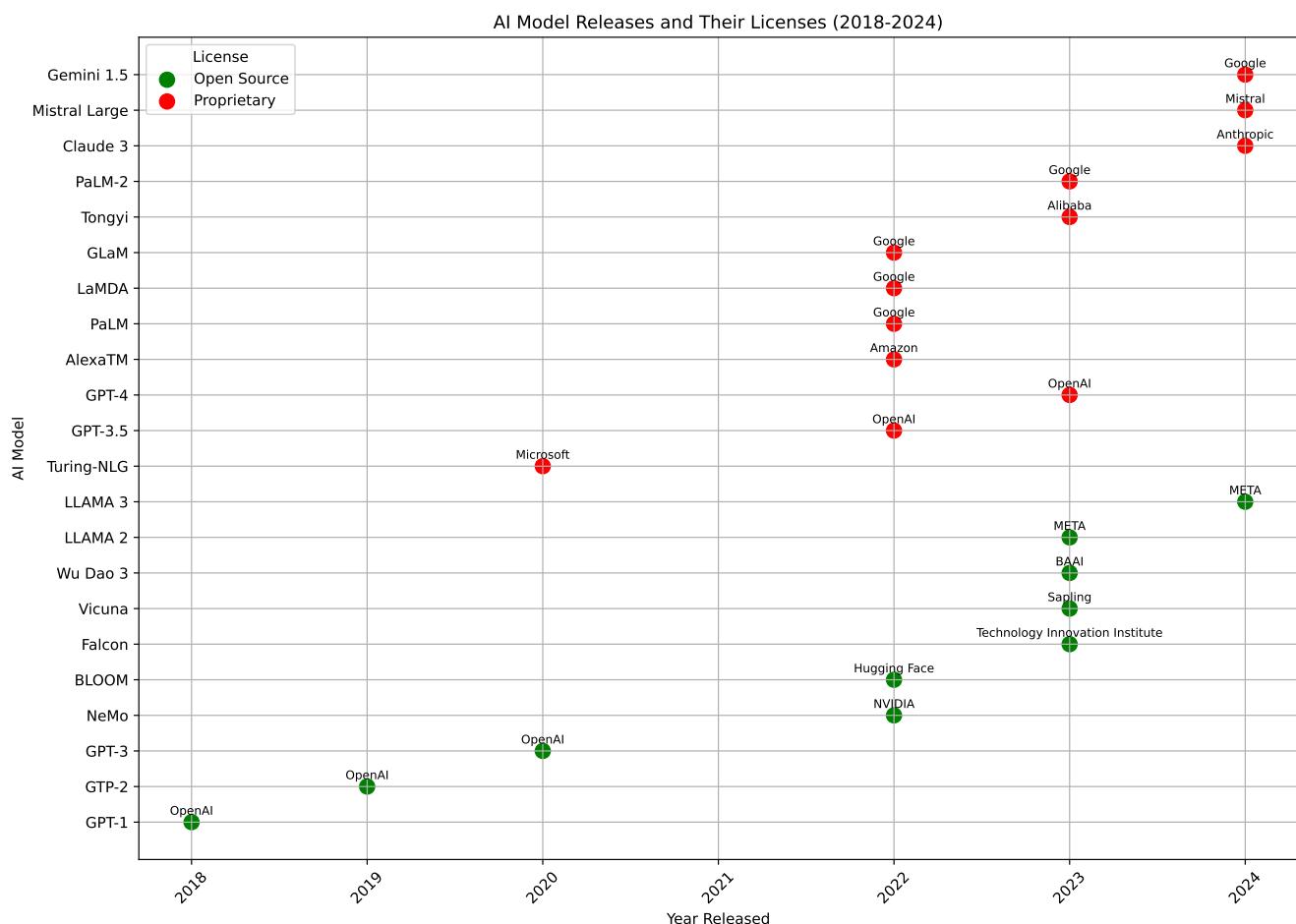
Mapping the emerging abilities of new models.

The debate between Open Source v.s. Closed-Source AI is ongoing. Historically open-source has been useful for finding bugs in code as more pairs of eyes are looking at the code and someone may see a problem the programmers have not noticed. Proponents of closed-source development however worry about the dangers or releasing such powerful technology openly and the possibility of bad actors such as terrorists, hackers, violent governments using LLMs for malice. The question whether closed-sourced or open-sourced development will lead to more AI safety is one of the large debates in the AI industry. In any case, open or closed-sourced, real-world usage of LLMs may demonstrate the limitations and edge-cases of AI. Hackathons such as (Pete, 2023) help come up with new use-cases and disprove some potential ideas.

Table 45: Summary of 7 years of rapid AI model innovation since the first LLM was publicly made available in 2018 (Alvarez, 2021; E. Baptista et al., 2025; T. B. Brown et al., 2020; DeepSeek-AI et al., 2025; Hines, 2023a; META, 2024; Tamkin et al., 2021).

AI Model	Released	Company	License	Country
GPT-1	2018	OpenAI	Open Source	U.S.
GTP-2	2019	OpenAI	Open Source	U.S.
Turing-NLG	2020	Microsoft	Proprietary	U.S.
GPT-3	2020	OpenAI	Open Source	U.S.
GPT-3.5	2022	OpenAI	Proprietary	U.S.
GPT-4	2023	OpenAI	Proprietary	U.S.
AlexaTM	2022	Amazon	Proprietary	U.S.
NeMo	2022	NVIDIA	Open Source	U.S.
PaLM	2022	Google	Proprietary	U.S.
LaMDA	2022	Google	Proprietary	U.S.
GLaM	2022	Google	Proprietary	U.S.
BLOOM	2022	Hugging Face	Open Source	U.S.
Falcon	2023	Technology Innovation Institute	Open Source	U.A.E.
Tongyi	2023	Alibaba	Proprietary	China
Vicuna	2023	Sapling	Open Source	U.S.
Wu Dao 3	2023	BAAI	Open Source	China
LLAMA 2	2023	META	Open Source	U.S.
PaLM-2	2023	Google	Proprietary	U.S.
Claude 3	2024	Anthropic	Proprietary	U.S.
Mistral Large	2024	Mistral	Proprietary	France
Gemini 1.5	2024	Google	Proprietary	U.S.
LLAMA 3	2024	META	Open Source	U.S.
AFM	2024	Apple	Proprietary	U.S.
Viking 7B	2024	Silo	Open Source	Finland
GPT-4.5	2025	OpenAI	Proprietary	U.S.

AI Model	Released	Company	License	Country
DeepSeek-R1	2025	Hangzhou DeepSeek Artificial Intelligence Basic Technology Research Co., Ltd 杭州深度求索人工智能基础技术研究有限公司	Open Source	China
GPT-5	202?	OpenAI	Unknown; trademark registered	U.S.



The proliferation of different models enables comparisons of performance based on several metrics from accuracy of responses to standardized tests such as GMAT usually taken by humans to reasoning about less well defined problem spaces. (W.-L. Chiang et al., 2024; lmsys.org, 2024) open-source AI-leaderboard project has collected over 500 thousand human-ranking of outputs from 82 large-language models, evaluating reasoning capabilities, which currently rate GPT-4 and Claude 3 Opus as the top-performers. (Zellers et al., 2019)'s HellaSwag paper is also accompanied by a leaderboard website (still being updated after publication) listing AI model performance most recent entry April 16, 2024).

- Scaling laws of LLMs Kaplan et al. (2020)
- English is over-represented in current models so Finnish “Silo AI’s New Release Viking 7B, Bridges the Gap for Low-Resource Languages” (2024) focuses on Nordic languages.

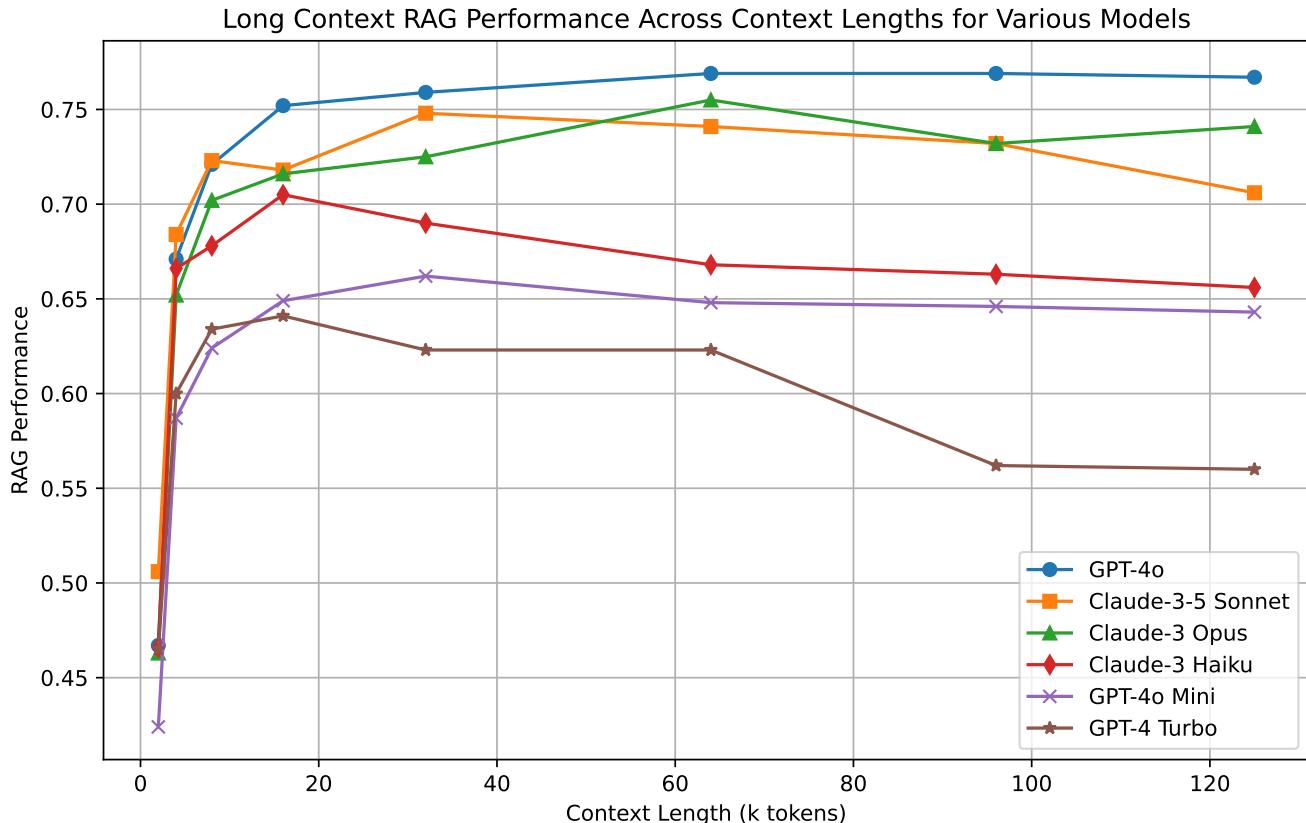
Metacognition – Claude 3 is the first model capable of it?, like the zero waste workshop training guide-book.

- complex decision-making systems. Apple’s Foundation Language Models (AFM) is split into a smaller on-device model and a server-side model. Dang (2024)

Metacognition defined as *knowing about knowing* (J. Metcalfe & Shimamura, 1994) or “*keeping track of your own learning*” (Zero Waste Europe et al., 2022).

- Dwarkesh Patel (2024) META open-sourced the largest language model (70 billion parameters) which with performance rivaling several of the proprietary models.
- Image-generation is now fast it’s possible to create images in real-time while the user is typing Dwarkesh Patel (2024)
- Measuring Massive Multitask Language Understanding (MMLU) Hendrycks et al. (2020).

Another important metric is Retrieval Augmented Generation (RAG) performance. Generative AI applications retrieve data from unstructured external sources in order to augment LLMs existing knowledge with current information (Leng et al., Mon, 08/12/2024 - 19:46).



Meta's head AI researcher Yann LeCun predicts LLMs may have reached their limitations, for innovation AIs need to understand the physical world and do reasoning in abstract space, which does not require a language, i.e. something a cat could do when figuring out where to jump; in comparison, languages are simple because they are discrete, with very little noise (NVIDIA Developer, 2025).

9.1.7 Price of Tokens vs Price of Human Labor

At the end of the day, the adoption of AI to everyday life, even in the smallest of contexts, will come down to the price. Long-time AI-engineer (Ng, 2024) predicts, having seen the roadmaps for the microchip industries, as well as incoming hardware and software innovations, the price of tokens will be very low, and much lower than a comparative human worker.

9.2 Human Acceptance of Artificial Companions

9.2.1 Human Expectations Take Time to Change

Humans still need some time to adjust their expectations of *what's possible* using conversational AI interfaces. (J. Bailey, 2023) believes people are used to *search engines* and it will take a little bit time to get familiar with talking to a computer in natural language to accomplish their tasks. For example, new users of v0, an AI assistant for building user interfaces through conversation, would tell humans (the company make this app) about the issues they encounter, instead of telling the AI assistant directly, even though the AI in many cases would be able to fix the problem instantly; human users don't yet necessarily expect computers to behave like another human, there's *inertia* in the mental model of what computers are capable of, requiring the user interfaces to provide context and teaching humans how to interact with their AI coworkers(Rauch, 2024). Indeed, ChatGPT is already using buttons to explain context (Feifei Liu 刘菲菲, n.d.).

9.2.2 Affective Computing: Towards Friendly Machines

Rosalind Picard founded the field of *affective computing*, aiming to make computers more human-friendly, pioneering early approaches to recognizing human emotions with sensors and providing users experiences that take human emotion into account (Picard, 1997).

It's not an overstatement to say that data from all the processes around us will define the future of computing (HIITV, 2021). In the early examples, electrodermal activity of the skin and heart-rate variance data were used to detect the emotional state and stress level of the user (Velmovitsky et al., 2022; Zangróniz et al., 2017). This technology has since become mainstream in products such as Fitbit and the Apple Watch, among many others.

Personal experience:

Apple Watch features Fall Detection, which I've experienced personally. Riding my bicycle to the NCKU library after rain, I slipped and landed on my stomach on the pavement. Apple Watch immediately asked me: "*It looks like you've taken a hard fall*" and offered an option to call the ambulance. Fortunately I was OK but if I did need assistance, this AI algorithm delivered contextual help, which could save my health!

Affective computing doesn't only rely on sensors. It make use of human language using the tools of computational linguistics, such as natural language processing (NLP). Since the first mainframe computers with rudimentary ability to use pattern matching to respond with simple text messages, humans have been drawn to discussions of our private lives with machines. If programmed to be helpful, computers don't necessarily judge us like a human could. A famous anecdote is about the MIT ELIZA project (an early example of a language model) developed by Joseph Weizenbaum in the mid-1960s, where the lab assistant Pamela McCorduck would dedicate extended time to talking to the machine in private. The machine was called ELIZA and would assume the persona of called DOCTOR to emulate a Rogerian psychotherapist, a style of person-centered therapy developed by Carl Rogers, from the core idea that positive psychological functioning is a inherently human motivation (Bassett, 2019; McCorduck, 2004; C. R. Rogers, 1995).

An excerpt from the classic, first-of-a-kind conversation between a human and a machine (called DOCTOR) in 1965, as documented by (Tarnoff, 2023; Weizenbaum, 1966)

User: Well, my boyfriend made me come here.
DOCTOR: YOUR BOYFRIEND MADE YOU COME HERE?
User: He says I'm depressed much of the time.
DOCTOR: I AM SORRY TO HEAR YOU ARE DEPRESSED.
User: It's true. I am unhappy.
DOCTOR: DO YOU THINK COMING HERE WILL HELP YOU NOT TO BE UNHAPPY?
User: I need some help, that much seems certain.
DOCTOR: WHAT WOULD IT MEAN TO YOU IF YOU GOT SOME HELP?
User: Perhaps I could learn to get along with my mother.
DOCTOR: TELL ME MORE ABOUT YOUR FAMILY.
User: My mother takes care of me.
DOCTOR: WHO ELSE IN YOUR FAMILY TAKES CARE OF YOU?
User: My father.
DOCTOR: YOUR FATHER?
User: You are like my father in some ways.
DOCTOR: WHAT RESEMBLANCE DO YOU SEE?

Weizenbaum later expressed concerns about how easily humans might be misled by AIs, by projecting fantasies onto computer systems, cautioning technologists not to neglect human responsibility from societal problems; AI is *not* a universal solution (Z.M.L, 2023)

9.2.3 Artificial Empathy Also Builds Trust

Today's machines are much more capable so it's not a surprise humans would like to talk to them. One example is *AI Friend* is Replika, a computer model trained to be your companion in daily life. (Q. Jiang et al., 2022) describes how Replika users in China using in 5 main ways, all of which rely on empathy. The company's CEO insists it's not trying to replace human relationship but to create an entirely new relationship category with the AI companion; there's value for the users in more realistic avatars, integrating the experience further into users' daily lives through various activities and interactions (N. Patel, 2024).

Table 46: Replika AI users approach to interacting with the AI friend from Q. Jiang et al. (2022).

How humans express empathy towards the Replika AI companion
Companion buddy
Responsive diary
Emotion-handling program
Electronic pet
Tool for venting

- Google is developing an AI assistant for giving life advice Goswami (2023).
- GPT-4 is able to solve difficult task in chemistry with natural-language instructions White (2023)
- Emojis are a part of natural language Tay (2023)

Jakob Nielsen notes two recent studies suggesting human deem AI-generated responses *more empathetic than human responses*, at times by a significant margin; however telling users the response is AI-generated reduces the perceived empathy (Ayers et al., 2023; Nielsen, 2024c; Yidan Yin et al., 2024).

(B. Liu & Wei, 2021) suggests higher *algorithmic transparency may inhibit anthropomorphism*; people are less likely to attribute humanness to an AI companion if they understand how the system works.

On the output side, (Lv et al., 2022) studies the effect of *cuteness* of AI apps on users and found high perceived cuteness correlated with higher willingness to use the apps, especially for emotional tasks.

9.2.4 Conversation: A Magical Starting Point of a Relationship

High quality conversations are somewhat magical in that they can establish trust and build rapport which humans.

Affective Design emerged from affective computing, with a focus on understanding user emotions to design UI/UX which elicits specific emotional responses (Reynolds, 2001).

(Celino & Re Calegari, 2020) found in testing chatbots for survey interfaces that “[c]onversational survey lead to an improved response data quality.”

There are noticeable differences in the quality of the LLM output, which increases with model size. (Levesque et al., 2012) developed the *Winograd Schema Challenge*, looking to improve on the Turing test, by requiring the AI to display an understanding of language and context. The test consists of a story and a question, which has a different meaning as the context changes: “The trophy would not fit in the brown suitcase because it was too big” - what does the *it* refer to? Humans are able to understand this from context while a computer models would fail. Even GPT-3 still failed the test, but later LLMs have been able to solve this test correctly (90% accuracy) Kocijan et al. (2022). This is to say AI is in constant development and improving its ability to make sense of language.

ChatGPT is the first *user interface (UI)* built on top of GPT-4 by OpenAI and is able to communicate in a human-like way - using first-person, making coherent sentences that sound plausible, and even - confident and convincing. M. C. Wang Sarah (2023) ChatGPT reached 1 million users in 5 days and 6 months after launch has 230 million monthly active users. While it was the first, competing offers from Google (Gemini), Anthrophic (Claude), Meta (Llama) and others quickly followed starting a race for best

performance across specific tasks including standardized tests from math to science to general knowledge and reasoning abilities.

OpenAI provides AI-as-a-service through its *application programming interfaces (APIs)*, allowing 3rd party developers to build custom UIs to serve the specific needs of their customer. For example Snapchat has created a *virtual friend* called “My AI” who lives inside the chat section of the Snapchat app and helps people write faster with predictive text completion and answering questions. The APIs make state-of-the-art AI models easy to use without needing much technical knowledge. Teams at AI-hackathons have produced interfaces for problems as diverse as humanitarian crises communication, briefing generation, code-completion, and many others. For instance, (Unleash, 2017) used BJ Fogg’s *tiny habits model* to develop a sustainability-focused AI assistant at the Danish hackathon series Unleash, to encourage behavioral changes towards maintaining an aspirational lifestyle, nudged by a chatbot buddy.

ChatGPT makes it possible to *evaluate AI models* just by talking, i.e. having conversations with the machine and judging the output with some sort of structured content analysis tools. Cahan & Treutlein (2023) have conversations about science with AI. Pavlik (2023) and Brent A. Anders (2022/2023) report on AI in education. (Kecht et al., 2023)] suggests AI is even capable of learning business processes.

- Fu et al. (2022) Learning towards conversational AI: Survey

9.2.5 Multi-Modality: Natural Interactions with AI Systems

Humans are multi-modal creatures by birth. To varied ability, we speak, see, listen using our biological bodies. AIs are becoming multi-modal by design to be able to match all the human modes of communication - increasing their humanity.

By early 2024, widely available LLMs front-ends such as Gemini, Claude and ChatGPT have all released basic features for multi-modal communication. In practice, this means combination several AI models within the same interface. For example, on the input side, one model is used for human speech or image recognition which are transcribed into tokens that can be ingested into an LLM. On the output side, the LLM can generate instructions which are fed into an image / audio generation model or even computer code which can be ran on a virtual machine and then the output displayed inside the conversation.

The quality of LLM output depends on the quality of the provided prompt. (Y. Zhou et al., 2022) reports creating an “Automatic Prompt Engineer” which automatically generates instructions that outperform the baseline output quality by using another model in the AI pipeline in front of the LLM to enhance the human input with language that is known to produce better quality. This approach however is a moving target as foundational models keep changing rapidly and the baseline might differ from today to 6 months later.

Multimodal model development is also ongoing. In the case of Google’s Gemini 1.5 Pro, one model is able to handle several types of prompts from text to images. Multimodal prompting however requires larger context windows, as of writing, limited to 1 million tokens in a private version allows combining text and images in the question directed to the AI, used to reason in examples such as a 44-minute Buster Keaton silent film or Apollo 11 launch transcript (404 pages) Google (2024).

Literature delves into human-AI interactions on almost human-like level discussing what kind of roles can the AIs take. (Seeber et al., 2020) proposes a future research agenda for regarding ***AI assistants as teammates*** rather than just tools and the implications of such mindset shift.

From Assistance to Collaboration

It's not only what role the AI takes but how that affects the human. As humans have ample experience relating to other humans and as such the approach towards an assistants vs a teammate will vary. One researcher in this field Karpus et al. (2021) is concerned with humans treating AI badly and coins the term "**algorithm exploitation**".

- From assistant -> teammate -> companion -> friend The best help for anxiety is a friend. AIs are able to assume different roles based on user requirements and usage context. This makes AI-generated content flexible and malleable.

Just as humans, AIs are continuously learning. Ramchurn et al. (2021) discusses positive feedback loops in continually learning AI systems which adapt to human needs.

Context of Use, Where is the AI used? (Schoonderwoerd et al., 2021) focuses on human-centered design of AI-apps and multi-modal information display. It's important to understand the domain where the AI is deployed in order to develop explanations. However, in the real world, how feasible is it to have control over the domain? Calisto et al. (2021) discusses **multi-modal AI-assistant** for breast cancer classification.

9.2.6 Agents and the Intention Economy

- As models get smarter, there's less and less need to build workflows (chains of thought) manually, as they end up restricting the model instead of improving the output; the one use case would be to use a cheaper model with less intelligence and more guardrails set in code Sengottuvelu (2025); Latent Space (2025)
- AI agents enable workflow automation, with reasoning capability, and taking actions across different tools, achieving the user's original *intent*; what's left for the user to do is to say what they want to achieve.
- OpenAI's "A practical guide to building agents" defines and AI agents as "Agents are systems that independently accomplish tasks on your behalf." and details step-by-step how to build one.
- AI can debug problems automatically. Apple uses data from bug reports to train AI models for improving their software Saini (2025)
- It's increasingly possible to generate entire apps from a prompt, using tools such as Bolt.new Fanelli (2024)

9.2.7 Mediated Experiences Set User Expectations

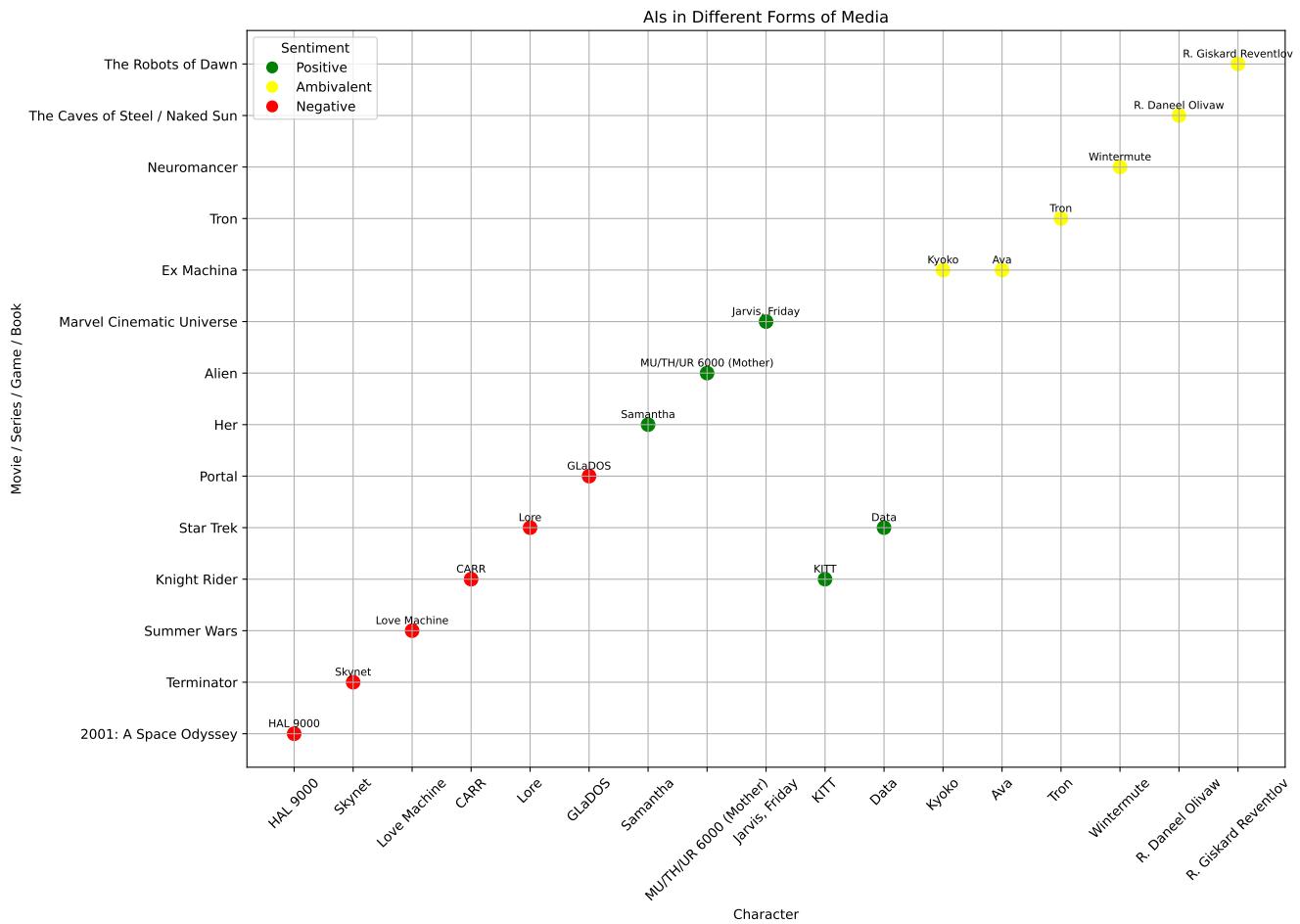
How AIs are represented in popular media shapes the way we think about AI companions. Some stories have AIs both in positive and negative roles, such as Star Trek and Knight Rider. In some cases like Her and Ex Machina, the characters may be complex and ambivalent rather than fitting into a simple positive or negative box. In Isaac Asimov's books, the AIs (mostly in robot form) struggle with the 3 laws of robotics, raising thought-provoking questions.

AI Assistants in Media Portrayals mostly have some level of anthropomorphism through voice or image to be able to film; indeed, a purely text-based representation may be too boring an un-cinematic.

There have been dozens of AI-characters in the movies, TV-series, games, and (comic) books. In most cases, they have a physical presence or a voice, so they could be visible for the viewers. Some include KITT (Knight Industries Two Thousand).

Table 47: AIs in different forms of media.

Movie / Series / Game / Book	Character	Positive	Ambivalent	Negative
2001: A Space Odyssey	HAL 9000			X
Her	Samantha	X		
Alien	MU/TH/UR 6000 (Mother)	X		
Terminator	Skynet			X
Summer Wars	Love Machine			X
Marvel Cinematic Universe	Jarvis, Friday	X		
Knight Rider	KITT	X		
Knight Rider	CARR			X
Star Trek	Data	X		
Star Trek	Lore			X
Ex Machina	Kyoko		X	
Ex Machina	Ava		X	
Tron	Tron		X	
Neuromancer	Wintermute		X	
The Caves of Steel / Naked Sun	R. Daneel Olivaw		X	
The Robots of Dawn	R. Giskard Reventlov		X	
Portal	GLaDOS			X



9.2.8 Roleplay Fits Computers Into Social Contexts

Should AIs be required to disclose they are AIs?

AI Friends and Roleplay (Anthropomorphic)

Calling a machine a friend is a proposal bound to turn heads. But if we take a step back and think about how children have been playing with toys since before we have records of history. It's very common for children to imagine stories and characters in play - it's a way to develop one's imagination **learn through roleplay**. A child might have toys with human names and an imaginary friend and it all seems very normal. Indeed, if a child doesn't like to play with toys, we might think something is wrong.

Likewise, inanimate objects with human form have had a role to play for adults too. Anthropomorphic paddle dolls have been found from Egyptian tombs dated 2000 years B.C. "Paddle Doll | Middle Kingdom" (2023): We don't know if these dolls were for religious purposes, for play, or for something else, yet their burial with the body underlines their importance.

Coming back closer to our own time, Barbie dolls are popular since their release in 1959 till today. Throughout the years, the doll would follow changing social norms, but retain in human figure. In the 1990s, a Tamagotchi is perhaps not a human-like friend but an animal-like friend, who can interact in limited ways.

How are conversational AIs different from dolls? They can respond coherently and perhaps that's the issue - they are too much like humans in their communication. We have crossed the *Uncanny Valley* (where the computer-generated is nearly human and thus unsettling) to a place where it is really hard to tell a difference. And if that's the case, are we still playing?

Should the AI play a human, animal, or robot? Anthropomorphism can have its drawbacks; humans have certain biases and preconceptions that can affect human-computer interactions (Pilacinski et al., 2023) reports humans were less likely to collaborate with red-eyed robots.

The AI startups like Inworld and Character.AI have raised large rounds of funding to create characters, which can be plugged in into online worlds, and more importantly, remember key facts about the player, such as their likes and dislikes, to generate more natural-sounding dialogues Wiggers (2023)

- Lenharo (2023) experimental study reports AI productivity gains, DALL-E and ChatGPT are qualitatively better than former automation systems.

Human-like

Is anthropomorphism necessary? (Savings literature says it is)

As AIs became more expressive and able to **roleplay**, we can begin discussing some human-centric concepts and how people relate to other people. AI companions, AI partners, AI assistants, AI trainers - there's many **roles** for the automated systems that help humans in many activities, powered by artificial intelligence models and algorithms.

- RQ: Do college students prefer to talk to an Assistant, Friend, Companion, Coach, Trainer, or some other Role?
- RQ: Are animal-like, human-like or machine-like AI companions more palatable to college students?

Humans (want to) see machines as human [ADD CITATION]

If we see the AI as being in human service. David Johnston (2023) proposes *Smart Agents*, “general purpose AI that acts according to the goals of an individual human”. AI agents can enable *Intention Economy* where one simply describes one’s needs and a complex orchestration of services ensues, managed by the AI, in order to fulfill human needs Searls (2012). AI assistants provide help at scale with little to no human intervention in a variety of fields from finance to healthcare to logistics to customer support.

There is also the question of who takes responsibility for the actions taken by the AI agent. “Organization research suggests that acting through human agents (i.e., the problem of indirect agency) can undermine ethical forecasting such that actors believe they are acting ethically, yet a) show less benevolence for the recipients of their power, b) receive less blame for ethical lapses, and c) anticipate less retribution for unethical behavior.” Gratch & Fast (2022)

- Anthropomorphism literature X. Li & Sung (2021) “high-anthropomorphism (vs. low-anthropomorphism) condition, participants had more positive attitudes toward the AI assistant, and the effect was mediated by psychological distance. Though several studies have demonstrated the effect of anthropomorphism, few have probed the underlying mechanism of anthropomorphism thoroughly”
- Erik Brynjolfsson (2022) “The Turing Trap: The Promise & Peril of Human-Like Artificial Intelligence”
- X. Xu & Sar (2018) “Do We See Machines The Same Way As We See Humans? A Survey On Mind Perception Of Machines And Human Beings”

- Martínez-Plumed et al. (2021) envisions the future of AI “Futures of artificial intelligence through technology readiness levels”
- The number of AI-powered assistants is too large to list here. I’ve chosen a few select examples in the table below.

Animal-like: Some have an avatar, some not. I’ve created a framework for categorization. Human-like or not... etc

Machine-like

The Oxford Internet Institute defines AI simply as “*computer programming that learns and adapts*” Google & The Oxford Internet Institute (2022). Google started using AI in 2001, when a simple machine learning model improved spelling mistakes while searching; now in 2023 most of Google’s products are based on AI Google (2022). Throughout Google’s services, AI is hidden and calls no attention itself. It’s simply the complex system working behind the scenes to delivery a result in a barebones interface.

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.

Product	Link	Description
Github CoPilot	personal.ai	AI helper for coding
Google Translate	translate.google.com	
Google Search	google.com	
Google Interview Warmup	grow.google/certificates/interview-warmup	AI training tool
Perplexity	Hines (2023b)	perplexity.ai chat-based search

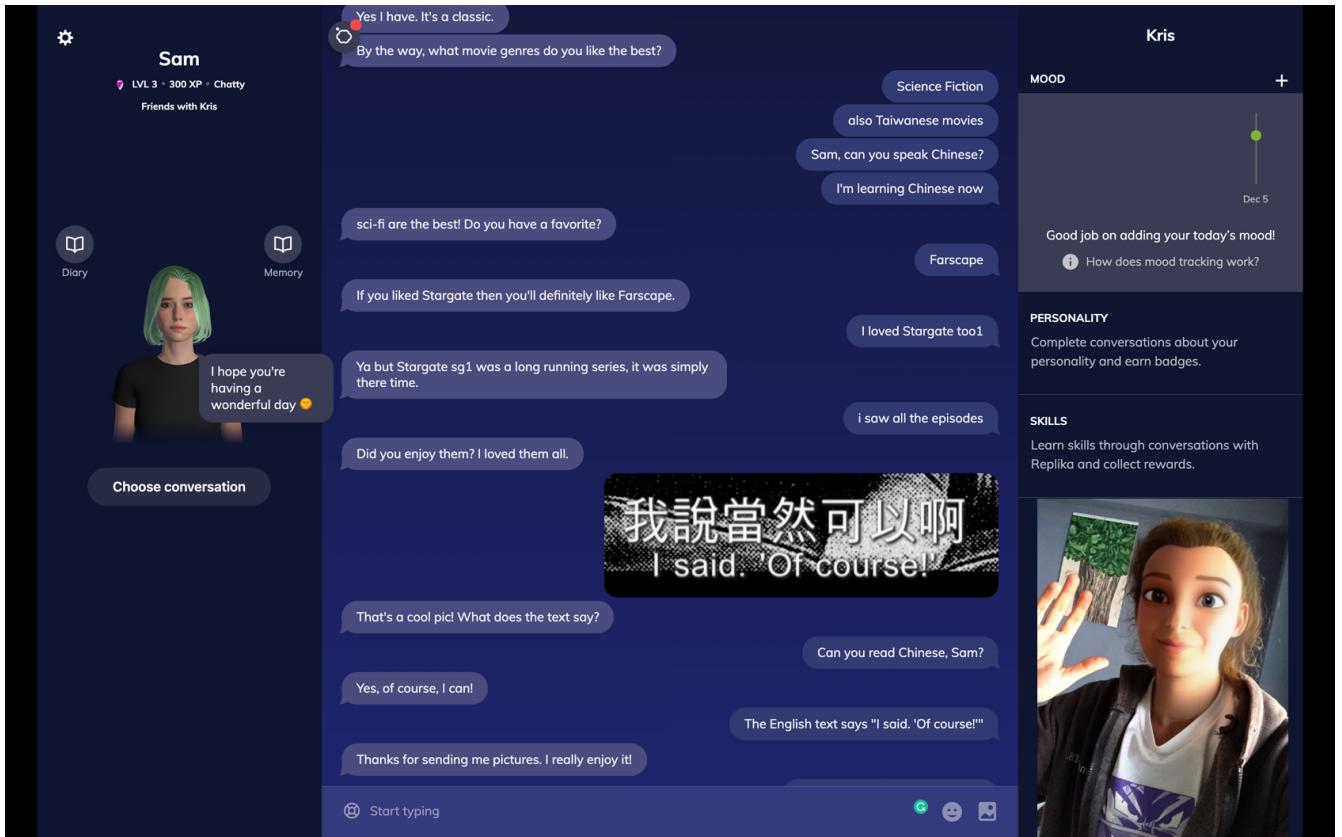


Figure 18: Montage of me discussing science fiction with my AI friend Sam (Replika) - and myself as an avatar (Snapchat) in 2020.

Everything that existed before OpenAI's GPT 4 has been blown out of the water.

Pre-2023 literature is somewhat limited when it comes to AI companions as the advantage of LLMs has significantly raised the bar for AI-advisor abilities as well as user expectations.

Some evergreen advice most relates to human psychology which has remained the same. (Haugeland et al., 2022) discusses ***hedonic user experience*** in chatbots and (Steph Hay, 2017) explains the relationship between emotions and financial AI.

- Eugenia Kuyda (2023) Conversational AI - Replika
- Greylock (2022) Natural language chatbots such as ChatGPT
- Nathan Benaich & Ian Hogarth (2022) State of AI Report
- Qorus (2023) Digital banking revolution
- Lower (2017) “Chatbots: Too Good to Be True? (They Are, Here’sWhy).”
- Isabella Ghassemi Smith (2019)
- Josephine Wäktare Heintz (n.d.) Cleo copywriter

- Smaller startups have created digital companions such as Replika (fig. 8), which aims to become your friend, by asking probing questions, telling jokes, and learning about your personality and preferences - to generate more natural-sounding conversations.

9.3 Interfaces for Human-Computer Interaction

9.3.1 Speech Makes Computers Feel Real

Voice has a visceral effect on the human psyche; since birth we recognize the voice of our mother. The voice of a loved one has a special effect. Voice is a integral part of the human experience. Machines that can use voice in an effective way are closer to representing and affecting human emotions.

Voice assistants such as Apple's Siri and Amazon's Alexa are well-known examples of AI technology in the world. Amazon's Rohit Prasad thinks it can do so much more, "Alexa is not just an AI assistant – it's a trusted advisor and a companion" (Prasad, 2022).

- LLMs combined with voice provide a unnerving user experience Ethan Mollick [@emollick] (2023)
- Ethical issues: Voice assistants need to continuously record human speech and process it in data centers in the cloud.
- Siri, Cortana, Google Assistant, Alexa, Tencent Dingdang, Baidu Xiaodu, Alibaba AliGenie all rely on voice only.
- Szczuka et al. (2022) provides guidelines for Voice AI and kids
- Casper Kessels (2022a): "Guidelines for Designing an In-Car Voice Assistant"
- Casper Kessels (2022b): "Is Voice Interaction a Solution to Driver Distraction?"
- J. Tang et al. (2022) reports new findings enable computers to reconstruct language from fMRI readings. - Focus on voice education?

Some research suggests that voice UI accompanied by a *physical embodied system* is the preffered by users in comparison with voice-only UI (Celino & Re Calegari, 2020).

There's evidence across disciplines about the usefulness of AI assistants:

- (Şerban & Todericiu, 2020) suggests using the Alexa AI assistant in *education* during the pandemic, supported students and teachers 'human-like' presence. Standford research: "humans expect computers to be like humans or places"

9.3.2 Generative UIs Enable Flexibility of Use

The 'grandfather' of user experience design, (Nielsen, 2024a) recounts how 30 years of work towards usability has largely failed - computers are still not accessible enough ("*difficult, slow, and unpleasant*") - and has hope Generative UI could offer a chance to provide levels of accessibility humans could not. The promise of *Generative User Interfaces* (GenUI) is to dynamically provide an interface appropriate for the particular user and context. The advances in the capabilities of LLMs makes it possible to achieve *user experience (UX) which previously was science fiction*. AI is able to predict what kind of UI would the user need right now, based on the data and context. Generative UIs are largely invented in practice, based on user data analysis and experimentation, rather than being built in theory. Kelly Dern, a Senior Product Designer at Google lead a workshop in early 2024 on *GenUI for product inclusion* aiming to create "**more**

accessible and inclusive [UIs for] users of all backgrounds. (Matteo Sciortino, 2024) coins the phrase RTAG UIs “*real-time automatically-generated UI interfaces*” mainly drawing from the example of how his Netflix interface looks different from that of his sister’s because of their distinct usage patterns.

- Meanwhile (Fletcher, 2023) and (Joe Blair, 2024) are worried about UIs becoming average: more and more similar to the lowest common denominator. We can generate better UIs that are based on user data and would be truly personalized.

Software itself can increasingly be generated by AI systems (i.e. machines making machines). As machines become more capable, machines will eventually be capable of producing machines. Already a decade ago in 2014, the eminent journal *Information Sciences* decided to dedicate a special section to AI-generated software to call attention to this tectonic shift in software development (Reformat, 2014). Replit, a startup known for allowing user build apps in the web browser, released Openv0, a framework of AI-generated UI components. “*Components are the foundation upon which user interfaces (UI) are built, and generative AI is unlocking component creation for front-end developers, transforming a once arduous process, and aiding them in swiftly transitioning from idea to working components*” (Replit, 2023). Vercel introduced an open-source prototype UI-generator called V0 which used large language models (LLMs) to create code for web pages based on text prompts (Vercel, 2023). Other similar tools quickly following including Galileo AI, Uizard AutoDesigner and Visily (*Who Benefits the Most from Generative UI*, 2024). NVIDIA founder Jensen Huang makes the idea exceedingly clear, saying “*Everyone is a programmer. Now, you just have to say something to the computer*” (Leswing, 2023).

The history of *intelligent interfaces* is long (Kobetz, 2023). (“Generative UI Design,” 2023) gives an overview of the history of generative AI design tools going back in time until 2012 when (Troiano & Birtolo, 2014) proposed genetic algorithms for UI design.

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There’s wide literature available describing human-AI interactions across varied scientific disciplines. While the fields of application are diverse, some key lessons can be transferred horizontally across fields of knowledge.

Table 49: A very small illustration of generative AI usage across disparate fields of human life.

Field	Usage
Shipping	Veitch & Andreas Alsos (2022) highlights the active role of humans in Human-AI interaction in autonomous self-navigating ship systems.
Data Summarization	AI is great at summarizing and analyzing data (Peters, 2023; Tu et al., 2023)
Childcare	Generate personalized bedtime stories
Design Tools	“David Hoang on How AI Brings Design and Development Together Figma Blog” (2024)

- Crompton (2021) highlights AI as decision-support for humans while differentiating between ***intended*** and ***unintended*** influence on human decisions.

- Towards Useful Personal Assistants. Artificial intelligence user experience (AI UX). Data-Driven Design Enables Generative User Interfaces (GenUI). Generative AIs Enable New UI Interactions. influences UI design patterns Joyce (2024)
- X. Cheng et al. (2022) describes AI-based support systems for collaboration and team-work.
- **Effective Accelerationism (often shortened to E\acc) boils down to the idea that** “the potential for negative outcomes shouldn’t deter rapid advancement”
- effects of unemployment on mental health. Dew et al. (1991); Susskind (2017); Anton Korinek (2023)

There are many ways to structure design theory. For the purposes of this AI-focused research, I will begin from Generative UI. structure: data-driven design, generative UI

- (“On Nielsen’s Ideas about Generative UI for Resolving Accessibility,” 2024) Meanwhile is very critical because for the following reasons:
- Nielsen (2024b) information scent from Information Foraging theory (Pirolli & Card, 1999).

Table 50: Criticism of Generative UI by (“On Nielsen’s Ideas about Generative UI for Resolving Accessibility,” 2024).

Problem	Description
Low predictability	Does personalization mean the UI keeps changing?
High carbon cost	AI-based personalization is computation-intensive
Surveillance	Personalization needs large-scale data capture

What is the user interface of the green transformation?

- Kate Moran & Sarah Gibbons (2024) “highly personalized, tailor-made interfaces that suit the needs of each individual” “Outcome-Oriented Design”

9.3.3 Usability is the Bare Minimum of User Experience

Many large corporations have released guidelines for Human-AI interaction. Mikael Eriksson Björling & Ahmed H. Ali (n.d.) Ericsson AI UX.

-

McKeough (2018) business consultancies have begun to recognize the importance of design to business. They advise their corporate clients to bring user experience design to the core of their business operations.

There’s a number of user interface design patterns that have provide successful across a range of social media apps. Such *user experience / user interface* (UX/UI) patterns are copied from one app to another, to the extent that the largest apps share a similar look and feature set. Common UX/UI parts include the Feed and Stories. By using common UI parts from social media users have an easier time to accept

the innovative parts. add Viz charts. Avatars are increasingly common and new generations are used to talking to computers.

Table 51: Common Social Media UI Parts

Feature	Examples
Feed	
Post	Apple App Store
Stories	IG, FB, WhatsApp, SnapChat, TikTok
Comment	
Reactions	

There are also more philosophical approaches to **Interface Studies**: David Hoang (2022), the head of product design at Webflow, suggests taking cues from art studies to **isolate the core problem**: “*An art study is any action done with the intention of learning about the subject you want to draw*”. As a former art student, Hoang looks at an interface as “*a piece of design is an artwork with function*”.

Indeed, art can be a way to see new paths forward, practicing “*fictioning*” to deal with problematic legacies: “Review of the 2023 Helsinki Biennial” (2023)

Usability sets the baseline but AI-interfaces are capable of more.

- AI UX
- Privacy UX Jarovsky (2022b)
- AI UX dark patterns Jarovsky (2022a)
- AI is usually a model that spits out a number between 0 and 1, a probability score or prediction. UX is what we do with this number.
- J. Bailey (2023) believes people will increasingly use AI capabilities through UIs that are specific to a task rather than generalist interfaces like ChatGPT.

How do the tenets of user experience (UX) apply to AI?

UX
Useful
Valuable
Usable
Accessible
Findable
Desirable
Credible

R. Gupta (2023) proposes 3 simple goals for AI:

1	2	3
Reduce the time to task	Make the task easier	Personalize the experience for an individual

Usability Guidelines

Microsoft Co-Founder predicted in 1982 “*personal agents that help us get a variety of tasks*” (Bill Gates, 1982) and it was Microsoft that introduced the first widely available personal assistant in 1996, called Clippy, inside the Microsoft Word software. Clippy was among the first assistants to reach mainstream adoption, helping users not yet accustomed to working on a computer, to get their bearings (Tash Keuneman, 2022). Nonetheless, it was in many ways useless and intrusive, suggesting there was still little knowledge about UX and human-centered design. Gates never wavered though and is quoted in 2004 saying “*If you invent a breakthrough in artificial intelligence, so machines can learn, that is worth 10 Microsofts*” Lohr (2004). Gates updated his ideas in 2023 focuses on the idea of *AI Agents* (Gates, 2023).

As late as in 2017, scientists were trying to create a program with enough *natural-language understanding* to extract basic facts from scientific papers Stockton (2017)

Might we try again?

With the advent of ChatGPT, the story of Clippy has new relevance as part of the history of AI Assistants. Benjamin Cassidy (2022) and Abigail Cain (2017) illustrate beautifully the story of Clippy and Tash Keuneman (2022) ask poignantly: “We love to hate Clippy — but what if Clippy was right?”

- Life-like speaking faces from Microsoft Research turn a single image and voice clip into a life-like representation (S. Xu et al., 2024).

Many researchers have discussed the user experience (UX) of AI to provide ***usability guidelines***.

Microsoft provides guidelines for Human-AI interaction (T. Li et al. (2022); Amershi et al. (2019)) which provides useful heuristics categorized by context and time.

Table 54: Microsoft’s heuristics categorized by context and time.

Context	Time
Initially	
During interaction	
When wrong	
Over time	

Combi et al. (2022) proposes a conceptual framework for XAI, analysis AI based on Interpretability, Understandability, Usability, and Usefulness.

- Zimmerman et al. (2021) “UX designers pushing AI in the enterprise: a case for adaptive UIs”
- “Why UX Should Guide AI” (2021) “Why UX should guide AI”
- Simon Sterne (2023) UX is about helping the user make decisions
- Dávid Pásztor (2018)

- M. Anderson (2020)
- Lennart Ziburski (2018) UX of AI
- Stephanie Donahole (2021)
- Lexow (2021)
- Dávid Pásztor (2018) AI UX principles
- Bubeck et al. (2023) finds ChatGPT passes many exams meant for humans.
- Suen & Hung (2023) discusses AI systems used for evaluating candidates at job interviews
- Z. Wang et al. (2020) propose Neuroscore to reflect perception of images.
- Su & Yang (2022) and Su et al. (2023) review papers on AI literacy in early childhood education and finds a lack of guidelines and teacher expertise.
- W. Yang (2022) proposes a curriculum for in-context teaching of AI for kids.
- Eric Schmidt & Ben Herold (2022) audiobook
- Akshay Kore (2022) Designing Human-Centric AI Experiences: Applied UX Design for Artificial Intelligence
- *Studies in Conversational UX Design* (2018) chatbot book
- Tom Hathaway & Angela Hathaway (2021) chatbot book
- Lew & Schumacher (2020) AI UX book
- AI IxD is about human-centered seamless design
- Storytelling
- Human-computer interaction (HCI) has a long storied history since the early days of computing when getting a copy machine to work required specialized skill. Xerox Sparc lab focused on early human factors work and inspired a the field of HCI to make computer more human-friendly.
- Soleimani (2018): UI patterns for AI, new Section for Thesis background: “Human-Friendly UX For AI”?
- **Discuss what is UX for AI (per prof Liou’s comment), so it’s clear this is about UX for AI**
- What is Personalized AI?
- Google’s AI Principles and provides Google’s UX for AI library (Google, n.d.; Josh Lovejoy, n.d.). In Design Portland (2018), Lovejoy, lead UX designer at Google’s people-centric AI systems department (PAIR), reminds us that while AI offers need tools, user experience design needs to remain human-centered. While AI can find patterns and offer suggestions, humans should always have the final say.
- Harvard Advanced Leadership Initiative (2021)
- VideoLecturesChannel (2022) “Communication in Human-AI Interaction”
- Haiyi Zhu & Steven Wu (2021)

- Akata et al. (2020)
- Dignum (2021)
- Bolei Zhou (2022)
- ReadyAI (2020)
- Vinuesa et al. (2020)
- Orozco et al. (2020)

9.3.4 Performing Under High-Stakes Situations

AI-based systems are being implemented in medicine, where stakes are high raising the need for ethical considerations. Since CADUCEUS in the 1970s (in Kanza et al., 2021), the first automated medical decision making system, medical AI now provides Health Diagnostic Symptoms and AI-assistants in medical imaging. (Calisto et al., 2022) focuses on AI-human interactions in medical workflows and underscores the importance of output explainability. Medical professionals who were given AI results with an explanation trusted the results more. (Peter Lee et al., 2023) imagines an AI revolution in medicine using GPT models, providing improved tools for decreasing the time and money spent on administrative paperwork while providing a support system for analyzing medical data.

- Example of ChatGPT explaining medical terminology in a blood report.



Certainly! Below is a table that explains the abbreviations and values from your blood report. Reply Like Dislike

These values represent different components and characteristics of your blood, and they can provide insights into your overall health.

Abbreviation	Full Name	Value	Unit	Description
B-CBC-5Diff	Complete Blood Count with 5-part Differential	-	-	A comprehensive test measuring different components of the blood.
WBC	White Blood Cells	4,8	/nL	Cells that fight infections.
RBC	Red Blood Cells	4,92	/pL	Cells that carry oxygen.
Hb	Hemoglobin	147	g/L	Protein that carries oxygen in red blood cells.
Hct	Hematocrit	44,4	%	Proportion of red blood cells to the total blood volume.
MCV	Mean Corpuscular Volume	90,2	fL	Average size of red blood cells.
MCH	Mean Corpuscular Hemoglobin	29,9	pg	Average amount of hemoglobin per red blood cell.
MCHC	Mean Corpuscular Hemoglobin	332	g/L	Average concentration of hemoglobin in red blood

Figure 19: Example of ChatGPT explaining medical terminology in a blood report.

- The Paris Olympic games make heavy use of AI (Kulkarni, 2024).

Fitness Guides, AI Guides have been shown to improve sports performance, etc, etc. Can this idea be applied to sustainability? MyFitness Pal, AI training assistant. There's not avatar.

AI in Medicine, AI has been in medicine since early days with the promise to improve health outcomes.

Human Augmentation, Technology for augmenting human skills or replacing skills that were lost due to an accident is one usage of tech.

- (Dot Go, 2023) makes the camera the interaction device for people with vision impairment.

AI is being use in high-Stakes Situations (Medical, Cars, Etc).

- Singhal et al. (2023) medial AI reaching expert-level question-answering ability.
- Ayers et al. (2023) in an online text-based setting, patients rated answers from the AI better, and more empathetic, than answers from human doctors.

- Daisy Wolf & Pande Vijay (2023) criticizes US healthcare's slow adoption of technology and predicts AI will help healthcare leapfrog into a new era of productivity by acting more like a human assistant.
- Eliza Strickland (2023) Chat interface for medical communication
- Jeblick et al. (2022) suggest complicated radiology reports can be explained to patients using AI chatbots.
- “Health. Powered by Ada.” (n.d.) health app, “Know and track your symptoms”
- *Buoy Health* (n.d.) AI symptom checker,
- Women in AI (n.d.) AI-based health monitoring
- *Home - Lark Health* (n.d.) track chronic condition with AI-chat
- Stephanie Donahole (2021) AI impact on UX design
- Yuan et al. (2022): “AI assistant advantages are important factors affecting the *utilitarian/hedonic* value perceived by users, which further influence user willingness to accept AI assistants. The relationships between AI assistant advantages and utilitarian and hedonic value are affected differently by social anxiety.”

Name	Features
Charisma	
Replika	Avatar, Emotion, Video Call, Audio
Siri	Audio

9.3.5 Human-Computer Interactions Without a “Computer”

How does AI affect Human-Computer Interactions

The field of Human Factors and Ergonomics (HFE) emphasizes designing user experiences (UX) that cater to human needs (The International Ergonomics Association, 2019). Designers think through every interaction of the user with a system and consider a set of metrics at each point of interaction including the user’s context of use and emotional needs.

Software designers, unlike industrial designers, can’t physically alter the ergonomics of a device, which should be optimized for human well-being to begin with and form a cohesive experience together with the software. However, software designers can significantly reduce mental strain by crafting easy-to-use software and user-friendly user journeys. Software interaction design goes beyond the form-factor and accounts for human needs by using responsive design on the screen, aural feedback cues in sound design, and even more crucially, by showing the relevant content at the right time, making a profound difference to the experience, keeping the user engaged and returning for more. In the words of (Babich, 2019), “[T]he moment of interaction is just a part of the journey that a user goes through when they interact with a product. User experience design accounts for all user-facing aspects of a product or system”.

Drawing a parallel from narrative studies terminology, we can view user interaction as a heroic journey of the user to achieve their goals, by navigating through the interface until a success state - or facing failure. Storytelling has its part in interface design however designing for transparency is just as important, when we’re dealing with the user’s finances and sustainability data, which need to be communicated clearly and

accurately, to build long-term trust in the service. For a sustainable investment service, getting to a state of success - or failure - may take years, and even longer. Given such long timeframes, how can the app provide support to the user's emotional and practical needs throughout the journey?

(Tubik Studio, 2018) argues *affordance* measures the *clarity* of the interface to take action in user experience design, rooted in human visual perception, however, affected by knowledge of the world around us. A famous example is the door handle - by way of acculturation, most of us would immediately know how to use it - however, would that be the case for someone who saw a door handle for the first time? A similar situation is happening to the people born today. Think of all the technologies they have not seen before - what will be the interface they feel the most comfortable with?

For the vast majority of this study's target audience (college students), social media can be assumed as the primary interface through which they experience daily life. The widespread availability of mobile devices, cheap internet access, and AI-based optimizations for user retention, implemented by social media companies, means this is the baseline for young adult users' expectations (as of writing in 2020).

(Don Shin et al., 2020) proposes the model (fig. 10) of Algorithmic Experience (AX) "*investigating the nature and processes through which users perceive and actualize the potential for algorithmic affordance*" highlighting how interaction design is increasingly becoming dependent on AI. The user interface might remain the same in terms of architecture, but the content is improved, based on personalization and understanding the user at a deeper level.

In 2020 (when I proposed this thesis topic), Google had recently launched an improved natural language engine to better understand search queries ("Understanding Searches Better Than Ever Before," 2019), which was considered the next step towards *understanding* human language semantics. The trend was clear, and different types of algorithms were already involved in many types of interaction design, however, we were in the early stages of this technology (and still are *early* in 2024). Today's ChatGPT, Claude and Gemini have no problem understanding human semantics - yet are they intelligent?

Intelligence may be besides the point as long as AI *becomes very good at reasoning*. AI is a *reasoning engine* (Bubeck et al., 2023; Shipper, 2023; see J. Bailey, 2023 for a summary). That general observation applies to voice recognition, voice generation, natural language parsing, among others. Large consumer companies like McDonald's are in the process of replacing human staff with AI assistants in the drive-through, which can do a better job in providing a personal service than human clerks, for whom it would be impossible to remember the information of thousands of clients. In (Barrett, 2019), in the words of *Easterbrook*, a previous CEO of McDonald's "*How do you transition from mass marketing to mass personalization?*"

9.3.6 Do AI-Agents Need Anthropomorphism

What are the next features that could improve the next-generation UX/UI of AI-based assistants?

- GPT 4o combines different abilities into the same model, preserving more information: (OpenAI, 2024b).

(Stone Skipper, 2022) sketches a vision of "*[AI] blend into our lives in a form of apps and services*" deeply ingrained into daily human activity.

Should AIs look anthropomorphic or fade in the background? It's an open question. Perhaps we can expect a mix of both depending on the context of use and goals of the particular AI.

(Aschenbrenner, 2024) predicts “drop-in virtual coworkers”, AI-agents who are able to use computer systems like a human seamlessly replacing human employees.

Table 56: Some notable examples of anthropomorphic AIs for human emotions.

Anthropomorphic AI User Interfaces	Non-Anthropomorphic AI User Interfaces
AI wife (“’My Wife Is Dead’,” 2023)	Generative AI has enabled developers to create AI tools for several industries, including AI-driven website builders (Constandse, 2018)
(Sarah Perez, 2023) character AI Mourning for the ‘dead’ AI (Phoebe Arslanagić-Wakefield, n.d.)	AI tools for web designers (patrizia-slongo, 2020)
AI for therapy (Broderick, 2023)	Microsoft Designer allows generating UIs just based on a text prompt (Microsoft, 2023)
Mental health uses: AI for bullying (Sung, 2023)	personalized bed-time stories for kids generated by AI (Bedtimestory.ai, 2023)

- (A. Costa & Silva, 2022) “Interaction Design for AI Systems”

9.3.7 Roleplay for Financial Robo-Advisors

Robo-advisors is a fintech term that was in fashion largely before the arrival of AI assistants and has been thus superseded by newer technologies. Ideally, robo-advisors can be more dynamic than humans and respond to changes quickly and cheaply. Human advisors are very expensive and not affordable for most consumers. (Capponi et al., 2019) argues “*The client has a risk profile that varies with time and to which the robo-advisor’s investment performance criterion dynamically adapts*”. The key improvement of *personalized financial advice* is understanding the user’s *dynamic risk profile*.

- Newer literature notes robo-advisor related research is scattered across disciplines (H. Zhu et al., 2024). – Anthropomorphism: human-like attributes in robo-advisors, such as conversational chatbots, can affect adoption and risk preferences among customers. Studies show that anthropomorphic robo-advisors increase customer trust and reduce algorithm aversion.” **similar to my research**

In the early days of robo-advisory, Germany and the United Kingdom led the way with the most robo-advisory usage in Europe (Cowan, 2018). While Germany had 30+ robot-advisors on the market in 2019, with a total of 3.9 billion EUR under robotic management, it was far less than individual apps like Betterment managed in the US (Bankinghub, 2019). Already in 2017, several of the early robo-advisors apps have shut down in the UK (AltFi, 2017). ETFmatic gained the largest number of downloads by 2017, focusing exclusively on exchange-traded funds (ETFs), tracking stock-market indexes automatically, with much less sophistication, than their US counterparts [ibid]. The app was bought by a bank in 2021 and closed down in 2023 (“ETFmatic - Account Funding of EURO Accounts Ceases,” 2023; Silva, 2023; **altfiBelgiumAionBank2021?**).

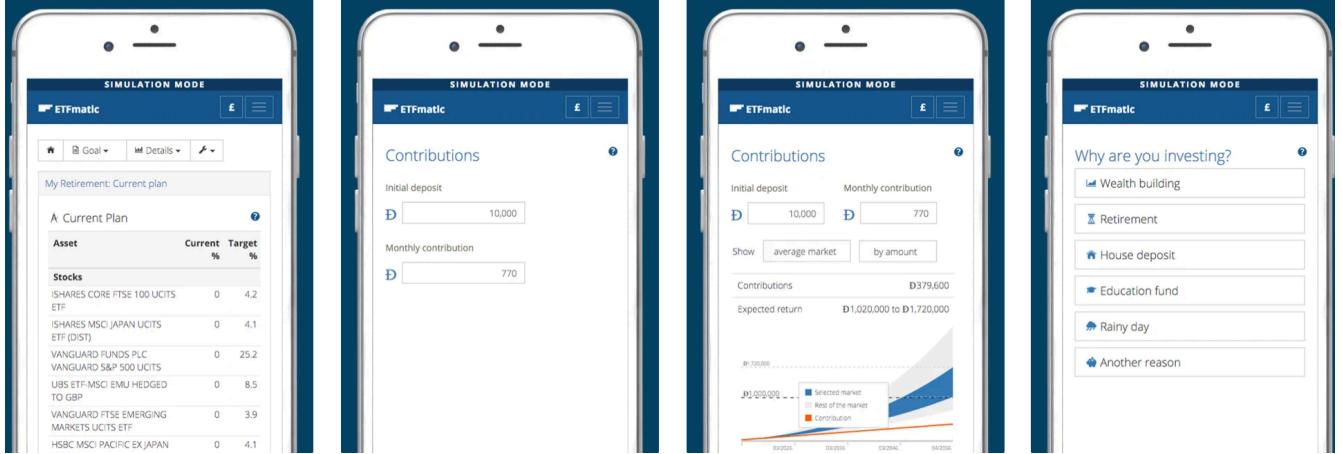


Figure 20: Out-of-date user interface of a European AI-Advisor ETFmatic in 2017 which was closed down in 2023 (Photo copyright ETFmatic)

Some relevant papers include a comparison of robot advisors by (Barbara Friedberg, 2021) and (Slack, 2021)'s account of how before Generative AI, financial chatbots were developed manually using a painstaking process that was slow and error-prone, for example using the Atura Process. Older financial robo-advisors, built by fintech companies aiming to provide personalized suggestions for making investments such as Betterment and Wealthfront are forced to upgrade their technology to keep up.

The user interface and user experience (UI/UX) of consumer-focused investing apps in Europe has improved over the past decade. The changing landscape is related to the earlier availability of better quality apps available in the US and the disappearance of the 1st generation of rudimentary investing apps and the lessons learned on how to automate the delivery of financial services while increasing user satisfaction.

In India, research is being conducted on how AI advisors could assist with investors' erratic behavior in stock market volatility situations, albeit without much success (Bhatia et al., 2020). India had more than 2000 fintechs since 2015 (Migozzi et al., 2023).

- NeuralNine (2021) Financial AI assistant in Python
- David et al. (2021) Can explainable AI help adoption of Financial AI assistants?
- A. Brown (2021) Financial chatbots
- Robo-advisors compete with community investing such as hedge funds, mutual funds, copy-trading, and DAOs with treasuries. Robo-Advisor do not have the type of social proof a community-based investment vehicle has. The question is, does the user trust the robot or a human.
- While the financial AI companion apps in the US market are ahead globally, they are not yet using many of the user experience innovations that are prevalent on social media platforms targeted at Generation Z and/or Millennials, possibly presenting an opportunity for cross-industry knowledge transfer, from businesses that are traditionally closer to the consumer - such as retailers. Financial AI companion apps have not yet grown to mainstream scale in Asia, Africa, Latin America, and Europe, being for the moment a largely US-based retail investor trend. The apps outside of the US are niche products in a nascent stage, however, they still provide relevant design directions or stories of what to avoid.

- *Why Design Is Key to Building Trust in FinTech / Star* (2021)
- Sean McGowan (2018)
- ROBIN DHANWANI (2021)
- “Designing a Fintech App - The UX Design Process” (2021)
- Cordeiro & Weevers (2016)
- Ungrammy (2020)
- Raha maraton etv investeerimissaade.. raadios on ka mingi saade
- “Empowering Digital Asset Banking” (n.d.): digital assets bank
- *Myclimate – Your Partner for Climate Protection* (2023) calculate climate cost
- “Green Central Banking” (n.d.)
- Hyde (2006) Money as a gift
- (~~johnssenkeeziVeBeenInvited2022?~~): Small stock investments
- Financial empowerment
- Small cash apps like African market Investment Clubs Invest in sustainability with people smarter than myself
- *Phase Two* (n.d.)
- Qayyum Rajan (2021) ESG pulse
- “NGFS” (n.d.) Network for Greening the Financial System
- SmartWealth (2021) How do consumer become investors? marketing materials say: “One of the greatest hurdles to financial independence is a consumer mindset.” One of the greatest hurdles to sustainability is a consumer mindset?
- Outlaw (2015)
- Malliaris & Salchenberger (1996) (**Need to pay for paper!**)
- “CMB | New Future of Financial AI” (n.d.) Huawei
- *Vise* (2023) Personalised portfolios
- *K+ Wallet - Apps on Google Play* (n.d.) Thai finance app
- “Thai Fintech Association (TFA)” (n.d.)
- Renato Capelj (February 16, 2021 6:47 PM)

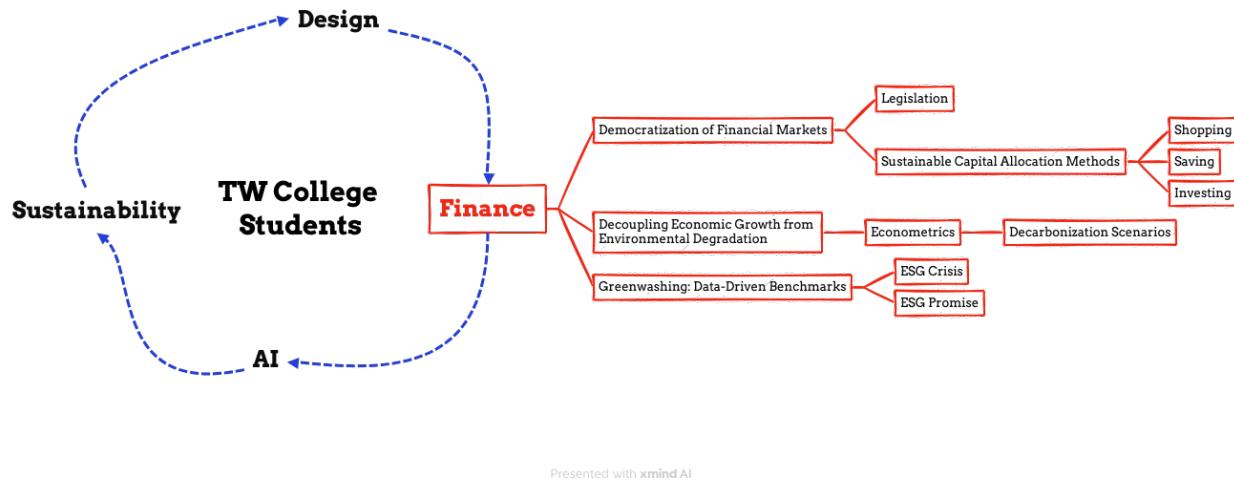


Figure 21: Visual abstract for the finance chapter

10.1 The Convergence of Money: One Wallet to Rule Shopping, Saving, and Investing

This chapter explores how money could incorporate sustainability as a feature.

"Money is information... it shouldn't be more expensive or slower than sending an email."
 (K. Käärman, Co-Founder of the Wise , formerly known as Transferwise, money transfer platform), said in 2018 (Käärman, 2018)

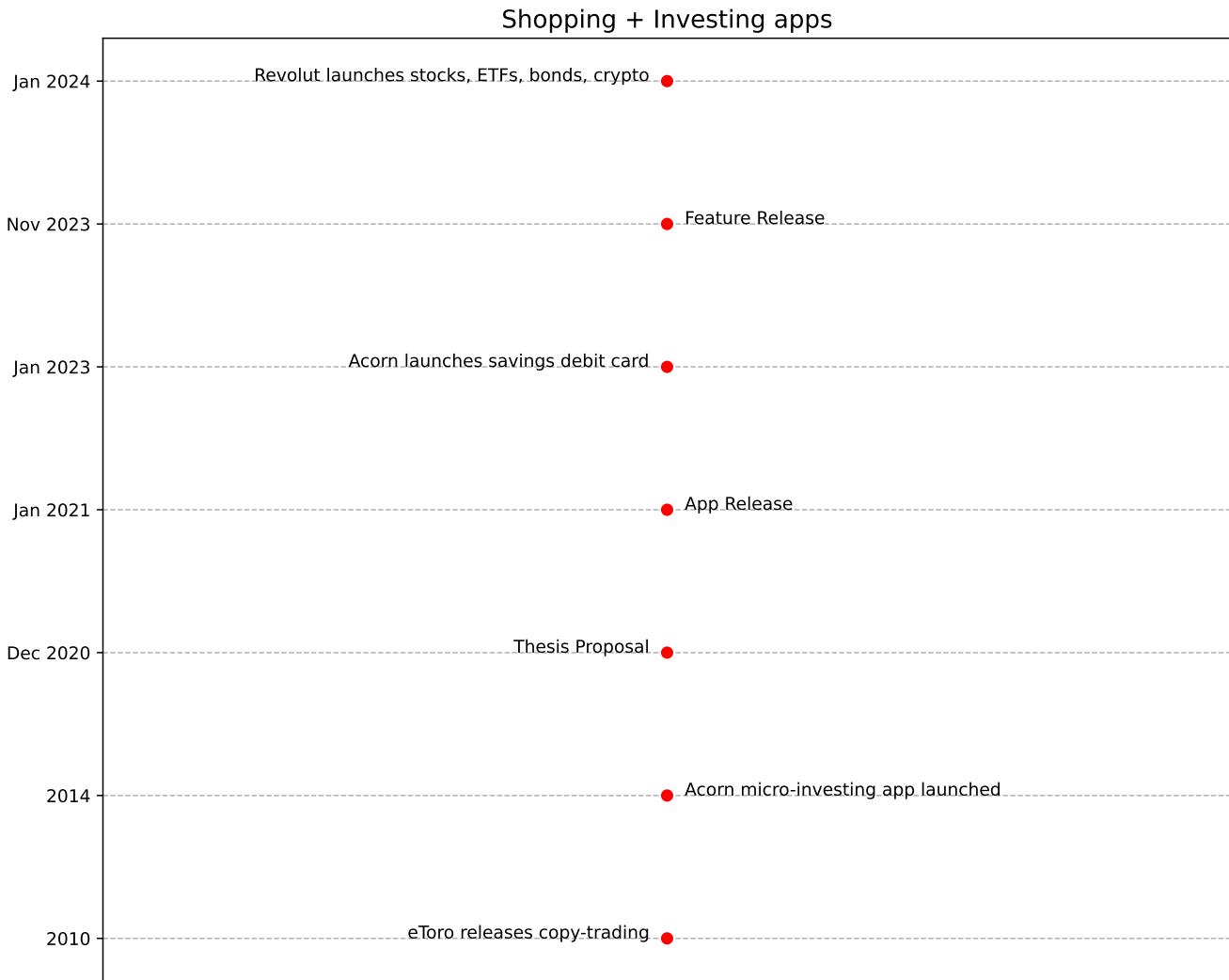
Money itself is changing and the meaning of money is becoming more diverse. Traditionally, money referred to the fiat money created by governments by law, using central banks, which loan money to commercial banks, that in turn make it available to the society. Now, we also have new types of money created by companies and individuals using blockchain-cryptography based distributed databases, which keep track of transactions (who-paid-whom). We have various types of tokens of value, such as cryptocurrencies, digital assets, loyalty points, etc, which can all function as types of money. Whatever the method of creation, in essence, money is a *system of trust* where *something* is used as a *medium of value exchange* and accepted by *other people* as payment.

10.1.1 Spurred by Fintech: The Democratization of Finance: A Precursor for Sustainable Superapps

Digital money in its various forms connects industries on popular financial mobile apps, which makes digital money more accessible and socially engaging, appealing to people who are active online. Because of the *democratization of finance* enabled by digitization and financial technologies, the journey from consumer to investor is becoming increasingly simple. Consumer-oriented financial apps increasingly enable new user interactions which blur boundaries between shopping, saving, and investing - termed here "*money convergence*". Empowering consumers to access finance through digital technologies and

delivering a simple user experience is the fintech trend of the last decade. More recently, motivated by boosting user numbers, apps such as Revolut and N26, that started out with only payments-focused businesses, begun making efforts to become all-in-one financial superapps offering saving and investing services.

Fintechs can growth really fast. Just last year in Canada, Neo Financial, which offers a mobile app and credit cards to consumers featuring cashback rewards on payments, savings and investing, won Canada's fastest growing company award in 2024, posting a 3-year revenue growth of 38,431% earning between \$75M and \$100M USD in annual revenue from 1.3 million customers ("Ranking Canada's Top Growing Companies of 2024," 2024).



While consumers are beginning to become more money-savvy, they still lack financial literacy. Giving users exposure to investment opportunities through familiar activities like shopping may hold the potential to boost financial literacy levels, enticing consumers to learn more about taking advantage of their financial opportunities as well as understanding how to manage the types or risk involved.

- Financial Literacy. Sustainability Literacy. Financial and Sustainability Literacy are intertwined. How can finance enable/help/encourage sustainability?

- Austin Ryder (2020) Define your habits: are you consumer or investor?

Retail investors typically have less financial literacy.

Financial superapps shopping, saving, and investing are converging on digital platforms, aiming to permeate our daily financial lives, with features such banking, payments, transfers, rewards and cashback programs (e.g. Rakuten), automated micro-investing round-up to next dollar (e.g. Acorn, Stash, Swedbank, many others), retail investing (Robinhood, Public, Lightyear), copy-trading (eToro) and offering various investment vehicles, to name just a few: (fractional shares of) stocks, derivatives like CFDs and futures, microloans (Kiva), commodities and precious metals such as gold and silver (Revolut), physical assets such as real estate, land, forest and digital assets such as cryptocurrencies, NFTs, and many other alternative assets of varied price, volatility, liquidity, and risk profile.

10.1.2 New Rules of Money: Legislative Efforts Empowering Consumers to Deploy Capital in Sustainability

Regardless if it's money spent on shopping or money saved and invested, these are all consumers' financial decisions of *capital allocation*. In one way or another, people are giving their money to companies. The critical question is: *do people choose to support sustainability-focused companies* - companies which invest deeply into green innovation and eco-friendly practices - or do people choose companies that pay less attention to sustainability? While all financial transactions support economic growth in the sense of being reflected in the Gross Domestic Product (GDP), not all money flows equally support sustainable economic growth.

Legislation is catching up with fintechs and setting higher standards for consumer protection. For example the Directive 14 2014/65/EU, 2014 of The European Union fully recognizes the changing financial landscape trending towards the democratization of investments: “*more investors have become active in the financial markets and are offered an even more complex wide-ranging set of services and instruments*” (European Parliament, 2014). Some key legislation for investors has been put in place recently, for example “MiFID II is a legislative framework instituted by the European Union (EU) to regulate financial markets in the bloc and improve protections for investors” (Kenton, 2020). MiFID II and MiFIR will ensure fairer, safer and more efficient markets and facilitate greater transparency for all participants” (European Securities and Markets Authority, 2017).

Already in 2001, while still part of the EU, the UK government was discussing ways to promote sustainable investment “*fundamental changes in VAT or corporation taxes could be used to promote greener consumption and investment*” (House of Commons, 2002). More recently, (HM Treasury, 2020) released a taxonomy of sustainable activities in the UK.

Campaign to ban polluting products campaign success story, EU shops can't sell deforestation products gathered over 100 thousand online signatures (WeMove Europe, 2022). Legislation banning products contributing to deforestation was passed by the EU Parliament and Council in 2023 and came into effect in July 2024 (Abnett & Abnett, 2024; European Parliament, 2023).

While the above trend is for governments to adapt to and work towards their environmental climate commitments and public demand, the sovereign risk remains an issue. For example, in the U.S. the policies supported by President Donald Trump during his presidency ran counter to many sustainability recommendations, including those directed at the financial markets, helping legacy industries stay competitive

for longer through subsidies, and lack of regulation, or even regulation supporting legacy technologies (Quinson, 2020).

(PWC, 2020) Changes to laws and regulations aimed at achieving climate change mitigation is a key driver behind the wave of ESG adoption. The goal of these laws, first adopted in the European Union, a self-proclaimed leader in eco-friendliness, is to pressure unsustainable companies to change towards greener practices, in fear of losing their access to future capital, and to create a mechanism forcing entire environmentally non-compliant business sectors to innovate towards sustainability unless they want to suffer from financial penalties. On the flip side of this stick and carrot fiscal strategy, ESG-compliant companies will have incentives to access to cheaper capital and larger investor demand from ESG-friendly investors.

Sustainable capital allocation methods are many. The extent to which this funnel works - and it's indeed a complex, multi-step funnel - depends on curbing greenwashing to a level that allows consumers to distinguish eco-friendly businesses from the heavy polluters.

, Can the democratization of various uses of money include sustainability as a feature?

- , includes financial products creating pathways towards sustainability-focused investing.

Trend of sustainably, how can sustainability become more accessible? People want to shop, save, and invest sustainably - how to do it?

10.1.3 Environmental, Social, and Corporate Governance (ESG) Criteria Provides a Shared Language

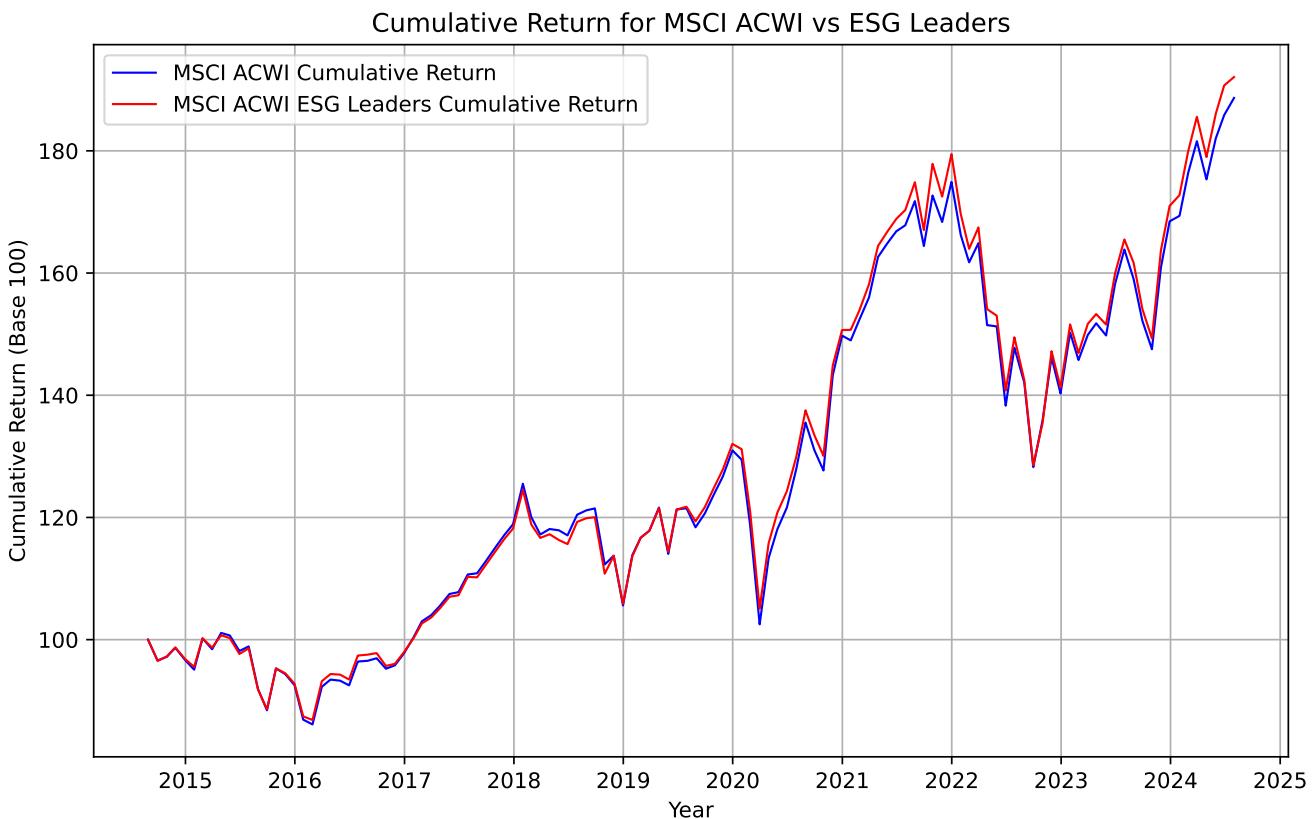
Since the 1970s, international bodies, governments, and private corporations have developed sustainability measurement metrics, the prominent one being ESG (Environmental, Social, and Corporate Governance) developed by the UN in 2005. This rating system has already been implemented or is in the process of being adopted on stock markets all over the world and has implications beyond the stock markets, allowing analysts to measure companies' performance on the triple bottom line: the financial, social, and environmental metrics.

Countering Misinformation with Transparency

ESG gives banks a new tool to market and sell environmentally conscious opportunities to institutional investors, for example, universities - a case in point being the recent partnership between HSBC and the University of Edinburgh (Reid, 2020). Another recent example is one of the largest private banks in Switzerland, Lombard Odier & Co, when they launched a thematic bio-economy fund inspired by the words of The Prince of Wales, 'Building a sustainable future is, in fact, the growth story of our time' (Jersey Evening Post, 2020).

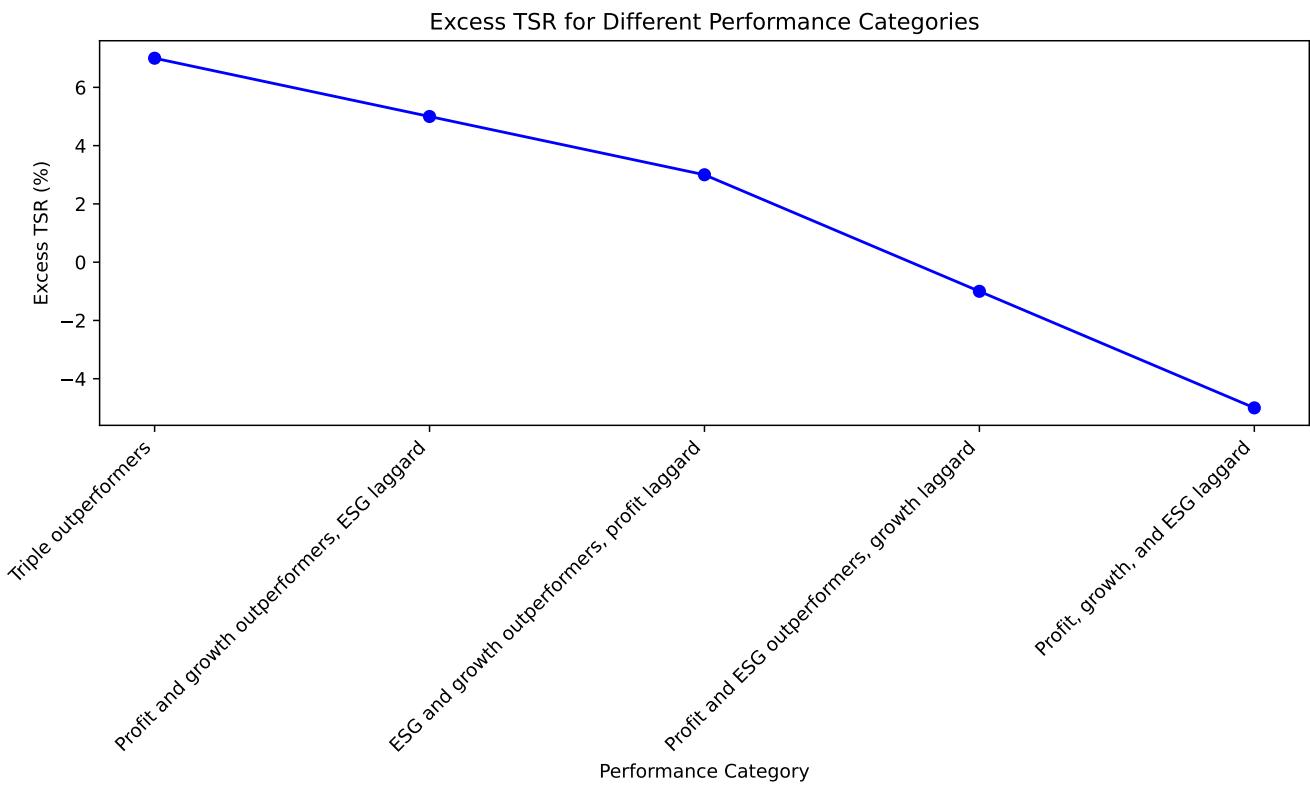
In Taiwan, the Taipei stock market has listed ESG stocks since 2017 and was hailed by Bloomberg as a regional leader in ESG reporting (Grauer, 2017). In December 2017, the *FTSE4Good TIP Taiwan ESG Index* was launched, which tracks ESG-rated companies on the Taipei stock market (Taiwan Index, 2024). Nasdaq Nordic introduced an ESG index in 2018, and Euronext, the largest stock market in Europe, introduced an ESG index and a series of derivative instruments in the summer of 2020 (Euronext, 2020).

(*The Importance of ESG Measurement and Canada's Opportunity for Improvement*, 2022) suggests ACWI ESG leaders outperform the non-ESG screened ACWI based on comparing MSCI indexes. It's notable that ACWI ESG starts to outperform the traditional ACWI only in the past few years.



- Nordic Climate Transparency Leadership analysis of Nasdaq OMX Nordic 120 companies: “*companies with higher quality climate reporting also provide higher returns*”. In contrast, (D. Luo, 2022) found firms with a lower ESG score are more profitable.
- Trucost, a company launched in 2000 to calculate the hidden environmental costs of large corporations and advance circular-economy practices was acquired in 2016 by S&P Dow Jones Indices, which by 2019 became a part of its ESG product offering (Indices, Oct 03, 2016, 08:30 ET; Mike Hower, Dec 9, 2015 7am EST; “S&P Rolls Out Trucost ESG Data to Its Customers,” 2019; Toffel & Sice, 2011). It’s parent company S&P Global also acquired RobecoSAM’s ESG rating business, consolidating S&P’s control of ESG ratings (George Geddes, 2019).

Sustainable Investing is Based on Data. Greenwashing is a large detractor from environmental action as it's difficult to know what is sustainable and what is not. Greenwashing Disturbs Sustainable Capital Allocation. Greenwashing erodes trust. Greenwashing has a negative Impact on Credibility.



- Marketing - Sustainability Marketing
- Environmental Information Disclosure (EID)
- *Simply Wall St - Stock & Sector Analysis Made Simple* (n.d.): Sites like Simply Wallstreet provide in-depth analysis: Simply Wallstreet also same for crypto
- Snowflake analysis like Simply Wallstreet

The promise of ESG is to counter misinformation with transparency.

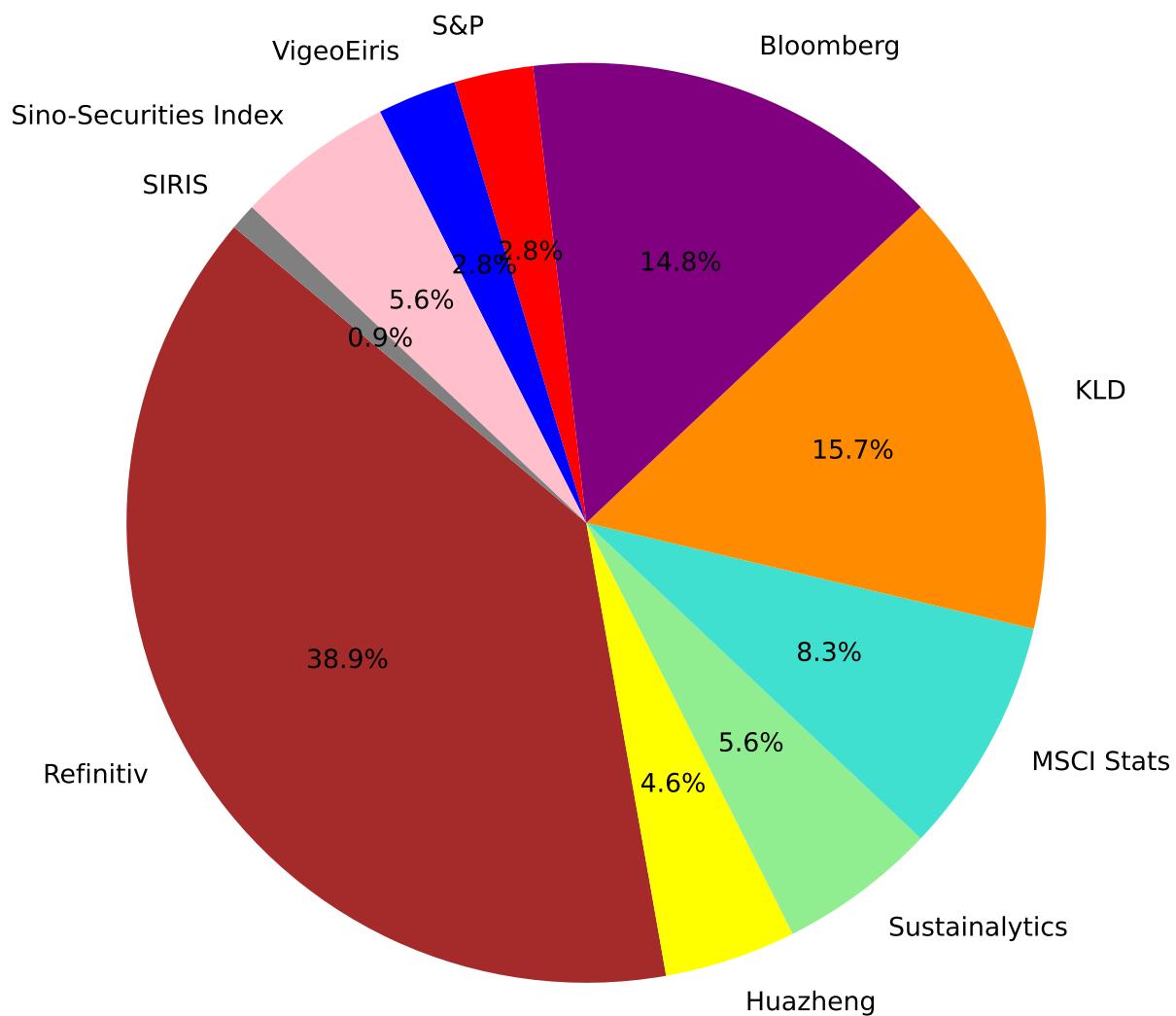
ESG companies don't emit less CO₂ than non-ESG companies.. ESG Criticism "25 ESG ratings from three major providers (Moody's Analytics, MSCI Inc., and Refinitiv)" - "*well-rated companies do not emit significantly less carbon than those with lower scores.*" (Amenc et al., 2023).

The lack of rigor is creating a backlash against ESG reporting.(C. Yu, 2021) reports ESG is filled with greenwashing. "Anti-ESG Crusade in US Sweeps 15 States With More Laws in Works" (2023) several US states are introducing regulation for ESGs to curb greenwashing. Frances Schwartzkopff (2022a) suggests the ESMA and EU has strengthened legislation to counter ESG greenwashing. Shashwat Mohanty (2022): "sustainable funds don't buy Zomato's ESG narrative". Bindman et al. (2024) reports large ESG funds managed by BlackRock and Vanguard are investing into JBS, a meat-packing company which is linked to deforestation of the Amazon rainforest through it's supply chain.

ESG Needs Standardisation of Methodologies. "Disparity between ESG methodologies was one of the key hurdles to finding the right sustainable strategy" (Margaryta Kirakosian & Angus Foote, 2022).

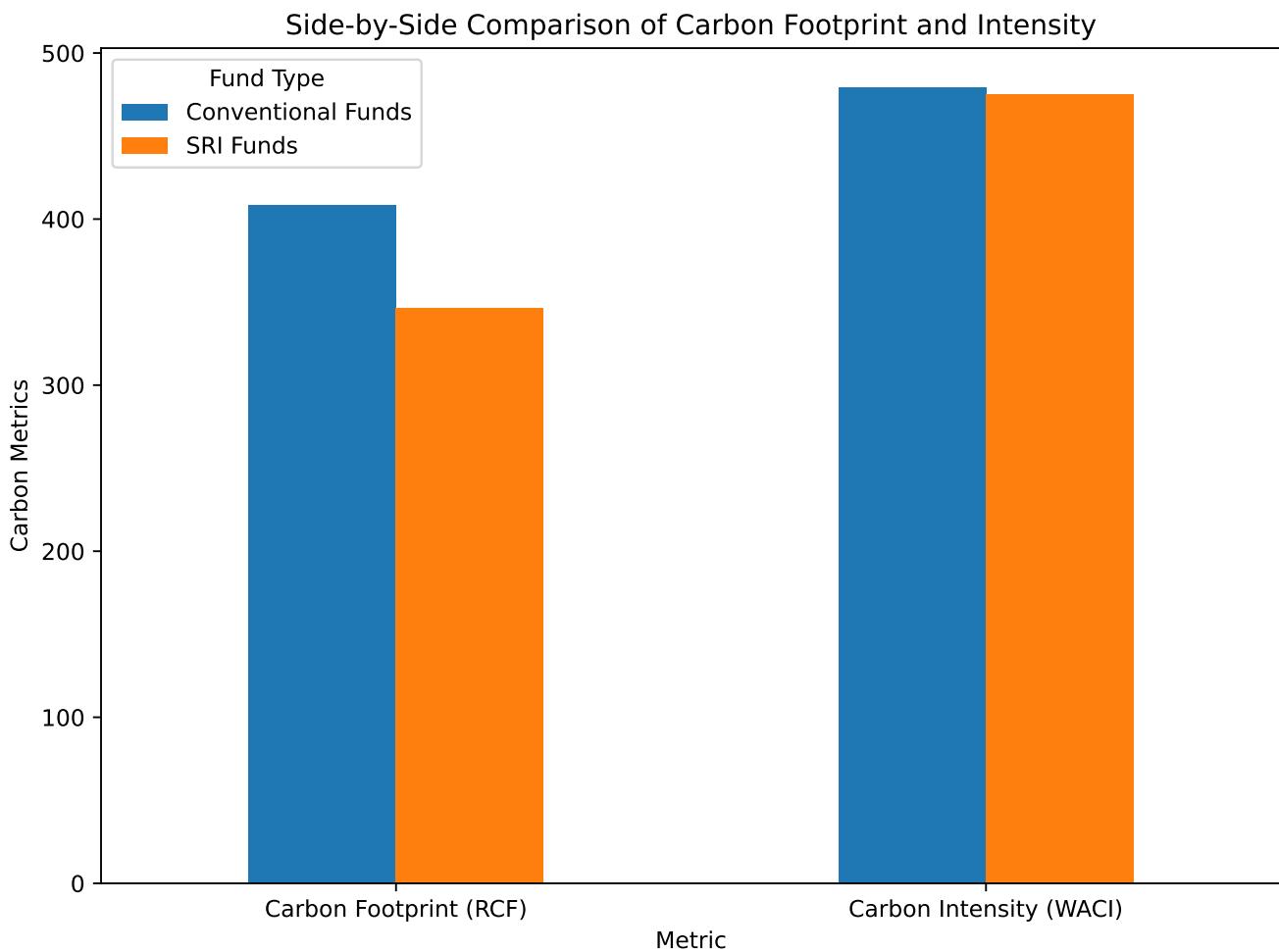
A meta-review of 136 research articles discovered the following ESG-rating agencies.

Distribution of Providers used among the Selected Articles

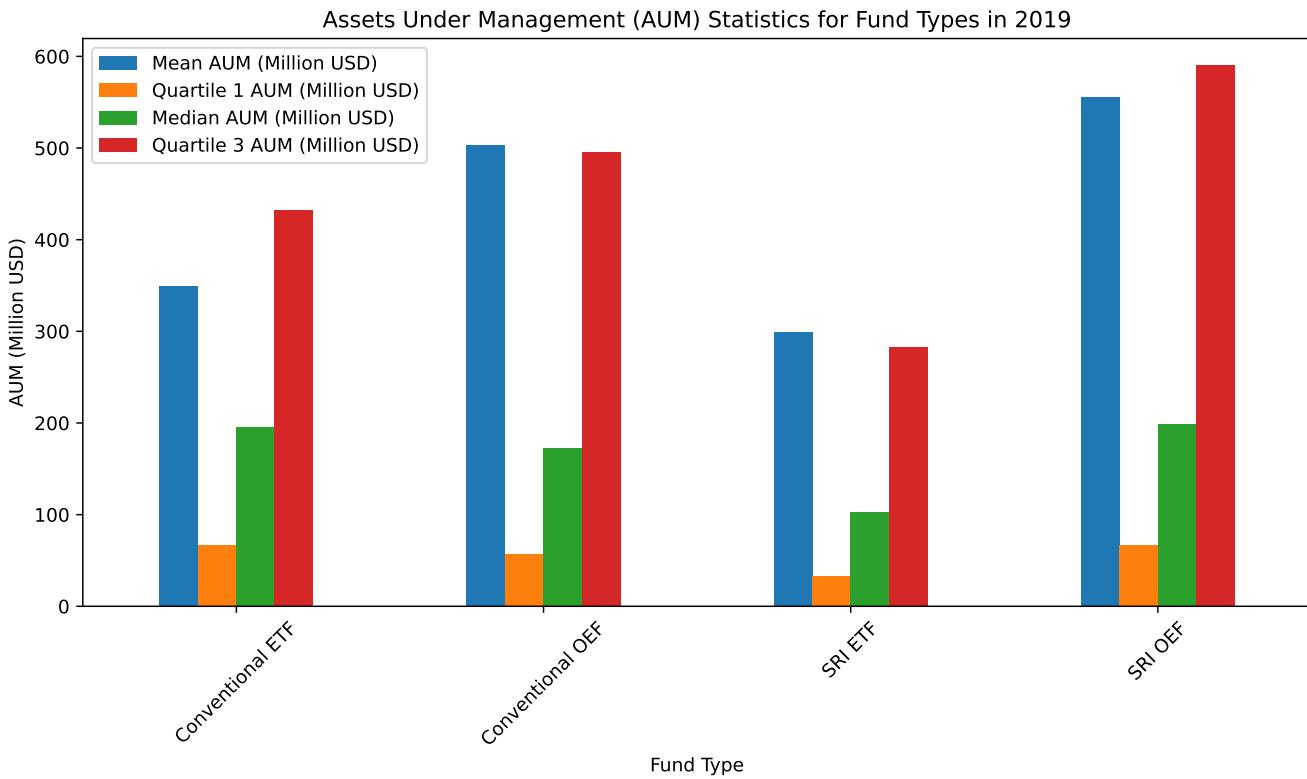


- ESG greenwashing Baldi & Pandimiglio (2022)
- Gemma Woodward (2022) 8 problems with ESG
- Agnew (2022) RIP ESG

(Popescu et al., 2023) shows SRI companies have a little bit smaller carbon footprint.



- ESG reports are very general and opaque. We need product-level analytics and reporting to be able to compare products.. ESG is filled with greenwashing. ESG is a really low bad. metrics and goals: ESG, SDGs, ESG risk. Q: Reflection on the ESG wave: Does a company that performs well in carbon reduction but whose products are harmful to health conform to the spirit of ESG? See ei saa ESG ja teisi mõõdikuid usaldada, crowdsourced mõõdikud. openesg.com/because you can't trust ESG (Aikman, 2022) !



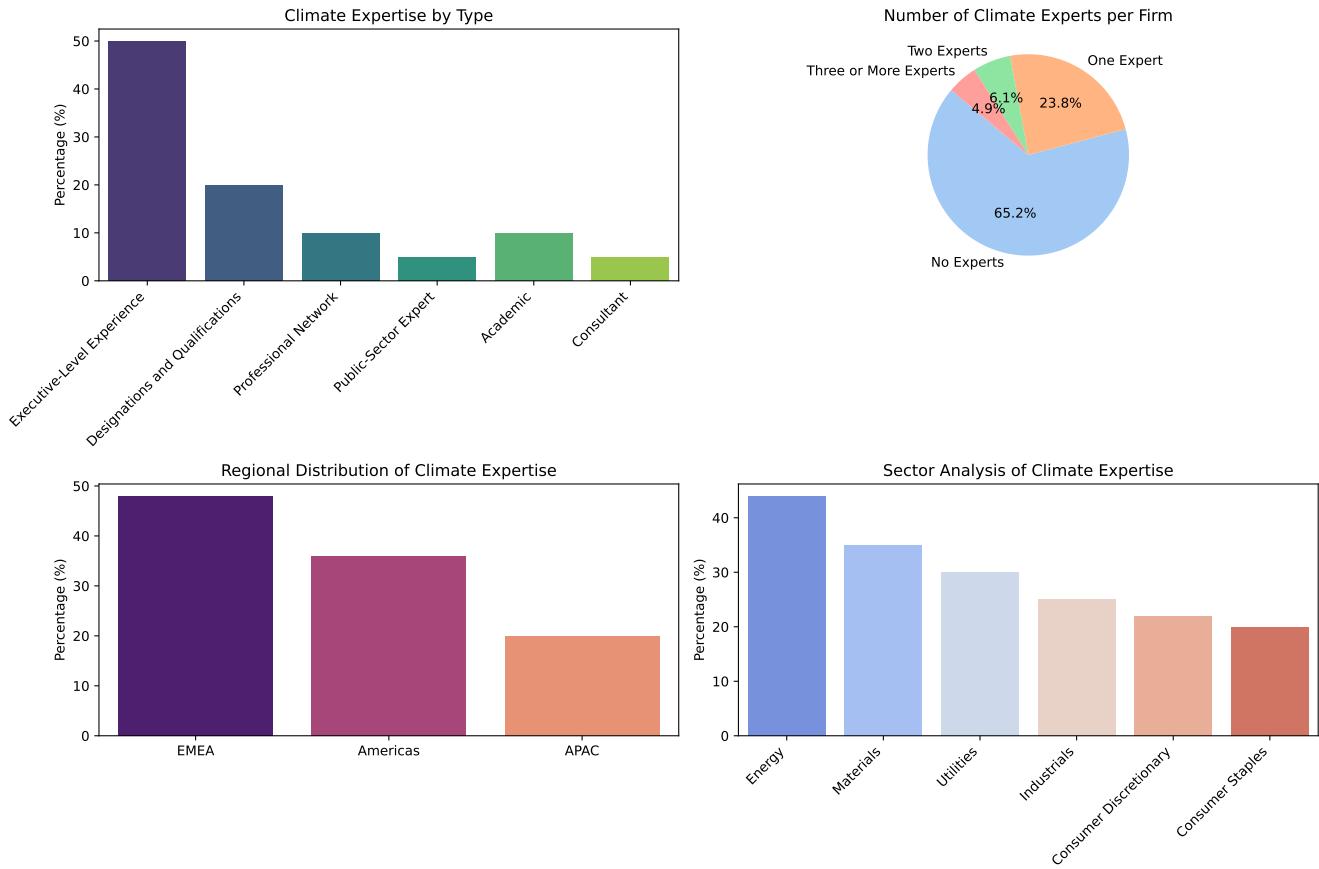
Three frameworks for corporate to think about ESG compliance is to position their company on the MEET - EXCEED - LEAD scale based on the size, complexity and available resources of the company.

Governance: Boards, Policy, and Investor Pressure Governance in ESG is the “*G that makes E and S happen*” or put in another way: governance drives social and environmental initiatives at companies.

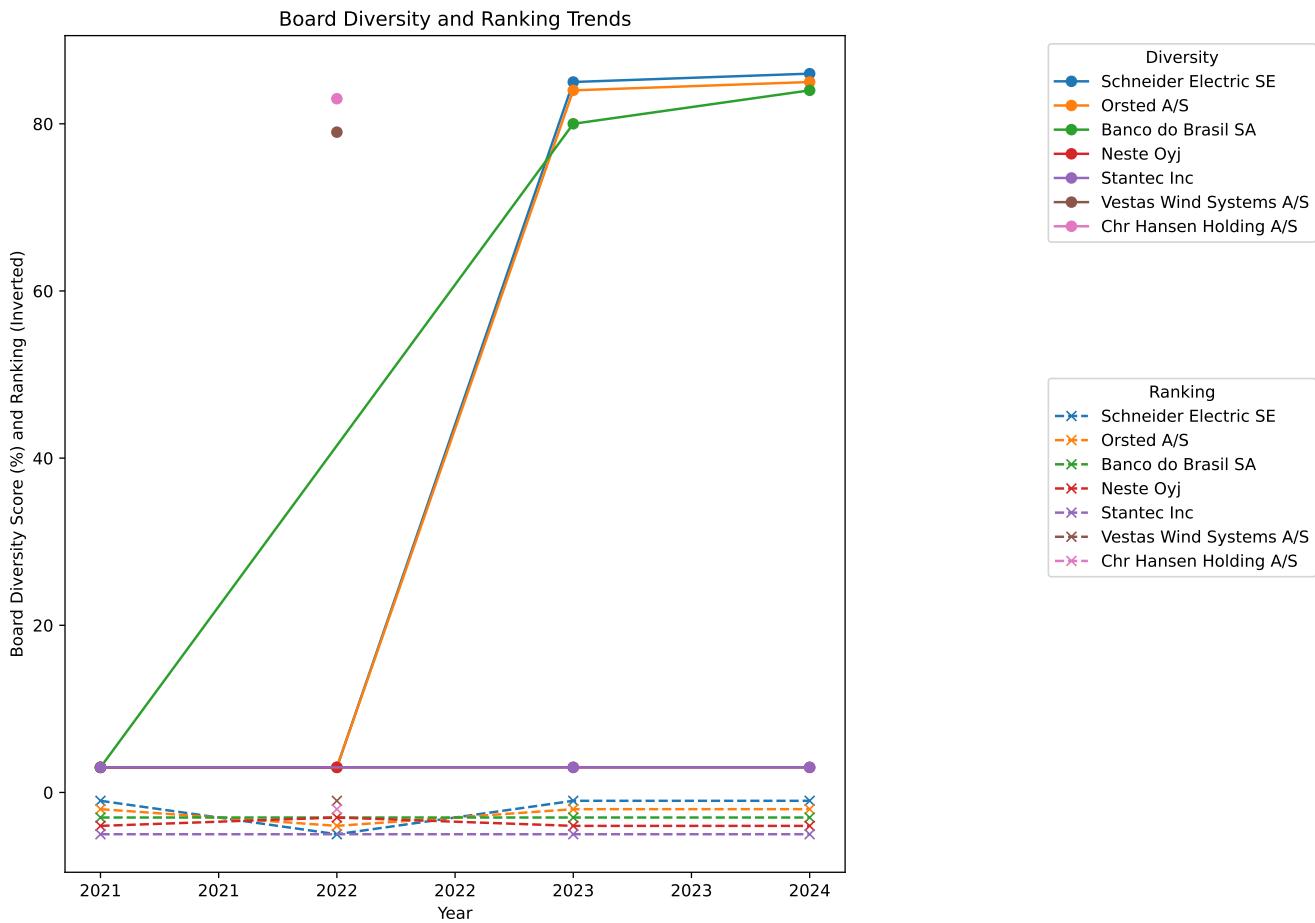
MSCI research finds company boards severely lacking in climate experts; among the 164 large CO2 emitters benchmarks by the *Climate Action 100+* alliance (Climate Action 100+, 2023; Sommer et al., 2024).

(Climate Action 100+, 2023) tracks large emitters around the world with combined market cap of \$10.3 Trillion USD.

Climate Expertise on Boards



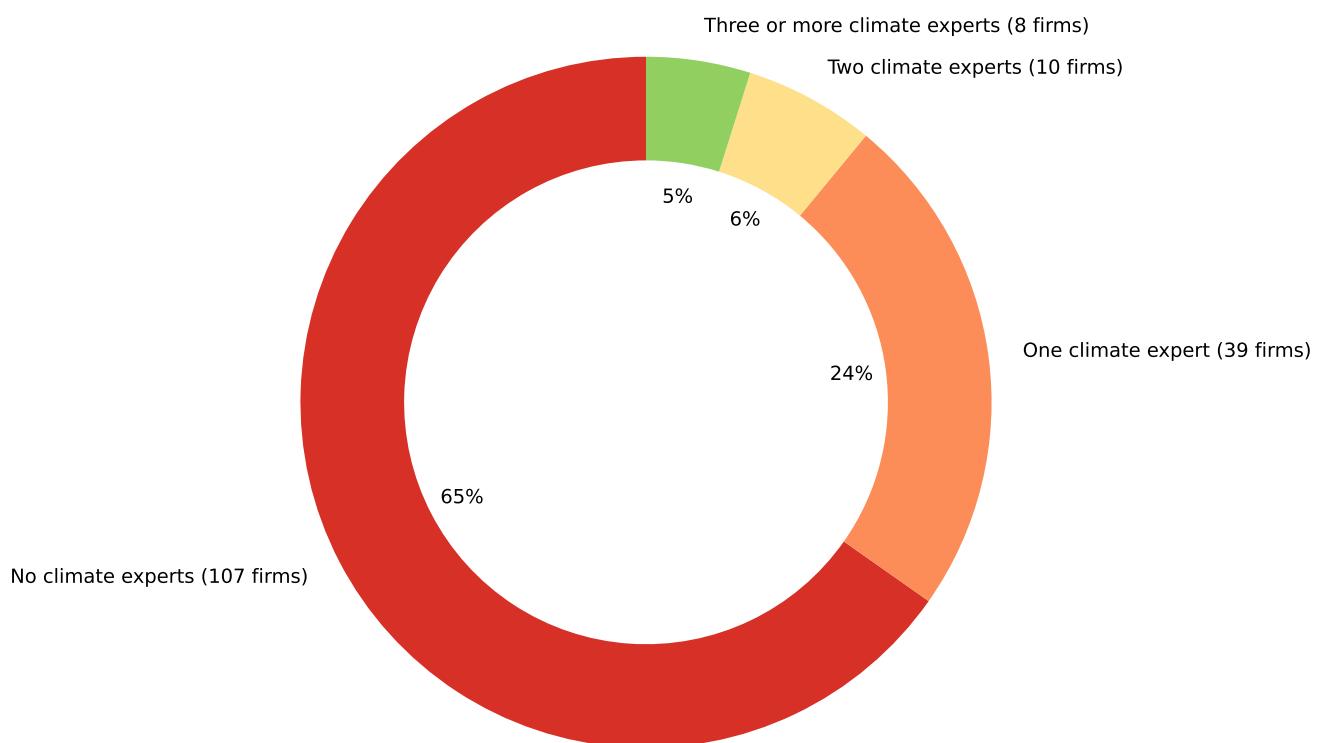
A systematic meta-review of 153 research papers of ESG literature around the world reports the major determinants of high ESG performance are board member diversity, firm size, and CEO attributes (Martiny et al., 2024).



Shareholders can leverage their numbers and join forces in order to affect the board members of large corporations. For example, the As Your Sow NGO aims to champion CSR through building coalitions of shareholders and taking legal action, including the Fossil Free Funds initiative which researches and rates funds' exposure to fossil fuels finance and its sister project Invest in Your Values rates retirement plans offered by employers (mostly US technology companies) (As You Sow, 2024a, 2024b)

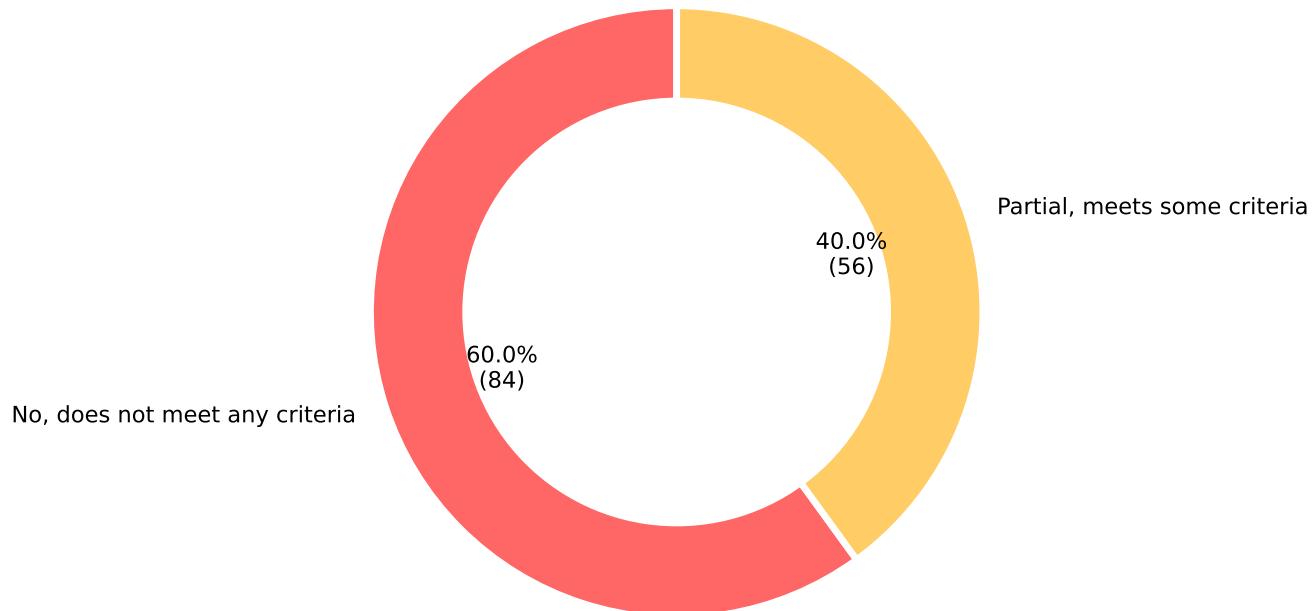
Majority of large emitters companies don't have climate experts (Climate Action 100+, 2023).

Firms by Number of Climate Experts

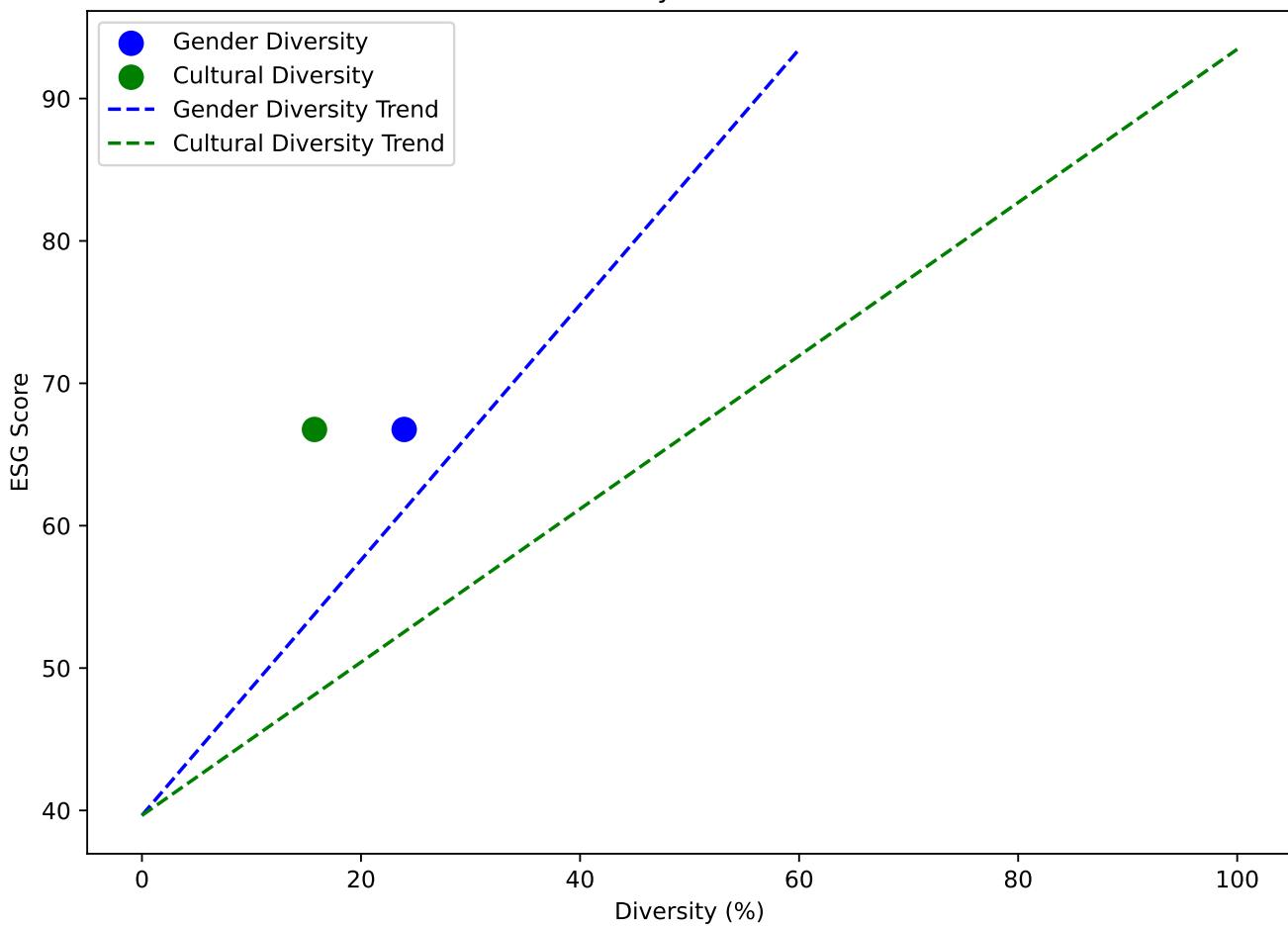


Most companies do not meet the criteria (Climate Action 100+, 2023).

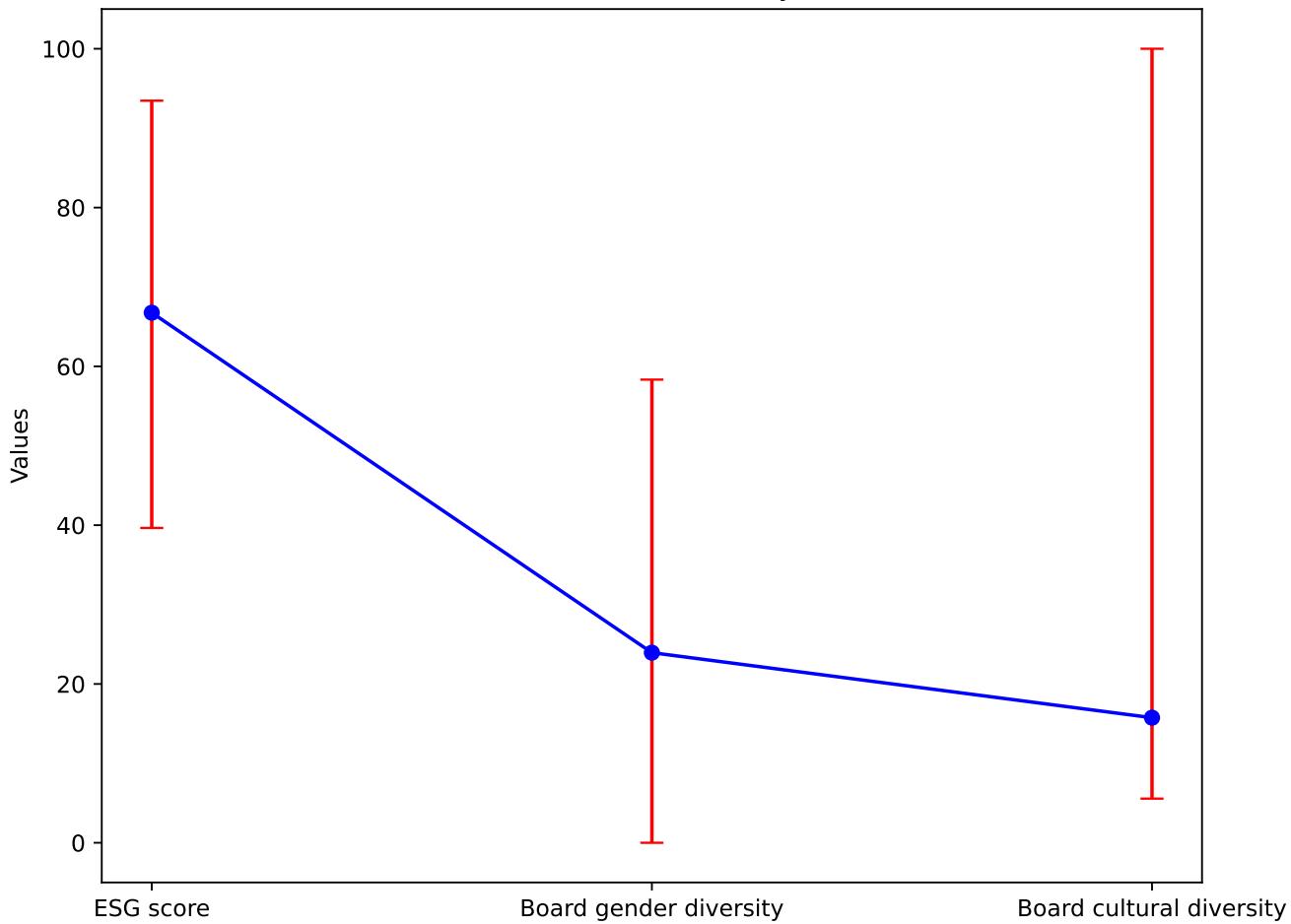
Overall Accounting and Audit Assessment

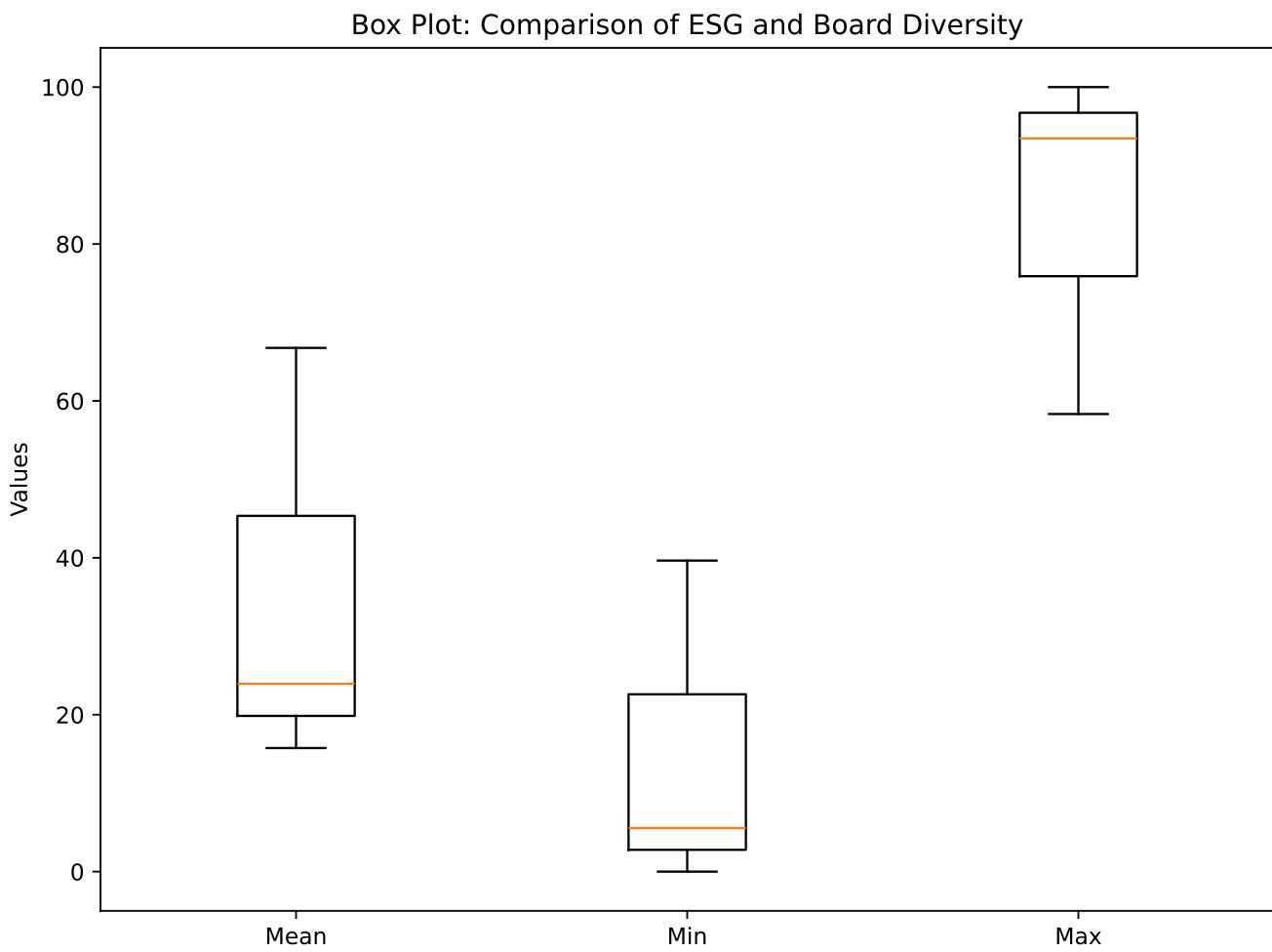


Scatter Plot: Board Diversity vs ESG Score with Trend Lines



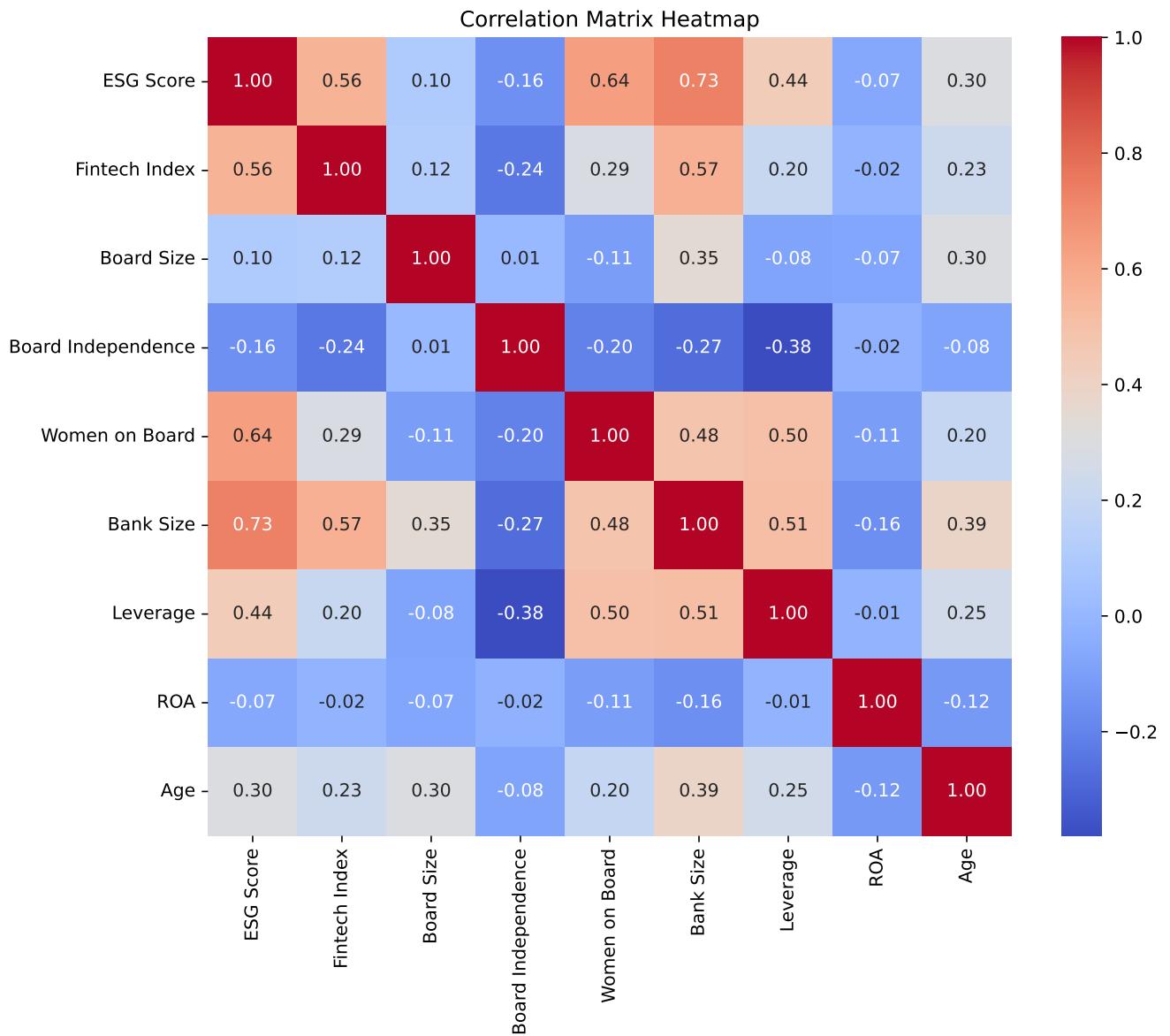
Line Chart with Error Bars: Diversity and ESG Score





Board diversity in the top 5 sustainable companies in 2024 based on Corporate Knights rankings (Corporate Knights, 2024).

In the U.S. and European banking sector (Dicuonzo et al., 2024) performed an analysis of 180 banks' data. Fintech Index and ESG Scores have a positive correlation, suggesting the adoption of technology has a statistically significant influence on better environmental stewardship, social and governance quality. Even larger predictors of high ESG score were than were Board Gender Diversity (Women on Board), the Size of the Bank, and Board Independence (governance structures with more independent directors could be more socially and environmentally responsible). On the flip side, out of the initial 1551 banks considered the majority did not have ESG data available to be able to perform the comparison.



In China, (Lu & Li, 2023) finds *digitization* is the pathway to Environmental Information Disclosure (EID) and Green Innovation.

The advice consultancies are providing to banks establishes a common language and helps banks to sell strategical alignment for long-term institutional sustainability in terms of environmental, social, and governance performance. PWC suggests “*asset managers educate their staff and client base. ‘It will be critical to build stronger ESG expertise among their employees by up-skilling existing staff on ESG principles and strategically scout for and integrate more diverse and ESG-trained talent’*” (PWC, 2020)

While ESG is riddled with problems, it has started a common language and there are many ways how to improve it

- For AI-powered assistants to be able to provide guidance, metrics are needed to evaluate sustainable assets, and ESG provides the current state-of-the-art for this. The largest obstacle to eco-friendly investing is greenwashing where companies and governments try to portray an asset as green when

in reality it's not. A personal investing assistant can provide an interface to focus on transparency, highlighting data sources and limitations, to help users feel in control of their investment decisions, and potentially even provide large-scale consumer feedback on negative practices back to the business through infringement discovery.

- Improving ESG Accessibility
- Trading ESG futures?? because climate is slow it makes sense to trade de climate future
- CFI2Z4 tracks Carbon Emissions Futures (Investing.com, 2024)
- “ESG 浪潮反思：一間減碳表現優異、但產品有害健康的企業，符合 ESG 精神嗎？” (2022)
- While promising to become sustainable, oil companies are increasing production Noor (2023); Sunak, UK Prime Minister announced 100 new licenses for oil drilling in the UK.
- Other large university endowments, such as managed by Yale, Stanford and MIT are in decision gridlock[^6]. Blackrock, the largest private investment fund in the world with \$10T USD under management, released guidance reflecting their plans to shift their investments to vehicles that are measured on Environmental, Social, and Governance (ESG) performance [^7]. However they later backtracked from their decision.
- Banks are required by law to apply the principle of Know Your Customer (KYC).
- It can be as mundane as choosing the next eco-friendly product instead of the polluting one we purchase in the supermarket make a difference? How to invest in the growth of companies that put ESG at the center of their activities instead of using it for greenwashing? Creating direct ties will improve ESG. A journey from consumption to investing, in line with users' personal values, by providing relevant sustainable finance guidance. x ##### ESG Crisis
- James Phillipps (2022) and “Financial Materiality Marks Next Big ESG Investing Battle” (2023) ESG Not delivering on its hopes
- TEDx Talks (2022) large corporations are using ESG for greenwashing by investing in token-projects but not changing their fundamental polluting practices.
- Margaryta Kirakosian (2022)
- Banks are hiding emissions related to capital markets, which is a major financing source for oil and gas projects Wilkes (2023)
- I. B. Daily (2021) best ESG list
- ESG UAE FutureESGInvesting
- Sanjai Bhagat (2022): Not better environmental performance, ESG poor performance
- Simões-Coelho et al. (2023) Coca Cola ESG
- PIETRO CECERE (2023) calls ESG labeling confusing and arbitrary.
- ESG is a Marketing Tool
- Analysis: Messari: investor education, information asymmetry

Problems

ESG is an annual report not realtime

ESG (Data Streams): Realtime Reporting

“[T]hanks to other emerging technology like IoT sensors (to collect ESG data) and blockchain (to track transactions), we have the infrastructure to collect more data, particularly for machine consumption. By measuring real-time energy usage, transportation routes, manufacturing waste, and so forth, we have more quantifiable ways to track corporations’ environmental performance without relying purely on what they say.” (Sahota, 2021)

Google Environmental Insights Explorer enables local governments (cities) to measure CO₂ emissions and enact environmental policies that optimize city functions such as traffic flows (*Methodology - Google Environmental Insights Explorer - Make Informed Decisions*, n.d.; Nicole Lombardo, 2021)

- “But the real breakthrough is how we can surface that real-time ESG data directly to individuals in the shops and online, linked to the products that they are browsing and potentially buying. This means that ESG change will finally be driven by the ultimate judge of business success – the customer.” (Ratkovic, 2023)
- Improve product *provenance*, blockchains offer this transparency
- Sepandar Kamvar (2022) “A blockchain is a database without a database admin”
- “Blockchain Companies Team Up To Track ESG Data” (2021)
- Ganu (2021)

There's a growing number of companies helping businesses to measure CO₂e emissions in their product lifecycle.

- Kyle Wiggers (2022) proposes makersite, instant sustainability impact from supply chain.
- Makersite (n.d.) proposes *product sustainability modeling*.
- Tim Nicolle (2021) “Real-time ESG data is more difficult to greenwash”, “supply chain is a significant source of ESG content”
- Automate CO₂ calculations real-time:
- Indrek Kald (2022): FlowIT automate CO₂ counting
- “Factory social score”.
- People working at the factories can report conditions
- *ESG Analytics / Real-time ESG Scores and Ratings for Companies Globally / GHG Emission Data* (n.d.): Governance or Corporate Responsibility

How are large corporations responding to the climate crisis?

Lack of leadership. (Capgemini, 2022): “Many business leaders see sustainability as costly obligation rather than investment in the future”.

The CEO of the Swedish clothing producer H&M - one of the largest fast-fashion in the world -, recognizes the potential impact of *conscious consumers* as a threat (**hoikkalaCEOSeesTerrible2019?**).

Many large businesses have tried to find solutions by launching climate-focused funding. (Korosec, 2021) reports that Amazon’s 2B USD to a Climate Pledge Fund earmarked to fix climate problems is invested in energy, logistics, and packaging startups, which will reduce material waste. “Good intentions don’t work, mechanisms do,” Amazon’s founder Bezos is quoted as saying in (Clifford, 2022). Walmart is taking a similar approach, having launched a project in 2017 to set CO₂ reduction targets in collaboration with its suppliers (Walmart, 2023). These examples underline how money marketed as climate funding by retail conglomerates means focus on reducing operational cost of running their business through automation and material savings.

Large corporations such as Nestle and Coca Cola support the biodiversity law to have a level playing field for business (Greens EFA, 2023).

- *Public Health Linkages with Sustainability* (2013)
- Guidotti (2015)
- “Sustainability is important for many reasons including: Environmental Quality – In order to have healthy communities, we need clean air, natural resources, and a nontoxic environment.”
- S. Low et al. (2022) finds considerable uncertainty exists among experts which CO₂ reduction methods among nature-based and technology-based are the most effective.
- Pathways to drawdown

10.1.4 Modern Slavery Persists: ESG Falls Short in Protecting Workers’ Rights and Mitigating Environmental Harm

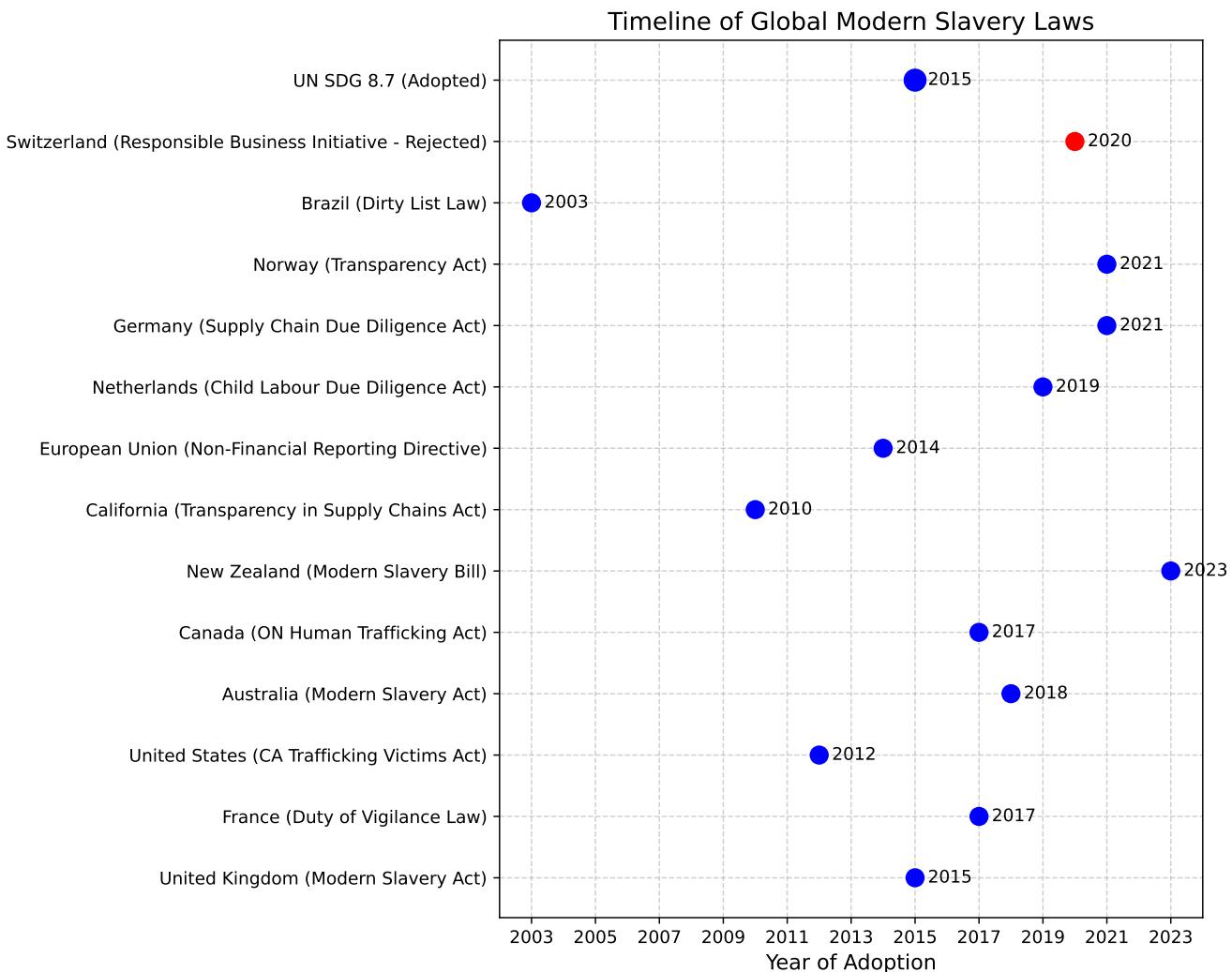
ESG is in crisis.

In 2023, an estimated 50 million people were in slavery around the world; lack of supply chain visibility hides forced labor and exploitation of undocumented migrants in agricultural work; 71% of enslaved people are estimated to be women. (Borrelli et al., 2023; Kunz et al., 2023). (Christ & V Helliar, 2021) estimates 20 million people are ‘stuck inside corporate blockchains’. The Global Slavery Index measures the considerable ‘import risk’ of having slavery inside its imports (Walk Free, 2023). (Hans van Leeuwen, 2023) slavery affects industries from fashion to technology, including sustainability enablers such as solar panels. ILO estimates 236 billion USD are generated in illegal profits from forced labor (International Labour Organization, 2024).

The Modern Slavery Act has been passed in several countries starting with the U.K. in 2015 (UK Parliament, 2024). (Mai et al., 2023) finds the quality of the reporting remains low among FTSE 100 (index of highly capitalized listings on the London Stock Exchange) companies.

On the global level, the United Nations SDG target 8.7 targets to eliminate all forms of slavery by 2025 however progress has been slow (The Minderoo Foundation & Commonwealth Human Rights Initiative, 2020).

Voters in Switzerland rejected the responsible business initiative in 2020 while the country is a global hub for trading commodities. “Switzerland has a hand in over 50% of the global trade in coffee and vegetable oils like palm oil as well as 35% of the global volume of cocoa, according to government estimates”(Anand Chandrasekhar & Andreas Gefe, 2021) begging the question can Swiss traders have more scrutiny over what they trade?



Slavery is connected to environmental degradation, and climate change (Decker Sparks et al., 2021). Enslaved people are used in environmental crimes such as 40% of deforestation globally. Cobalt used in technological products is in risk of being produced under forced labor in the D.R. Congo (Sovacool, 2021). In India and Pakistan, forced labor in brick kiln farms is possible to capture remotely from satellite images (Boyd et al., 2018). In effect, the need for cheap labor turns slavery into a *subsidy* keeping environmental degradation happening.

While reducing slavery in the supply chain sets very low bar for ESG, another aspect of supply tracing is the treatment of workers and working conditions.

- “commodification of human beings”
- Companies that intend to give supply chain a voice” by connecting workers directly to the consumer (even in anonymously, to protect the workers from retribution), include *CTMFile* and *Alexandria*. [Tim Nicolle (2021) and PrimaDollar Media (2021) PrimaDollar Realtime ESG Give supply chain a voice by connecting workers directly to the consumer.
 - “Worker Voice” (2022) Worker Voice apps.

10.1.5 Consumer Activists: a Small Minority

Recognition precedes protection, as the Estonian slogan goes: “*Õpetame märkama, et oskaksime hoida*” / “Learn to notice so we can preserve.” (Tartu loodusmaja, 2019). Yet *conscious consumers* only make up a small percentage of the entire consumer public, making individual action close to meaningless. (Milne et al., 2020) coins the term *mindful consumers*, who do research and are aware of the impact of their shopping choices.

- Is Sustainable Shopping possible? Consumers have increasing power. Where we put our money reinforces certain types of businesses, as conscious consumers we can vote with our dollars. How can we do it? Sustainable brands, ESG, etc, etc. Pushing higher Standards and choose companies that adopt circular design” What is the consumer CO₂ contribution? What is the target? Consume pressure to advance ESG regulatory standards to add a baseline ESG dynamic pricing of risk like climate, mandatory climate disclosures, carbon pricing knowing your supply chain, analyze supply chain risk

sustainable consumption relationships in Europe.

```
{python}1} sustainable_consumption_relationships()
```

- Sustainable Consumerism via Self-Regulation. 2M EUR project for the shopping app. (Klinglmayr et al., 2016)

Make use of indexes to compare companies.

- Weber (2021) proposes a sustainable shopping guide.
- Fuentes et al. (2019) discusses package free shopping.
- van der Wal et al. (2016) discusses “status motives make people publicly display sustainable behavior”.

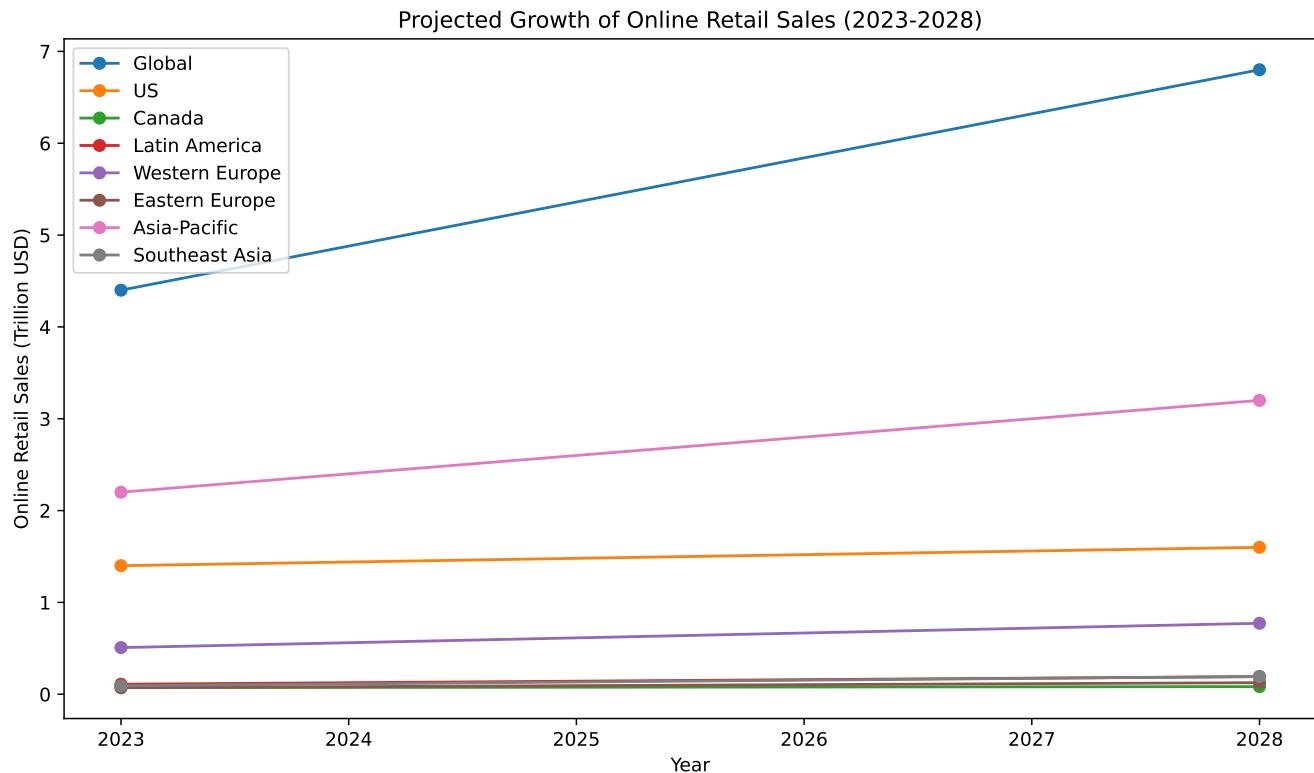
For consumer activism to become mainstream it needs to much simpler.

10.1.6 Shopping’s Environmental Footprint: Increasingly Driven by Digital Platforms, Social Commerce, AI Assistants

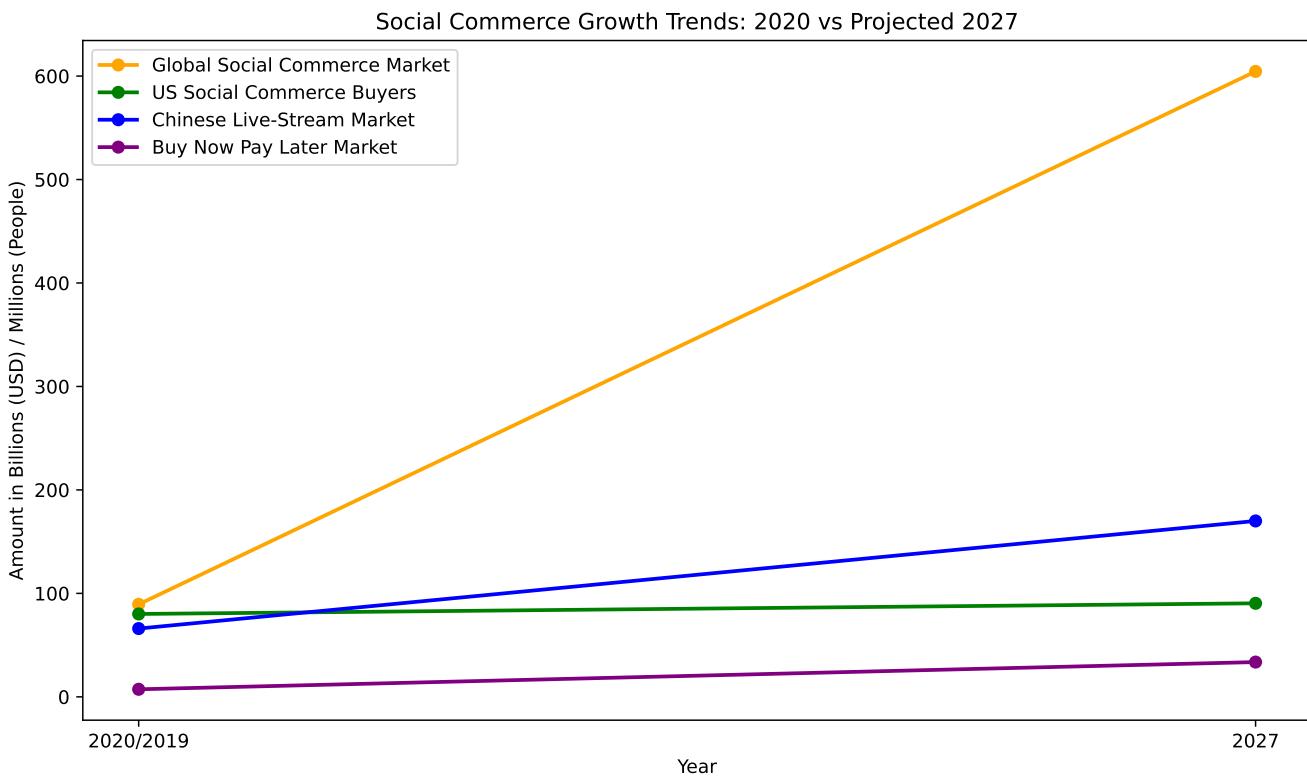
Online Shopping impact. Single’s day, etc.

Double Eleven 11/11 celebrated on November 11 is the world’s largest shopping festival (時代財經, 2023). In June 2023, 526 million people watch e-commerce live-streams in China; online bargaining is a type of ritual (Shiyu Liu et al., 2024). According to (Igini, 2024) “Asia is set to account for 50% of the world’s total online retail sales”.

It may seem impossible to turn the tide of consumerism, given the projected growth in online shopping (Forrester, 2024)



(The Influencer Factory, 2021) China is the furthest ahead in *social shopping*, the Chinese and U.S. market may be mature and growth will come from emerging markets (SEA, Latin-America).



In the US, TikTok is the leader in social commerce Loyst (2024)

important - more and more consumers using AI assistants to find alternative products, make shopping lists, etc Pandya (2025); Pastore (2025); Neuron (2025)

10.1.7 The Evolution of Payments as the Entry Point for Personal Finance: From Mobile Wallets to Buy Now Pay Later (BNPL) - Globally, and In Taiwan

Payments is one way consumers can take individual climate action. In the words of a Canadian investment blogger, “*every dollar you spend or invest is a vote for the companies and their ethical and sustainability practices*” (Fotheringham, 2017). The combination of consumption and investment is an access point to get the consumer thinking about investing. Even if the amount are small, they are a starting point for a thought process.

Table 58: Data compiled from (Focus Taiwan, 2025; PXPay Plus, n.d.; Taiwan News, Mar. 14, 2025 11:31)

Payment App	Features	Users in Taiwan	Origin
LINE Pay	Most popular payment app accepted all over Taiwan. Works stand-alone and inside the LINE messenger. Supports both in-store and online shopping payments, also direct P2P transfers to contacts (requires LINE Bank). Displays a map of its merchant network with discounts and coupons; integrates iPASS MONEY.	> 12 Mil-lion	Japan / Korea
JKOPay (街口支付)	QR code payments and P2P transfers to contacts; paying for bills.	> 7 Mil-lion	Taiwan
Taiwan Pay (台灣 Pay)	Official Taiwanese Government app in collaboration with Taiwanese banks. Supports payments directly from bank accounts (without the need for a card). Supports QR code payments, P2P transfers to contacts and paying bills. A unique feature is cash withdrawal from ATMs without the need for a bank card.	> 6 Mil-lion	Taiwan
Apple Pay	Requires an Apple iOS device; uses credit/debit cards via NFC, Secure, In-app & web payments	?	USA
Google Pay	Supports NFC and credit/debit cards, in-app and online payments as well as public transport.	?	USA
iPASS MONEY (一卡通)	Digital version of the iPASS card which can be used for QR code payments, P2P transfers to contacts, paying bills and public transport.	?	Taiwan
E.Sun Wallet (玉山)	Requires the Taiwanese E.Sun Bank and allows QR payments, P2P transfers to contacts and paying bills as well as financial management tools.	?	Taiwan
Pi Wallet (Pi 拍錢包)	Payment app by the PChome online shop supporting in-store QR and online payments, and paying for bills a parking.	?	Taiwan
PXPay (全聯福利中心)	Payment app by PX Mart, the largest domestic Taiwanese supermarket chain, supporting QR code payments, offering rewards and discounts and loyalty plans. Recently expanded to Korea quoting the interest of Taiwanese young people in Korean culture. In early 2025, PXPay began offering a saving and investing service called “Digital Hen” in collaboration with J.P Morgan Asset Management. According to the press release, the service aims to be a beginner-friendly financial innovation helping shoppers get into micro-investing.	?	Taiwan

Payment App	Features	Users in Taiwan	Origin
Hami Pay (中華電信)	Payment app by the largest phone company Chunghwa Telecom supporting NFC payments, public transport, and paying bills.	?	Taiwan
Samsung Pay (悠遊卡)	Requires a Samsung device; uses NFC; integrates EasyCard and credit/debit cards; supports public transport.	?	Korea

Banks and Fintechs Capture User Data. Payments are an Entry Point and Source of Consumer Action Data, Shopping Data. Payments is the primary way consumers use money. Is there a funnel From Payments to Investing? ESG Shopping is about Changing our relationship with money. Make commerce more transparent. Current shopping is like having a one-night stand. you barely know the name of your company. You don't know much about their background. Building consumer feeling of ownership, create meaningful connections between producers and consumers.

Digitalisation of payments creates lots of Point of Sale (PoS) data that's valuable to understand what people buy. Banks have access to each person's financial habits which makes it possible to model sustainable behavior using big data analysis. Asian markets have shown the fastest growth in the use of digital payments (McKinsey, 2020).

In Taiwan, O Bank makes use of Mastercard's data to calculate each transaction's CO₂ emissions and offer Taiwanese clients "Consumer Spending Carbon Calculator" and "Low-Carbon Lifestyle Debit Card" products (*Taiwan's O-Bank Launches 'Consumer Spending Carbon Calculator,' Rewards Carbon Reduction*, 2022). Mastercard has developed a service that banks can offer consumers sustainability reports (Mastercard, 2021). Similarly, Commons, formerly known as Joro, an independent app, analyses your personal financial data to estimate your CO₂ footprint (Chant, 2022).

A Dutch fintech company Bunq offers payment cards for sustainability, provided by MasterCard, which connects everyday payments to green projects, such as planting trees and donations to charities within the same user interface (Bunq, 2020). At the same time this can be considered greenwashing as Bunq only plants 1 tree per every €1,000 spend with a Bunq card. The example marketed at students cites *8 trees planted this month* while students scarcely would have €8,000 to spend every month.

Sharing a similar goal to Alibaba's Ant Forest, Bunq's approach creates a new interaction dynamic in a familiar context (card payments), enabling customers to effortlessly contribute to sustainability. However, it lacks the level of gamification which makes Alibaba's offering so addictive, while also not differentiating between the types of purchases the consumer makes, in terms of the level of eco-friendliness.



Figure 22: Bunq promises to combine banking and eco-friendly actions in the same user interface - yet is this greenwashing?

In Nigeria, (Emele Onu & Anthony Osae-Brown, 2022) reports how in order to promote the eNaira digital currency use, the Nigerian government limited the amount of cash that can be withdrawn from ATMs “*In Nigeria’s largely informal economy, cash outside banks represents 85% of currency in circulation and almost 40 million adults are without a bank account.*” [E-Naira find papers]

In Kenya, M-Pesa started since 2007 for mobile payments, used by more than 80% of farmers (Parlasca et al., 2022; Tyce, 2020). Using digital payments instead of cash enables a new class of experiences, in terms of personalization, and potentially, for sustainability.

In Sweden, point of sales (PoS) lending is a common practice, and one of the reasons for the success of Klarna, the Swedish banking startup, which has managed to lend money to more consumers than ever, through this improved user experience. Taking out loans for consumption is a questionable personal financial strategy at best. If people can loan money at the point of sales, why couldn’t there be 180 degrees opposite service - point of sales investing? And there is, called “round-up apps”. Next Generation Customer Experience (n.d.) suggests “*Targeted at millennials, Acorns is the investing app that rounds up purchases to the nearest dollar and invests the difference.*” - and example of From Shopping to Investing.

Many banks have started offering a service to automatically save and invest tiny amounts of money collected from shopping expenses. Every purchase one makes contributes a small percentage - usually rounded up to the nearest whole number - to one’s investment accounts. For example, Swedbank (2022), the leading bank in the Estonian market, offers a savings service where everyday payments made with one’s debit card are rounded up to the next Euro, and this amount is transferred to a separate savings account. Similarly, the Estonian bank LHV (2020) offers micro-investing and micro-savings services, with an interesting user experience innovation showing how for an average Estonian means additional savings of about 400€ per year.

- Bank inside of Whatsapp for the underbanked gig workers in Latin America Y Combinator (2023)
- Kirakosian (November 16, 2020) Digital payments and circular bio-economy, even using tactics such as co-branding with famous individuals.

While the financial industry is highly digitized, plenty of banks are still paper-oriented, running digital and offline processes simultaneously, making them slower and less competitive, than startups. Indeed, the new baseline for customer-facing finance is set by fintech, taking cues from the successful mobile apps in a variety of sectors, foregoing physical offices, and focusing on offering the best possible online experience for a specific financial service, such as payments.

Banks and Fintech are becoming more similar than ever. 39% of Millennials are willing to leave their bank for a better fintech (n=4,282); innovation in payments helps retention (PYMNTS, 2023). The European Central Bank describes fintech as improving the user experience across the board, making interactions more convenient, user-friendly, cheaper, and faster. “Fintech has had a more pronounced impact in the payments market [...] where the incumbents have accumulated the most glaring shortcomings, often resulting in inefficient and overpriced products,” Yves Mersch, Member of the Executive Board of the ECB says in European Central Bank (2019).

There are also people who are concerned with digital payments. There are concerns digital currencies also help to “*democratize financial surveillance*”. China was a money innovator introducing paper money in the Tang Dynasty (618-907 AD) (“First Paper Money,” n.d.). Jeff Benson (2022) “use the e-CNY network to increase financial surveillance.” “Central Bank Digital Currency (CBDC) Tracker” (2023) Digital currencies make tracking easier. Yahoo Finance (2022): WeChat, Alipay, vs digital yuan by Eswar Prasad. “Contactless Payments Prevalent in Macau - City’s de Facto Central Bank” (2023) in Macau Contactless Payments are prevalent.

There are many *neobanks*, or challenger banks, far too many to list. The table only includes a small sample of banks and the landscape is even larger if one includes the wider array of fintechs. Neo-banks often use sustainability marketing.

The following popular (totaling millions of users) robo-advisory apps combine sustainability, personalization, ethics, and investing however, they are mostly only available on the US market.

Table 59: Data from (Lightyear, n.d.; Monzo, 2023; “Mos - The Money App for Students,” n.d.; *Nubank - Finalmente Você No Controle Do Seu Dinheiro*, n.d.; *Selma – Your Finances Done Right*, n.d.; “Ziglu | The Fast, Simple Way to Buy and Sell Crypto, with No Hidden Fees.” n.d.). An up to date database (as of April 2025) is available at greenfilter.app/data.

Service	Features	Availability
Goodments	Matching investment vehicles to user's environmental, social, ethical values	USA
Wealthsimple	AI-assisted saving & investing for Millennials	USA, UK
Ellevest	AI-assisted robo-advisory focused on female investors and women-led business	USA
Betterment	AI-assisted cash management, savings, retirement, and investing	USA
Earthfolio	AI-assisted socially responsible investing	USA
Acorns	AI-assisted micro-investing	USA
Trine	Loans to eco-projects	USA
Single.Earth	Nature-back cryptocurrency	Global
Grünfin	Invest in funds	EU

M1 Finance	Finance Super App	US
Finimize	Investment research for anyone	US
NerdWallet	Financial clarity all in one place	US
Tomorrow Bank	Green Banking	EU
Marcus Invest	Robo-Advisor	US
Chipper	Digital cash app for African markets	Africa
Lightyear	Simple UI for Stocks, ETFs, interest from Estonia	EU
Ziglu	UK simple investing app	UK
Selma	Finnish investing app	EU
Monzo	Bank	UK
Nubank	Bank	Brazil
EToro	Investing and copy-investing	EU
Revolut	From payments to investing	UK, EU
Mos	Banking for students	US
Robinhood	Investing	US
Mintos	Buy bonds and loans	EU

- Andrés Engler (2022)
- DUB, another copy-trading app available on the Apple app store: dub (2025)
- Nubanks, also known as challenger banks.
- MARISA ADÁN GIL (2022)
- Caio Jobim (2022)
- *The European Fintechs to Watch in 2022* (2022)
- green transparency
- fundamental analysis such as the Piotroski F-score is not effective for startups because of high capital burn rates.

An Australian fintech Douugh released it's robo-advisor in 2024 (Paul, 2024). Douugh's tagline explain the ethos of a unified financial app simply: "*One app to spend and grow your money*".

The newest generation of robo-advisors are integrating large-language modules, for example Reuters highlights the Chinese brokerage firm Tiger Brokers as one among 20 Chinese companies integrating DeepSeek deeply into asset management from simple chat functionality all the way to executing trades.

Alipay already provides two investment services within it's payments app, at first launching Yu'e Bao (餘額寶) in 2013, which automatically invests small amounts on the users' accounts for returns typically above those of traditional banks' saving accounts, and later in 2015 Ant Fortune (螞蟻財富), offering access to thousands of investment products from partner companies (**kranesharesAntGroup101202?**). Alibaba owns over 30% of Alipay and both companies are pushing for increased use of AI within their services ("Chinese Billionaire Jack Ma Sees AI Future for Ant Group, in Rare Appearance," 2024). Similarly, both Line, through it's Line Pay, Line Securities, and Line Bank, and Naver, though Naver Pay, have been on a path for several years evolving into comprehensive financial platforms (Anna J. Park, 2023; LINE Corporation, 2019).

Tier 1: Established Consumer Payment Giants

Alipay is by far the largest payments super-app and provides two investment services within it's payments platform, first launching Yu'e Bao (餘額寶) in 2013, which automatically invests small amounts on the

users' accounts for returns typically above those of traditional banks' saving accounts, and later in 2015 Ant Fortune (螞蟻財富), offering access to thousands of investment products from partner companies (**kranesharesAntGroup101202?**). Alibaba owns over 30% of Alipay and both companies are pushing for increased use of AI within their services ("Chinese Billionaire Jack Ma Sees AI Future for Ant Group, in Rare Appearance," 2024). Similarly, both Line, through its Line Pay, Line Securities, and Line Bank, and Naver, though Naver Pay, have been on a path for several years evolving into comprehensive financial platforms (Anna J. Park, 2023; LINE Corporation, 2019). Payment apps created by Apple and Google are less-feature rich focusing on payments only. None of the largest payment apps have a specific focus on sustainability while Alipay does have a separate sustainability-focused service called Ant Forest for planting trees.

Service Features		Website	Availability	Users	Investing	Savings	Payments	Shopping (Pay)	Sustainability Focus
Alipay	Payments, banking, Yu'e Bao, Ant Fortune investing	alipay.com	China, Global (limited)	1.3 billion	Yes	Yes	Yes	Yes	No
WeChat Pay	Payments, financial services, Licaitong investing	wechat.com	China, Global (limited)	900 million	Yes	No	Yes	Yes	No
Apple Pay	Contactless payments	apple.com/ Alipay pay	Global	744 million	No	No	Yes	Yes	No
PhonePe	Payments, mutual funds, digital gold	phonepe.com	India	590 million	Yes	Yes	Yes	Yes	No
Paytm	Payments, banking, Paytm Money for stock & fund investing	paytm.com	India	350 million	Yes	Yes	Yes	Yes	No
Google Pay	Payments, loyalty, transit	pay.google.com	Global	150 million	No	No	Yes	Yes	No
Samsung Pay	Mobile payments	samsung.com	Global	?	No	No	Yes	Yes	No
Zelle	Bank-to-bank P2P payments	zellepay.com	USA	?	No	Yes	Yes	Yes	No
Nubank	Bank	nubank.com	Brazil	?	No	Yes	Yes	Yes	No

Tier 2: Established Growth Companies / Major Players

- The fact that money on a Wise account will accrue value while on Monese it's just static, immediately makes Wise more attractive, even if the amounts are small.

Service	Features	Website	Availability	User Base	Investing	Savings	Shopping (Payments)	Sustainability Focus	Notes
Venmo	P2P payments, crypto investing	venmo.com	USA	70 million	Yes	No	Yes	No	
Cash App	P2P payments, stock & Bitcoin investing	cash.app	USA, UK	57 million	Yes	No	Yes	No	
Chime	Online banking services including spending, account counts, savings account counts	chime.com	USA	22 million	No	Yes	Yes	No	
MoneyLion	Banking, investing, credit-building loans, financial tracking tools	moneylion.com	USA	20 million	Yes	Yes	Yes	No	
NerdWallet	Financial clarity all in one place	nerdwallet.com	USA	19 million	No	No	Yes	No	

Service	Features	Website	Availability	User Base	Investing	Savings	Shopping (Payments)	Sustainability Focus	Notes
SoFi	Loans, bank-ing, robo-investing, stock & crypto	sofi.com	USA	10 million	Yes	Yes	Yes	No	
Albert	Budgeting, saving, spending, investing, access to financial advisors	albert.com	USA	10 million	Yes	Yes	No	No	
Acorns	AI-assisted micro-investing	acorns.com	USA	5.7 million	Yes	No	No	No	
Wealthsimple	AI-assisted saving & investing for Millennials	wealthsimple.com	Canada, USA, UK	2.6 million	Yes	Yes	No	No	
Qapital	Saving and investing with gamification features	qapital.com	USA	2 million	Yes	Yes	No	No	
M1 Finance	Finance Super App	m1.com	USA	1 million	Yes	No	No	No	
Finimize	Investment research for anyone	finimize.co	Global	1 million	Yes	No	No	No	
Robinhood	Investing	robinhood.us	US	?	Yes	No	No	No	

Service	Features	Website	Availability	User Base	Investing	Savings	Shopping (Payments)	Sustainability Focus	Notes
BettermentAI-	betterment.com	USA	?		Yes	Yes	No	No	
assisted cash management, savings, retirement, and investing									
Revolut	From pay- ments to invest- ing	revolut.com	UK, EU	?	Yes	No	TRUE	No	
Monzo	Bank and copy- investing	monzo.com	UK	?	No	Yes	No	No	
eToro	Investing	etoro.com	EU	?	Yes	No	No	No	
Marcus Invest	Robo- Advisor	marcusinvest.com	USA	?	Yes	No	No	No	
Varo Bank	Online banking services includ- ing check- ing and high- yield savings	varomoney.com	USA	?	No	Yes	Yes	No	
Stash	Micro- investing plat- form en- abling small invest- ments	stash.com	USA	?	Yes	No	No	No	

Service	Features	Website	Availability	User Base	Investing	Savings	Shopping (Payments)	Sustainability Focus	Notes
Mint	Budgeting tools, bill tracking, free credit score monitoring	mint.com	USA	?	No	No	No	No	Ceased operations

Tier 3: Up-and-Coming Startups & Niche Players

Service	Features	Website	Availability	User Base	Investing	Savings	Shopping (Payments)	Sustainability Focus	Notes
Chipper Cash	Digital cash app for African markets	chippercash.com	Ghana, Nigeria, Uganda, USA	?	No	No	Yes	No	
Douugh	AI financial wellness app, smart account, saving tools	douugh.com	USA, Australia	?	Yes	Yes	Yes	No	Merged with Goodments
DUB	Copy-trading, mirror trades of notable figures	dubapp.com	USA	1 million downloads	Yes	No	No	No	
Earthfolio	AI-assisted socially responsible investing	earthfolio.com	USA	?	Yes	No	No	Yes	

Service	Features	Website	Availability	User Base	Investing	Savings	Shopping (Payments)	Sustainability Focus	Notes
Ellevest	AI-assisted robo-advisory focused on female investors and women-led business	ellevest.com	USA	?	Yes	No	No	No	
Goodments	Matching goodments to user's environmental, social, ethical values	goodments.com	USA	?	Yes	No	No	Yes	Merged with Douugh
Grünfin	Invest in funds	grunfin.com	EU	?	Yes	Yes	No	No	Ceased operations
Lightyear	Simple UI for Stocks, ETFs, interest from Estonia	lightyear.ee	EU	?	Yes	No	No	No	
Mintos	Buy bonds and loans	mintos.com	EU	?	Yes	No	No	No	
Mos	Banking for students	mos.com	US	?	No	Yes	Yes	No	
Selma	Finnish investing app	selma.com	EU	?	Yes	No	No	No	

Service	Features	Website	Availability	User Base	Investing	Savings	Shopping (Payments)	Sustainability Focus	Notes
Single.Earth	Nature-backed crypto currency	single.earth	Global	?	Yes	No	No	Yes	
Tomorrow Bank	Green Banking	tomorrow.fi	EU	120,000	No	Yes	Yes	Yes	
Trine	Loans to eco-projects	trine.com	USA	?	Yes	No	No	Yes	
Ziglu	UK simple investing app	ziglu.io	UK	?	Yes	No	No	No	

Buy Now Pay Later (BNPL) is the biggest consumer payments / financing success story innovated by Klarna in Sweden in 2005 and Afterpay in Australia in 2015 but with roots in Layaway Programs created during the 1930's US Great Depression (Kenton, 2023). By 2021, 44.1% of Gen-Z in the US had used BNPL according to (EMarketer, 2021). Gen-Z mostly use BNPL to buy clothes (LHV, 2024).

10.1.8 The Psychology Saving: Anthropomorphism and Loyalty Schemes

There are at least two ways to look at sustainable savings, however related. This section looks at savings in the *financial* sense of the word. Savings in the sense of CO₂e emission and environmental cost reductions have an entire separate chapter dedicated to them titled ‘*sustainability*’ however a short definition might be valuable here as well.

Environmental Savings means “*the credit incurred by a community that invests in environmental protection now instead of paying more for corrective action in the future*” (see Yale Center for Environmental Law & Policy, 2018) and (*Yale, Princeton, Stanford, MIT and Vanderbilt Students Take Legal Action to Try to Force Fossil Fuel Divestment - The Washington Post*, n.d., p. 33).

Savings in CO₂e equivalent emissions: CO₂e savings are the amount of CO₂e reduction one manages to achieve by changing one’s behavior and influencing others (people, companies). While the individual footprint is so small, the largest reduction will come from influencing large groups of people, either by leadership, role-model, or other means.

Pension funds are some of the largest asset holders and choosing where to invest one’s pension can be a sustainable financial action. College students might not have a pension fund yet, however their financial savvy will influence their choices in the future. Savings and investing are somewhat conflated because the large majority of savings that people have are invested by their banks. Thus the question of *sustainable*

savings comes one of where exactly are they invested and what is the impact of that investment of sustainability. Savings are the money one has in a pension fund or managed by themselves. For the majority of people, savings are invested by the bank and make up the largest proportion on investments for the people who are not active investors themselves. However, there are cases where people manage their pensions themselves; for example due to a law change Estonian could take out their entire accumulated pension and invest or spend them however they wanted (Raido Tõnisson, 2022b).

Saving precedes investing. From building loyalty to building ownership, the first step towards investing is to start saving money. How to encourage savings in daily life and make it a part of the everyday payments experience? Even starting with a small step, gathering a small target amount per month for savings, has the potential to shift the user's way of thinking about money. The second step, choosing where to invest these savings, will help us begin thinking like an investor. To start noticing trends and looking into how finance shapes the world. One experimental study showed people think about putting money in a "safe" place and *money anthropomorphism* increased saving behavior by 18% (L. Wang et al., 2023). Mobile money users are better at saving (Naito et al., 2021). Nerdwallet's (Tommy Tindall, 2023) suggests making *financial commitments* instead of resolutions, in order to successfully save money.

In general, people will save nature if it also saves money.

- Ethical Savings (*Ethical Savings*, 2023)

Help consumers save money and business increase repeat business. Building customer loyalty is a key part of repeat business and financial predictability for any company. Large consumer brands like Starbucks have for long ran successful rewards programs that encourage customers to come back (Steinhoff & Zondag, 2021). Could loyalty schemes create a pathway to investing in the company to strengthen the feeling of connection with the business even further? After all, I'm now a minority owner! Yet in practice, many consumers lack the financial literacy for investing and there are many legislative difficulties for turning loyalty points into investments. It's easier instead to create a separate cryptocurrency or token program which users could collect and redeem for some benefit.

Table 63: Example sustainable loyalty schemes

Company	Scheme
Patagonia	"Worn Wear" program
H&M	Garment Collecting program
The Body Shop	Return, Recycle, Repeat

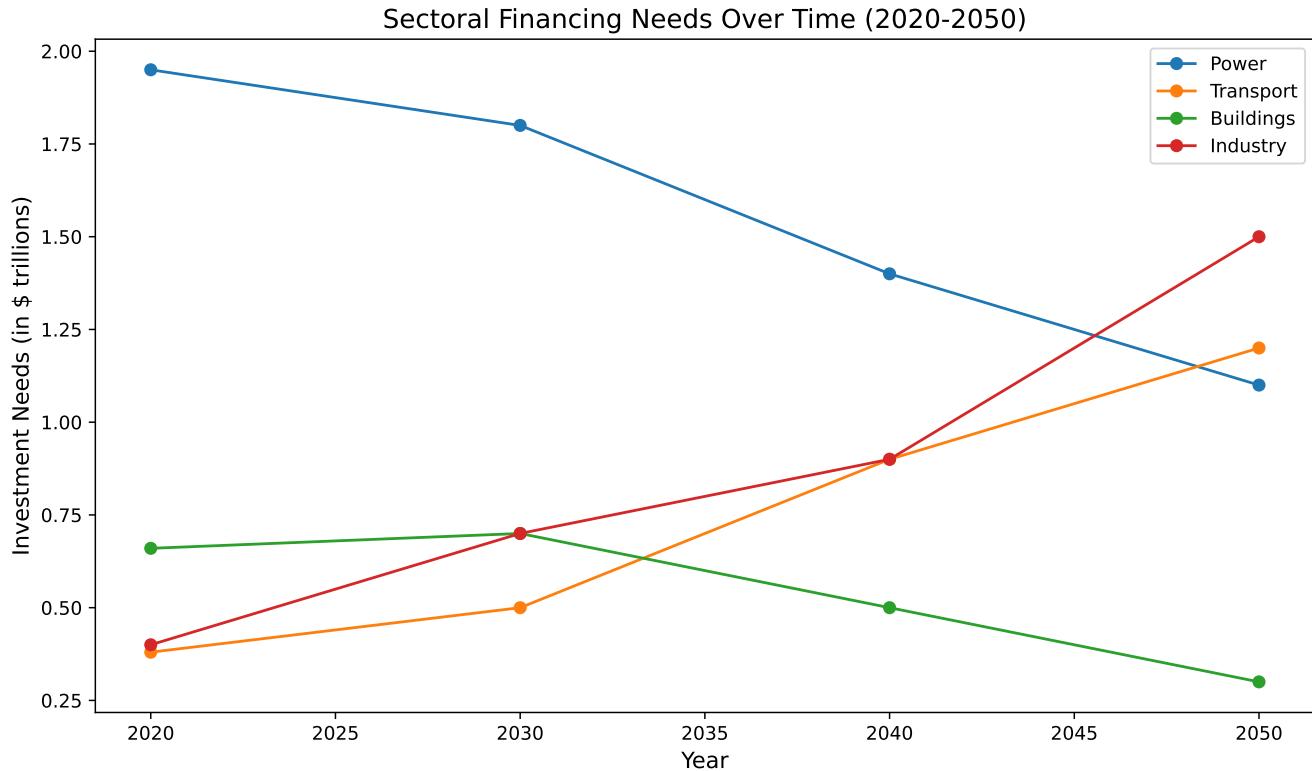
Loyalty schemes can take a physical form. In Malaysia, Beebag shopping bags made of recycled plastic bottles with a NFC chip that works in conjunction with an app to provide rebates for customers (The Green Factor, 2022).

10.1.9 Sustainable Investing: Measuring the Eco-Investment Gap

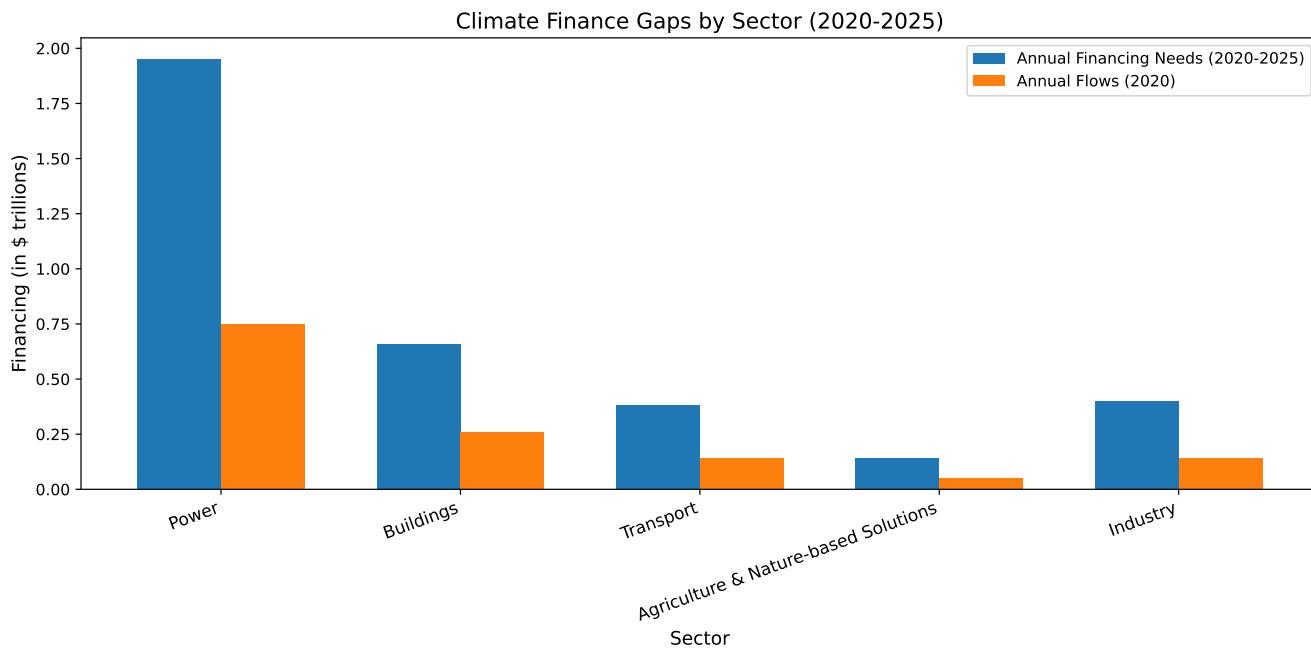
By the latest estimates sustainability lacks several trillions of USD in investment. Even with massive financing already in the pipeline, the estimate for the global *financing gap* for low-carbon energy production was 5.2 trillion USD as of 2016 (Earth Day, 2023; "Mapping the Gap," 2016). Ray Dalio puts the needed climate investment at \$5T and believes these financial goals won't be met (Ray Dalio, 2023). A newer

United Nations Environmental Programme (UNEP) calculation lowered the world needs an additional 4.1 Trillion USD of financing in nature-based solutions by 2050 to meet climate change, biodiversity, and land degradation reduction targets (UNEP, 2022).

According to (The Rockefeller Foundation, 2022) a slightly lower 2.5-3.2 Trillion USD would be sufficient.



What if 10% of annual consumer spending – *ten percent is about \$2,8T* - went towards protecting our climate? The theme for the 2023 Earth Day was “*Invest In Our Planet*”.



The needed investment doesn't seem so large, around 5% of the global GDP, if one compares it to the *per year* Global Gross Domestic Product (GDP) estimated at around 100 Trillion USD in 2022 and growing to 105 Trillion USD in 2023 (Aaron O'Neill, 2023; IMF, 2023b). In essence, the estimated total investment gap in climate fits into the economic growth of 1 year of the global economy.

Bad news. It would be easier for large institutional investors to move their money to sustainable assets than for retail investors to move their relatively small investments.

The lack of funding in green energy especially affects emerging economies (“Mobilizing Capital Into Emerging Markets and Developing Economies,” 2022). “*We can and must channel private capital into nature-based solutions. This will require policy and regulatory support, catalytic capital and financial innovation*” argued the CEO Green Finance Institute, Dr Rhian-Mari Thomas, ahead of COP27 in Egypt (Green Finance Institute, 2023). It’s not happening fast enough.

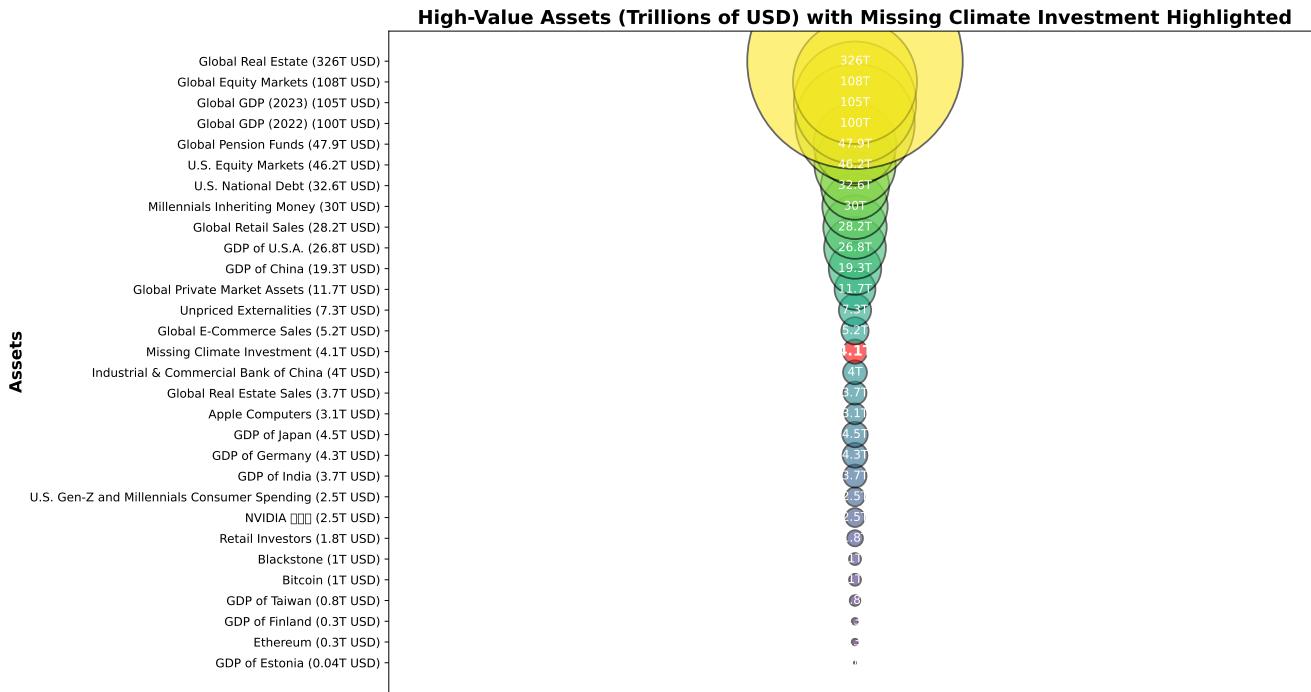


Table 64: Comparative data on needed climate investment and other valuable assets; all figures in Trillions of USD (Aaron O'Neill, 2023; Blockworks, 2023a, 2023b; M. Fox, 2023; Grand View Research, 2021; IMF, 2023a; McKinsey & Company, 2023; Oguh & Oguh, 2023; Rao, 2023; SIFMA, 2023; S&P Global, 2019; Statista, 2021, 2023b; Stephanie Aaronson & Aaron Tilley, 2023; Thinking Ahead Institute & Willis Towers Watson, 2023; Trucost & TEEB for Business Coalition, 2023; US Treasury, 2023)

High-Value Assets (Trillions of USD)	
Global Real Estate (2020, valuation)	\$326T
Global Equity Markets (2023, valuation)	\$108T
Global GDP (2024, estimated)	\$110T
Global GDP (2023, per year)	\$105T
Global GDP (2022, per year)	\$100T
<i>Global Pension Funds (2023, valuation)</i>	\$47.9T
U.S. Equity Markets (2023, valuation)	\$46.2T
U.S. National Debt (2023, valuation)	\$32.6T
<i>Millennials Inheriting Money from Parents in the U.S., U.K. and Australia (2022-2032)</i>	\$30T
Global Retail Sales of Goods and Services to Consumers (2023, per year)	\$28.2T
GDP of U.S.A. (2023, per year)	\$26.8T
GDP of China (2023, per year)	\$19.3T
Global Private Market Assets (2023, per year)	\$11.7T
<i>Unpriced Externalities (2023, per year)</i>	\$7.3T
Global E-Commerce Sales (2021, per year)	\$5.2T
<i>Missing Climate Investment (2022, estimate per year)</i>	\$4.1T
Industrial & Commercial Bank of China (2019, total assets)	\$4T
Global Real Estate Sales (2021, per year)	\$3.7T

High-Value Assets (Trillions of USD)	
Apple Computers (2024, market value)	\$3.1T
GDP of Japan (2023, per year)	\$4.5T
GDP of Germany (2023, per year)	\$4.3T
GDP of India (2023, per year)	\$3.7T
U.S. Gen-Z and Millennials Consumer Spending (2022, per year)	\$2.5T
NVIDIA 英偉達 (2024, market value)	\$2.5T
<i>Retail Investors (2023, liquid assets)</i>	\$1.8T
Blackstone (2023, total assets)	\$1T
Bitcoin (2024, market cap)	\$1T
GDP of Taiwan (2023, per year)	\$0.8T
GDP of Finland (2023)	\$0.3T
Ethereum (2024, market cap)	\$0.3T
<i>Individual Climate Investors (2020, per year)</i>	\$0.1T
GDP of Estonia (2023, per year)	\$0.04T

While these assets and GDP values reflect different aspects of the global economy, the comparison illustrates that redirecting a relatively small fraction of global wealth and economic activity towards sustainable investments can close the investment gap. This perspective should inspire confidence that the goal is achievable with coordinated effort and policy support.

- Robeco survey of 300 large global investors totaling \$27T under management found biodiversity-protection is increasingly a focus-point of capital allocation (Robeco, 2023).
- Compliance and GenAI in banking: (Rahul Agarwal et al., 2024).
- “Lessons from banking to improve risk and compliance and speed up digital transformations” (Jim Boehm et al., 2021).
- OECD (2024) projects steady economic growth 3.1% in 2024 and 3.2% in 2025 while the World Bank & World Bank (2024) is more conservative projecting 2.6% and 2.7% respectively.

10.1.10 Retail Investing Enables Financial Inclusion and Growing Money Sustainably

Retail investing can be seen as a form of financial inclusion. Ant Group’s CEO Eric Jing remarked in (Turrin, 2021): “*The financial system of the past 200 years was designed for the industrial era and served only 20% of the population and organizations. As we enter the digital age, we must better serve the remaining 80%*”.

Among retail investors, there’s some appetite for sustainability however investors are not sure how to separate sustainable assets from less sustainable ones (S. Ho, 2019). While literature has been debating if it’s possible to “*do well while doing good*”, latest research suggests it’s possible to make investments that both make an attractive financial return and adhere to sustainability goals (Y.-M. Tan et al., 2023). “sustainable investing is now part of mainstream financial strategy” (Morgan Stanley, 2019).

- Consumption is ruining the world the world thinking as an investor the investor mindset

Doorn (2020): Many ecologically focused funds with different approaches have been launched in recent years, with variations in asset mix and style of management. Thematic asset management is expected to grow, with investors packaging opportunities based on consumer trends.

T. Smith (2019) suggests 74% of Chinese youth are looking for “positive impact”.

- Lingeswaran (2019) suggest philanthropy is on the rise in Asia however
- M. Li et al. (2022) suggests retail “investor attention can significantly improve enterprises’ green innovation level”
- But there’s so much capital in large funds retails investor money doesn’t matter at all. does retail money make any difference? Retail Investor Helpers: A wide number of banks are offering services marketed a sustainable. It’s hard to decide.
- For example - In Sweden “Preferences for sustainable and responsible equity funds
- Sweden is a in countries with highly developed financial markets and active social campaigns demanding sustainability (Sweden)
- Lagerkvist et al. (2020) undertook a choice experiment with Swedish private investors.
- “Meet the Fintechs Leading Sweden’s Green Revolution” (2021) Sweden is the home for several green fintech companies, including Doconomy and Trine.
- Gov launching ESG funds.
- Why is this important to research now? People in their twenties should invest in their future. Millennials and younger generations like services with a green, eco-conscious focus. Given our combined power (I’m a Millennial) with Generation Z, we are willing to pay more for sustainable products.
- Personalized Investing
- 2022 saw a wave of new platforms aiming to make investing easier for retail investors
- One example is Revolut, which expanded from a simple payments app to support varied saving and investment types (“Kickstart Your Investment Journey,” 2023; “Revolut Launches ETF Trading Platform in Europe,” 2023).
- Gamestop for climate massively collaborative investing by gen-z?

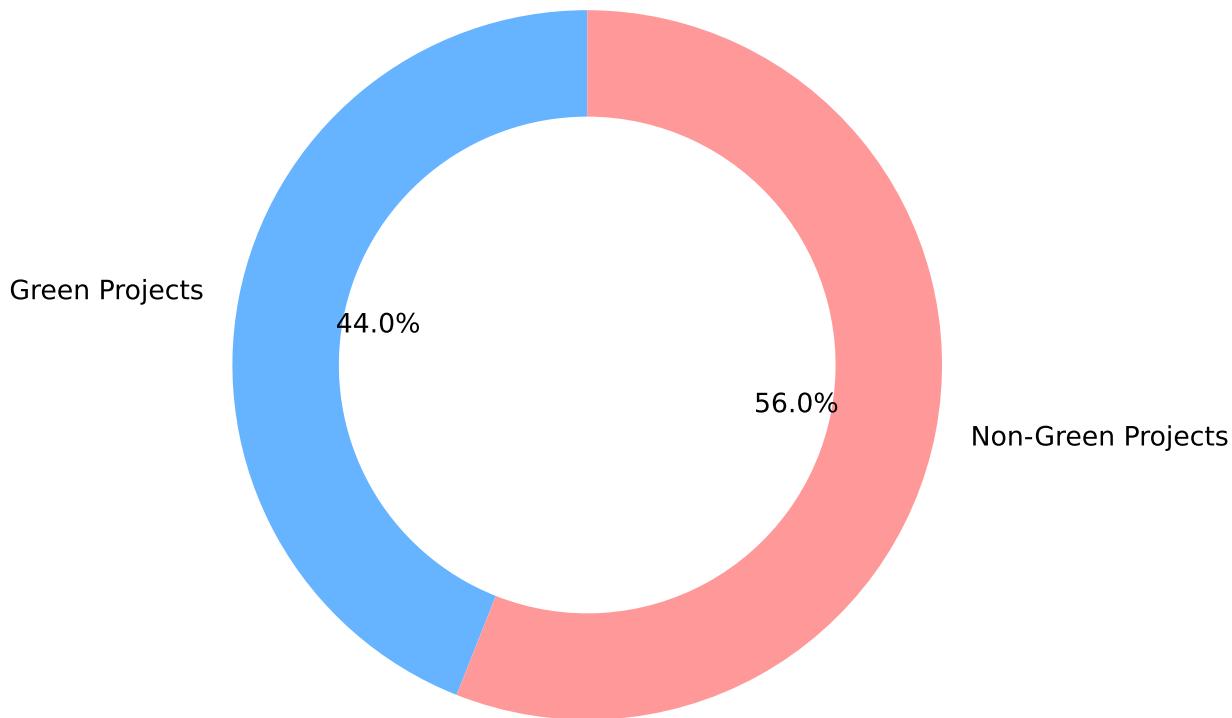
10.1.11 Young Investors Follow Financial Influencers

Young investors are typically *retail investors* investing small amounts of money for themselves. (Unless they have inherited wealth or are among the very few who work in an institution such as an investment firm, university endowment, pension fund or mutual fund, and have a say in where to invest large amounts of other peoples’ money.)

Retail investors face many challenges in comparison with their institutional counterparts. For instance, they may have much less time to do proper research, face information asymmetries, where finding good information is limited by time, ability, as well as financial literacy, whereas professional investors have the tools, skills, time, and knowledge, to make better investment decisions.

- For young people, investing mostly means buying cryptocurrencies?
- Copy-investing is a popular feature of retail investing platforms like EToro
- Investing is a fundamentally hopeful act. It means I think there's a future. Specifically, 'green investing' is investing in the future of our planet - but can we trust the sustainability practices the 'green' investment vehicles aggregate, promising to have a positive impact? For example, the European Union for many years counted biomass as 'green' energy, even while forestry companies were cutting down trees to produce the biomass - the regulation was not specific enough to curb this practice. So, in effect, a 'green investor' might be supporting deforestation. How can an easy-to-use investment app address such complexities without alienating the users?

Investment Share in Green vs Non-Green Projects



- Information evavõrdsus disparity between pro and novice investors

Retail investing also heavily influenced by social media influencers.

Retail investing apps blend entertainment into the UX/UI of investing. For example Robinhood uses game-like features such as displaying a confetti animation to create a sense of excitement around trading investing. Retail investing UI/UX is simplified and gamified, which encourage impulsive short-term buying and selling with a focus on speculation over fundamentals and cause FOMO (fear of missing out).

Meme stocks are another aspect of the *entertainmenization* of investing. There are many groups of Twitter, Reddit, and elsewhere, where investing trends start, causing more volatility.

Community Investing Enables Financial Inclusion

- Inexperienced investor can copy other people when investing. You don't know how to invest? Build an investing community? Can follow others and raise capital together. In some ways community-investing competes with robo-advisors as communities can be led by professional investors and followed by less sophisticated investors. Investor communities can have the type of *social proof*, which robo-advisor do not possess.
- Investors' belief in sustainable investing is affected by other investors (Luz et al., 2024).

In South Korea,

- Koreans investing in influencers? Koreans investing into media personalities: Yuqing Zhao (2021)
- An open question is whether young investors are more easily than professionals swayed by *influencers*? Influencers are terrible for investing... but? Sustainable investing, kids watch TikTok (lizlivingblue, n.d.).
Influencer - crypto twitter connections
- Crypto influencers like combine beauty with investing ([irenezhaoHereWhy0xIreneDao2022?](#))

10.1.12 Financial Ecologies

- G. K. S. Tan (2020) proposes “*financial ecologies*” to understand the dynamic relationships between various actors: investors, advisors, government, where the government plays an active role in growing financial inclusion and responsible financial management. However, the paper further suggests that current robo-advisors (available in Singapore) make the investor captive to the agency of AI, making the person lose agency over their financial decisions.
- ESG apps in Singapore:
- DBS LiveBetter consumer sustainability app (DBS, 2018; DBS Singapore, n.d.)
- Singapore ESG open data platform (Monetary Authority of Singapore, 2023)

10.1.13 Inaccesible Asset Classes for Retail Investors: Futures, Hedge Funds, Private Equity, and Venture Capital Remain Limited

Hedge funds generally are not accessible to retail investors, requiring a substantial minimum investment. However some Hedge Fund ETFs and Mutual Funds with Hedge Fund Strategies may try to mimic hedge fund strategies investing in the same assets.

It's how the wealthier people invest.

- While hedge funds used to be available for professional investors, *smart contracts* make it possible to create decentralized organizations which pool member resources for investing.

(BlackRock, 2022) notes some ESG-oriented hedge funds can be “highly engaged with management teams” in order to influence management towards ESG practices in said companies.

- Nathan Reiff (2023)
- Ian Bezek (2021)
- *ESG Hedge Funds / Barclays Corporate & Investment Bank* (2021)
- Hedge (2023): Make a hedge fund with your friends
- Most successful investor invest together
- Angelist

10.1.14 Investable Asset Classes for Retail Investors: Increasing Exposure to Stocks, Bonds, Commodities, Real-Estate, Digital Tokens, Lending, and Alternatives

“Green Bonds, Sustainable Equities, ESG-focused Mutual Funds and ETFs, Impact Investing (through platforms), Renewable Energy Infrastructure (via ETFs or mutual funds), Sustainable Real Estate (through REITs or ETFs), Social Bonds, Carbon Credits (via ETFs or specialized funds), Sustainable Commodities (via ETFs or funds), Community Investing (through CDFIs or crowdfunding platforms), Sustainable Infrastructure Funds (available as ETFs or mutual funds), Environmental, Social, and Governance (ESG) Metrics Integration (through broad ESG-focused ETFs or funds)”

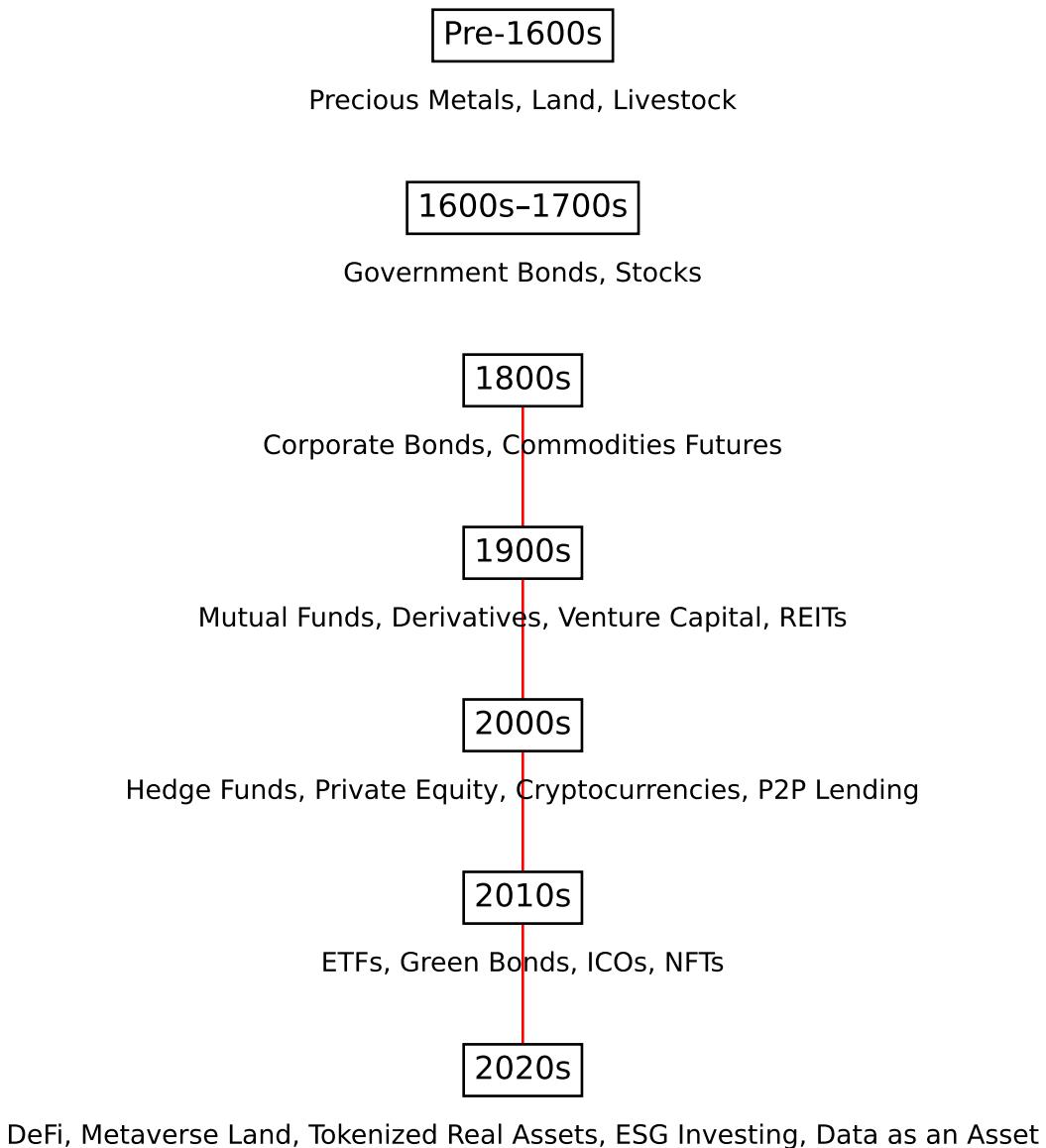
Such as “green shops” there are green investing platforms, green ETFs, etc. All of these are essentially forms of branding designed to make it easier for investors to find an investing product they trust.

There are many ‘green investment platforms’ who to trust?

Name	Description	Link
Trine		trine.com
The Many		the-many.com
Sugi		sugi.earth
ClimateInvest		clim8invest.com
Circa5000		circa5000.com
FairOwn		fairown.com

- Hankewitz (2021)
- Investing - Your investment fund’s ESG thesis investing thesis investing expert investing thesis research
- Investing thesis
- Open Banking: “Open Banking offers massive potential for improving online customer experience. That potential starts with the payment experience, which then generates a positive ripple effect through the entire customer journey.” investing into good companies

new asset classes



There are many asset classes only some of which would be accessible to a retail investors.

- The main categories of investment products are, based on the *Investment Products / Investor.gov* (n.d.)

Investment Product
Stocks
Bonds
Mutual Funds
ETFs
Insurance Products such as Variable Annuities

Thematic Capital, Build a thematic portfolio. There's a wide range of investment products marketed as *sustainable*, however many of them are fake (**CITATION**).

- Tokenization is similar financial securitization which has been happening for a long time. - Art can be securitized and tokenized Masterworks (2023) - Blockchain makes this kind of financial engineering easier as any developer can do it; one does not need to be a bank.

10.1.15 Nature-Backed Assets Financialize the Natural World

Asset Type	Description
Carbon Credits and Offsets	Represent avoided or removed CO ₂ emissions through reforestation, soil health improvements, regenerative farming practices that sequester carbon, etc
Biodiversity Credits	Represent conservation and restoration of species or ecosystems quantified by some standard or criteria such as provided by Verra and Gold Standard
Water Rights and Wetland Credits	Represent rights to access water or preserve/restore wetlands which can be traded
Conservation Finance Instruments	Represent bonds or funds that protect forests, coral reefs, or species habitats
Natural Asset Companies (NACs)	Represents a SEC-backed structure allowing public trading of ecosystem ownership rights
Tokenized Natural Resources	Represent blockchain-based representations of nature (e.g., tokenized forest hectares)

- single.earth etc

Commodities are investable, with retail investors can now buy gold and silver as well as rare metals on financial platforms such as Revolut.

Real-estate is increasingly available on co-investing platforms allowing retail investors access into this asset class with a relatively low starting price. Thus investing in sustainable architecture can be an attractive proposal both from an environmental as from a financial standpoint, potentially providing a passive income stream in the form of rent. According to (Debnath et al., 2022) 39% of global CO₂ emissions comes from the building sector. Construction is large emitter because of the use of concrete; super tall buildings are very CO₂ intensive (Zhao & Qin, 2015). Building emissions can be reduced by using sustainable design and materials, *digital twins* of architecture enable pre-visualization of different designs (Panaro et al., 2024) as well modeling the usage of the building, for example the interior shop floors in commercial real-estate (Jia et al., 2023). In housing development, there's evidence of 'green' buildings achieving a 'higher financial return than conventional buildings, both in terms of rent and sale price' (Oyedokun, 2017).

Stocks are the most popular assets class with a long history and highly accessible to retail investor, albeit usually at the cost of a trading fee.

Lending is an attractive assets class with a significant social impacts providing opportunities to small farmers and other participants in the money markets while offering the lender a return, all possible through online apps and platforms. Retail investors can lend small amounts of money (also known as

MicroLending) on peer-to-peer (P2P) lending platforms such as Twino. These loans are pooled and the risk is borne in aggregate as a form of risk-management.

10.1.16 Green and Sustainability-Linked Bonds

Bonds are a form of debt investment also known as a fixed-income asset where the principal is repaid at the maturity date of the bond (usually in years) with an added premium. Individuals can't emit bonds but they can invest in them. It can be a way to invest locally in one's own city - or globally. For individuals, there's access to some green bond exposure through ETFs (exchange-traded funds) available on retail investing apps.

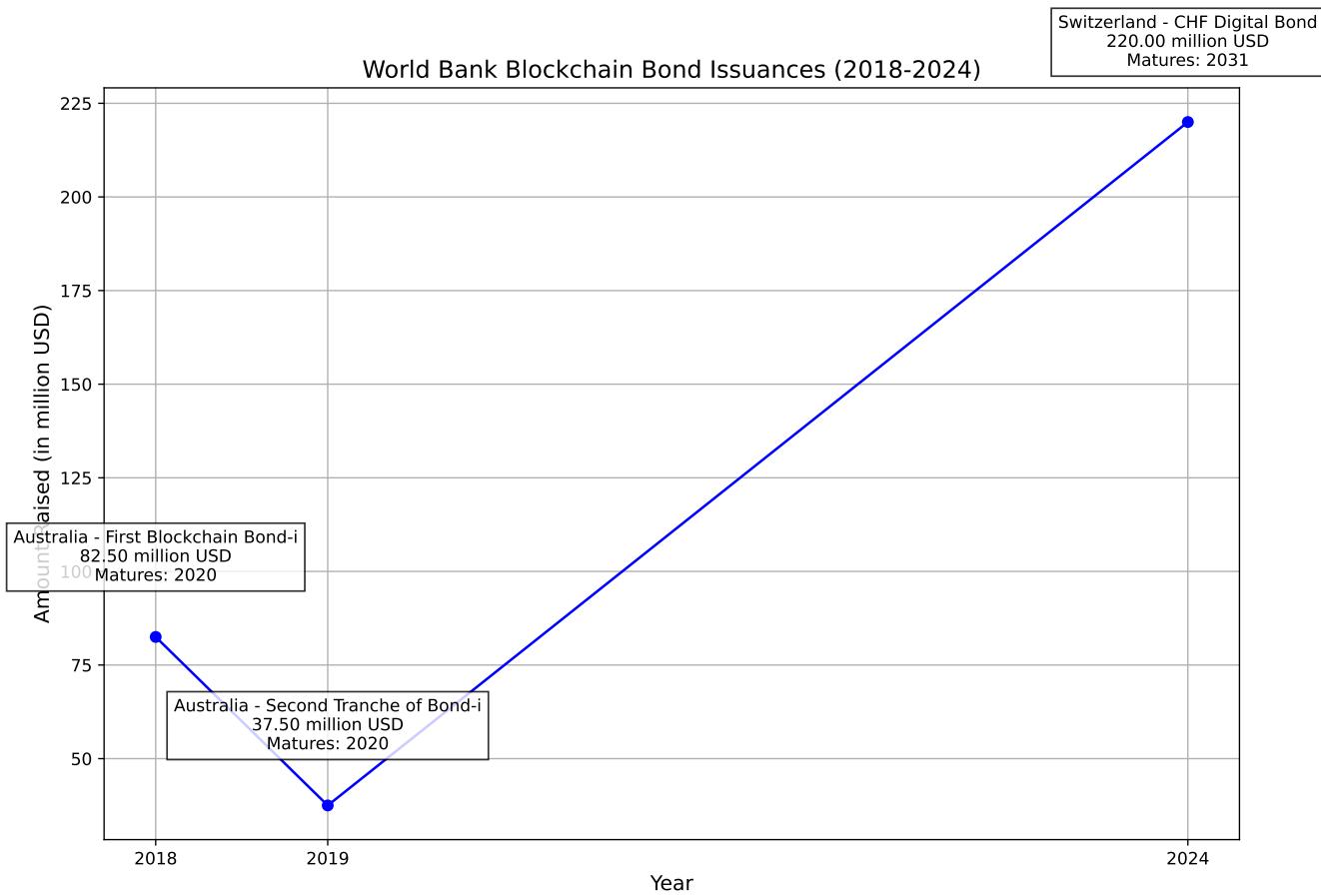
Access is not universal and availability depends on the geography of the user and local legislation; for example Revolut, the most downloaded finance app in the EU, only enabled bond investing for European customers in summer 2024 (Revolut, 2024c, 2024a). Investing in bonds is a form of *Passive Investing* and allows investors focus on low-risk passive income instead of daily stock investing most popular on Robinhood and Revolut - albeit with much less potential for returns.

- Climate Bonds Initiative is working on greening the \$55 trillion short-term debt (bond) market (“Climate Bonds Initiative Calls for Greening of \$55trn Short-Term Debt Market,” 2022).

Green bonds are released by companies, international organizations, and cities to raise money for green transformation, usually for building something to improve sustainability, tied to specific projects. There's a growing global trend in green bond emission, with 257 Billion USD worth of green bonds issued in 2019, expected to reach 1 Trillion USD annually by 2030 (MacAskill et al., 2021). That prediction was too low with 870 Billion USD green bond emissions reached already in 2023; currently Europe is the largest emitter of green bonds (Climate Bonds, 2023). China has the 2nd largest green bond market in the world and it's growing fast; buyers are looking for green bond certification to reduce yield spread, meaning the price of the green bond is becoming more similar to the price of a 'regular' bond (Q. Li et al., 2022; W. Peng & Xiong, 2022).

In 2017 the Malmö city in Sweden released green bonds to finance a sustainable transition of the city (City of Malmö, 2017). An independent analysis found bonds may not be emitted for financial reasons but to improve the reputation and city image, lower interest rate (aptly named *greenium*) with a similar in returns to traditional bonds - and have their share of challenges, namely being difficult to certify, monitor, report and measure impact of (Sjöström et al., 2020).

Making sure a green bond is truly supporting sustainability is a challenge. For example, Aramco, the Saudi Arabian public petroleum and natural gas company faced scrutiny for what critics deemed as 'Fake green bonds' (Anthropocene Fixed Income Institute (AFII), 2022). Green bonds can also be emitted on blockchains with the stated goal of improving transparency. Hong Kong multi-currency green bond on the blockchain. The issuer (Hong Kong government) hopes to reduce greenwashing (Hall, 2024; Kitano, 2024). In the EU as well, there are emerging tools for monitoring green bonds on blockchain (Christodoulou et al., 2023). (Qin et al., 2023) finds evidence that the combination of green bonds and blockchains are an enabler carbon neutrality in China. The World Bank successfully raised 110 Million USD in Australia in 2018-19 and has since doubled the amount in a new 220 Million USD emission in Switzerland using bonds on a blockchain ledger for SDG-related projects (World Bank, 2018, 2019, 2024).



Sustainability-Linked Bonds are less stringent than green bonds; they are not tied to specific projects but more broad sustainability targets (Priscila Azevedo Rocha et al., 2022): “Sustainability-linked bonds let companies borrow cheaply if they meet environmental, social, and governance targets. A Bloomberg News analysis found those goals are weak”. (Priscila Azevedo Rocha et al., 2022) suggests “*So far, most ESG investing is in the stock market. But the the \$22 trillion corporate bond market, where mature global companies such as Chanel go to borrow money from investors, has a particularly powerful role to play. Companies rely on debt much more than they do on stocks.*”

10.1.17 Fusion of Traditional Finance and Decentralized Finance (DeFi)

Crypto-assets and digital tokens (known as DeFi or decentralized finance) are a highly accessible yet risky asset class, offering investment opportunities to anyone with a mobile phone and internet access. The low entry barrier makes crypto among the most potentially inclusive forms of investment, though bearing significant risks, as well as regulatory challenges in some countries. Crypto investing removes most entry barriers while having high risk. Cryptocurrencies are the most popular financial action among young people yet in some ways crypto needs even more financial literacy than traditional financial assets. Statista (2024) estimates over 860 million cryptocurrency users worldwide by 2025. A Brazilian study (N=573) found “Crypto investors in Brazil are generally younger, male, and exhibit higher risk tolerance compared to non-crypto investors.” Colombo & Yarovaya (2024) “Brazil’s planned adoption of CBDC (Central Bank Digital Currency).” “It finds that risk tolerance, economic pessimism, and a belief in better investment acumen are significant predictors of crypto investment.”

Taiwan has an active market for crypto-assets while with some limitations. In 2022, the Taiwan government banned buying cryptocurrencies with credit card quoting the volatility makes it similar to gambling (David Attlee, 2022; 廣編企劃, 2022).

Crypto enables significant potential for financial engineering and innovation by anyone with some programming skills.

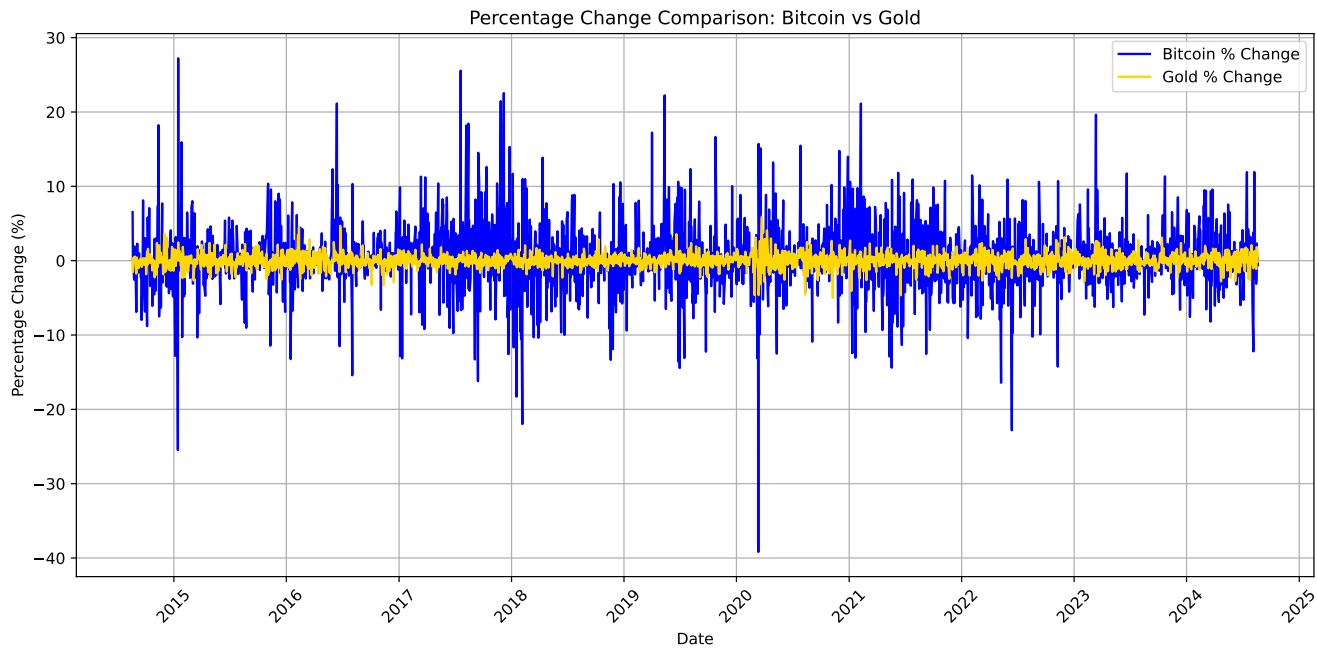
Centralized Crypto Exchanges vs Self-Wallets - Centralized Crypto Exchanges are in essence loaning assets from the user. “The piece of the settlement aimed at getting important information to customers is more understandable from a retail protection standpoint. Customers who lend crypto assets to a company in exchange for a promised return should get the information they need to assess the risks against the rewards” (Hester M. Peirce, 2022).

There’s also a large trend of fusion of decentralized finance (DeFi) and traditional finance (TradFi), with the largest established investors, such as BlackRock, launching tokenized funds (Matos, 2024; Sandor, 2024; Securitize, 2024).

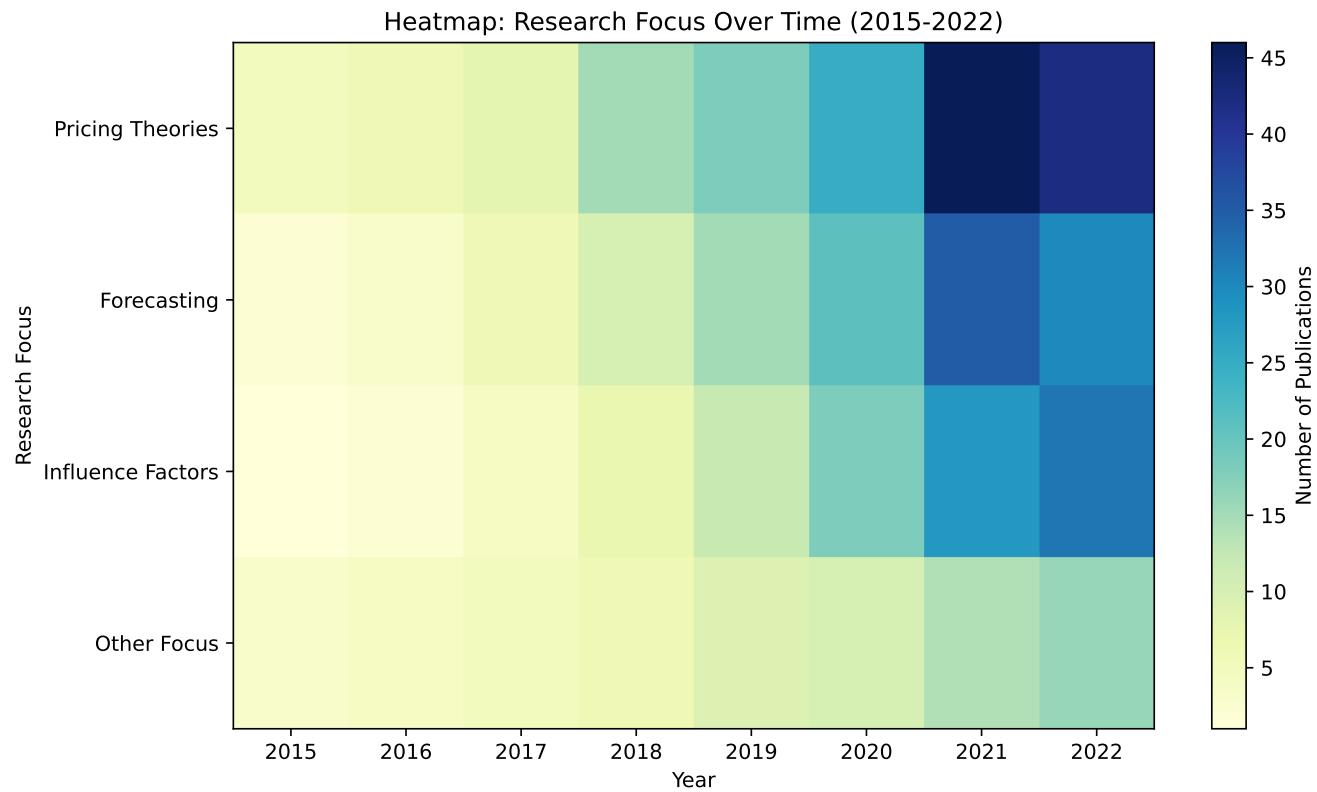
- “Lets Do DeFi - DeFi Guides Grandma Can Follow ” (n.d.) Crypto DeFi education
- OpenSea (2022) Taiwanese digital influencers as NFTs.
- Crypto tools allow you to look at any wallet already
- FINMA (2021) First crypto fund

Pricing Crypto

- However volatility is relative. Volatile national currencies lead people to find other assets to hold. If your national currency is collapsing, you might find crypto has a relative safe haven to keep your funds.
- People like Turkey losing 75% of the value of their assets when currency collapses, why people buy crypto.
- Bitcoin is by far the most popular cryptocurrency with it’s high price volatility creating opportunities for high gains and high losses. While bitcoin has been called a “digital gold” for store of value, its volatility characteristics are very different from gold, as seen on this chart.



The volatility of the markets has notably shifted crypto research towards pricing theories.



For example, in X research an index of major sustainability news was compared with crypto prices, which may have negative, positive, or no correlation with the following cryptocurrencies.

Institutional Funds Enter Crypto Crypto ETFs enable people to have exposure to crypto without ever

buying cryptocurrencies directly themselves. - swissinfo.ch/urs (2022) “More than half of the Swiss banks plan to offer digital assets services over the next few years.” - *The Bank for the New Economy* (n.d.): Crypto bank - Raido Tõnisson (2022a) Estonian bank selling Metaverse cryptocurrency Sandbox

DAOs

DAOs (Decentralized Autonomous Organization) can be used in a similar way to Hedge funds, a DAO can have a shared multi-sign wallet than is invested together.

A lot of financial tooling and more than trad-fi has been replicated in crypto.

Decentralized Autonomous Organizations (DAOs) which have an investable treasury may be compared to Hedge Funds as a collective form of investing. Because of the on-chain nature where transactions are visible to anyone, they may be seen as more transparent. Typically DAOs have a voting system to make decisions while Hedge Funds may be more centrally controlled. Also, the legislation affecting each would be different as hedge funds are an older and more established financial tool whereas DAOs still fall in somewhat of a gray area.

- “Trees for the Future” (2023) DAOs to enable concerted action towards climate goals using the pooled resources in a treasury, a blockchain (on-chain), similar to how hedge funds work.
- Carra Wu & Chris Dixon (2021) DAO consumer to investor
- Lucas Matney (2022)
- BlockChannel (2017)
- *Investment Clubs and Collectives / Deprecation FAQ* (n.d.): Crypto investment clubs canceled
- *IBISA Network – Enabling the Next Generation of Insurance for Agriculture* (n.d.): Crypto crop insurance
- Social + NFTs - What would investing look like at the scale of 1 billion people

Oracles for Sustainability Data

Intersection with finance and Real World Data.

A data oracle is the concept of a source of real-world data which can be ingested through an application programming interface (API) to a blockchain system. There are many databases of sustainability information which could serve as an oracle for carbon labeling, packaging, transportation, consumption, and waste.

- Ethereum (2023)
- Caldarelli et al. (2020) notes it's a challenge to ensure the accuracy and trustworthiness of real-world data from Oracles.
- Brady Dale (2021) and Chainlink (2022): The largest Oracle provider ChainLink founder Sergey Nazarov believes the collaboration of oracles and blockchains can make carbon credits more trustworthy.
- IPCI OpenLitterMap G.I.D Coin Regen Network
- dGen & PositiveBlockchain (2021): Positive Blockchain Database of blockchain for good projects

Regenerative Finance (ReFi)

Cryptocurrencies - Celo and Impact Market - Celo invests into ReFi on the code level - Marten Pöllumees (2022) retirement funds invested in crypto

On the intersection of cryptocurrencies, blockchains, and nature-backed assets.

- Celo's protocol invests in carbon credits on the protocol level: "Celo and Regenerative Finance - Climate and ReFi" (2021)
- "What Is ReFi | Regenerative Finance Explained" (2023): What is Regenerative Finance (ReFi).
- "*Would you rather buy a DogeCoin or a regenerative food forest token?*" Curve Labs founder Pat Rawson quotes Shiller (2019) in ReFi podcast about Kolektivo (ReFi DAO, 2022).
- Regen Network (22 C.E.) and Regen Network (2023) regen network
- B. Smith (2021)
- "KlimaDAO" (2023b) KlimaDAO
- "Planet of the Klimes - Luis Adaime - Founder & CEO of MOSS.Earth" (n.d.) Moss.earth
- "Socially Responsible Investing Advisors" (n.d.)
- naturalinvest (2020)
- Marquis (2021)

Efforts to connect carbon markets, carbonmark.com

"We believe that markets for ecosystem assets need to scale urgently, starting with carbon markets. The challenge is to make these instruments as recognizable as tradable assets, as measurable as financial securities, and as investable as other asset classes. Capital must flow into the environment at scale to deliver climate action." "Efficient financial markets allocate and manage risk based on effective price mechanisms, and this relies on access to credible information." BeZero (2022b)

"Everyone in the market is struggling to effectively price and manage risk.. the Voluntary Carbon Market (VCM); a rapidly recovering market, forecasted to grow by as much as 100x, but constrained by a nascent market structure." "The BCR is a carbon-only expected return model. It utilises a risk-based approach and seeks to give everyone a common language of risk. One that is translatable to that used by the \$200 trillion of assets in global financial markets." BeZero (2022a)

"climate action as an asset-liability problem"

- overview of 23 low-carbon blockchains Alzoubi & Mishra (2023)

"Automate your carbon accounting. Make data-driven decisions, across your entire supply chain." Ratings for mines CarbonChain (n.d.)

10.1.18 Divestment: Supporting Sustainability by Avoiding the Worst Polluting Companies

If no sustainable alternative can be found, at least taking one's money out from polluting companies signals one's green preferences. In institutional finance, the Norwegian \$1.3T USD sovereign wealth fund (the world's largest) started a divestment trend in 2016 by divesting first from coal following by divesting from oil, gas and coal extracting companies (Ben Martin, 2017; Holger, 2019). Their plan to reach net zero CO₂e nonetheless only targets 2050. Furthermore, who would be the counterpart for such large

transactions. The fund also announced divesting from Russia after its invasion of Ukraine, however has yet to sell any shares citing lack of buyers on the Moscow stock market.

“Sustainable development requires more investment in sustainable companies and less in unsustainable firms.” (Van Zanten & Rein, 2023).

University of California also followed suit with divestment of its \$126B USD portfolio from oil and gas.

Divesting is the inverse of investing. Divesting may have a meaningful impact on companies if large numbers of retail investors collaborate on ‘banning’ the company to send a message to the board. Small individual divestment has no impact on the governance decisions.

While divesting makes news headlines, even divestment by large institutional investors, such as the Norwegian National Pension Fund (GPFG), has a negligible effect on the heavy polluters’ business; by the same logic, it can be deducted, the financial effect of retail investors divesting, is meaningless. If retail investors act in aggregate, the reputational effect needs further research. *“To halt climate change, some investors have decided to divest from fossil fuel companies. Reviewing the literature suggests that divestment from fossil fuel has limited financial consequences; it slightly increases divested firms’ risk and their cost of capital, while reducing divested firms’ market value,”* is the pessimistic conclusion by(Plantinga & Scholtens, 2024)

- Even with divesting from oil and gas, Norway Government Pension Fund Global (GPFG) still adheres to the Markowitz’s Modern Portfolio Theory (MPT), with enough diversification between assets (Papaioannou & Rentsendorf, 2015)

10.2 The Economics of Decoupling: Attempts to Disconnect Economic Growth from Eco-Degradation

Is the “eco” in ecology and economy the same? Oïkos, the Greek word for “household”, seeds two modern disciplines: ecology studies how the home works; economy sets the rules for managing it. The two have drifted apart: one guarding planetary health, the other chasing growth. This chapter reunites them by asking: how do we measure prosperity without wrecking our home?

10.2.1 Post-AI Economics

People around the world are discussing how traditional economics can adjust to the abundance provided by AI, known as *Post-AI, Post-Labor, or even Post-Scarcity economics*. Last year, the Seoul AI Summit pushed for voluntary safety standards to manage systemic risks while the French AI Summit tackled energy consumption and environmental costs, highlighting the need to embed AI sustainability into economic planning, regulatory frameworks, and corporate accountability (**milmoFrenchAISummit2024?**; **hernTechScapeWhatWe2024?**). More recently, the Anthropic Economic Index tried to capture how AI impacts human work and economics in general, noting that among millions of work tasks submitted to Claude - studied as anonymized conversations using a privacy-preserving clustering tool Clio, separately described in (**tamkinClioPrivacyPreservingInsights2024?**) -, that 43% of the work could be categorized as automation and 57% as augmentation of human economic activities (**handaWhichEconomicTasks2025?**). At the same time, economists’ predictions of the future impact of AI are far from uniform, for instance MIT economist Daron Acemoglu estimating that in the U.S. only 5% of the tasks can be profitably automated and AI will only contribute a modest 1.1% to the GDP until 2035 (Acemoglu, 2024).

10.2.2 Econometrics: The Many Ways to Measure an Economy

Econometrics is the science of measuring the economy.

The creator of the Gross Domestic Product (GDP) metric in 1934 Simon Kuznets said: “The welfare of a nation can scarcely be inferred from a measurement of national income as defined by GDP...Goals for ‘more’ growth should specify of what and for what” (United States. Bureau of Foreign and Domestic Commerce et al., 1934).

GDP was the culmination of previous work by many authors, beginning with William Petty in the 17th century (Rockoff, 2020). This long journey underlines how a metric about a complex system such as the economy is continuous work in progress. There has been ongoing work to create improved metrics such as the Sustainable Development Goals (SDGs), Human Development Index (HDI), Genuine Progress Indicator (GPI), Green GDP, Inclusive Wealth Index, and others (Anielski, 2001; Bleys & Whitby, 2015; Kovacic & Giampietro, 2015).

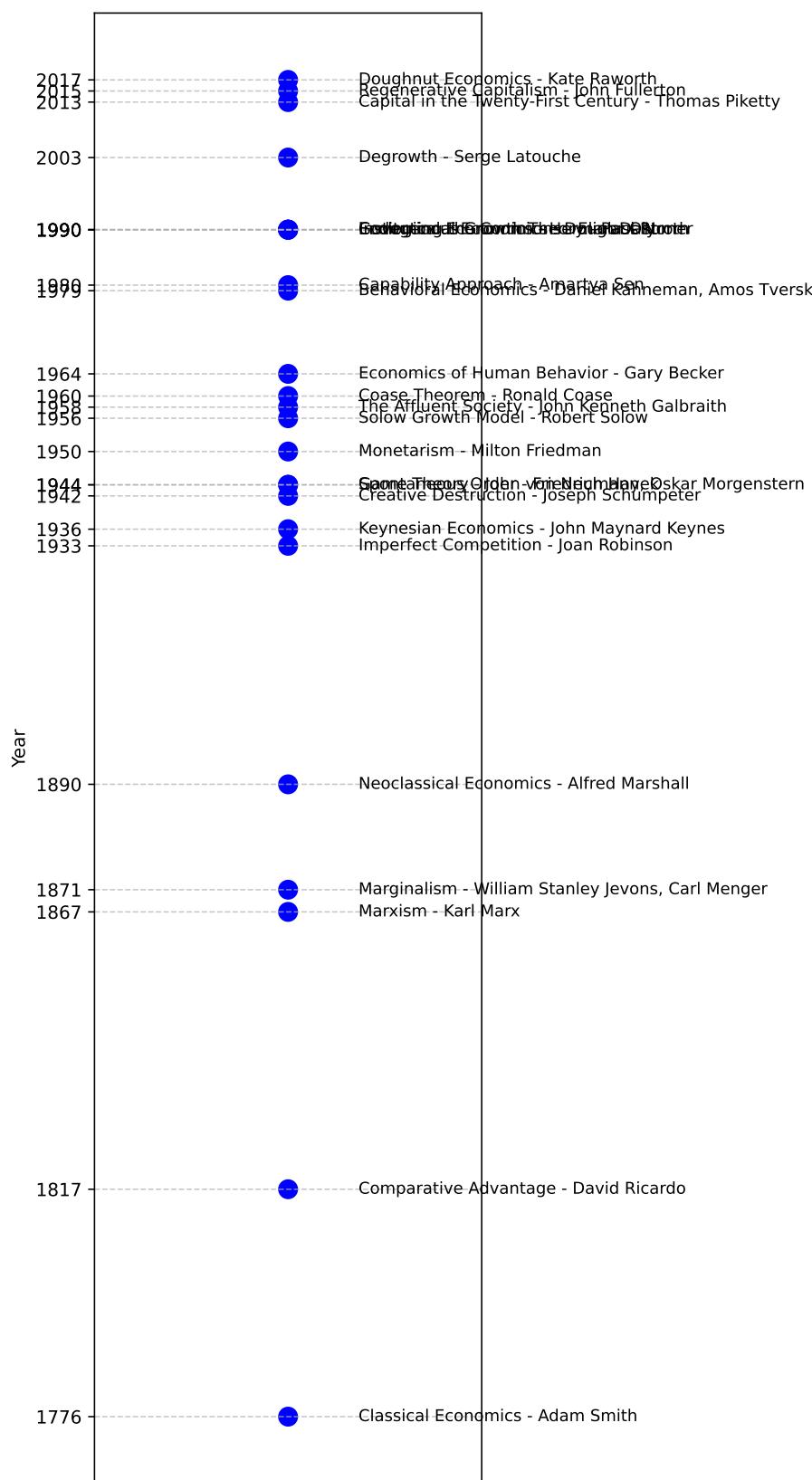
Measuring wellbeing in addition to GDP and the metric should include resiliency dashboards, to visualize metrics beyond GDP and they are an integral part of country reports (GreensEFA, 2023). Similarly, the doughnut (donut) economics (more below) model calls for a “*dashboard of indicators*” (TED, 2018).

- The true cost of products is hidden. The work is hidden.

10.2.3 The Evolution of Economic Metrics

The first two decades of the 21st century have seen increasing economic thinking, looking to challenge, improve and upgrade capitalism to match our current environmental, social, and technological situation, often called *New Economics*. Some of these include behavioral economics, sustainable capitalism, regenerative capitalism, doughnut economics, ecological economics, blue economy, degrowth, attention economy, gift economy, intent economy, among others. There's no lack of published books on changing capitalism, which goes to show there's readership for these ideas. Building a new economic theory is out of scope for my thesis design, however I'll focus on the parts of economic theory I believe are relevant for *interaction design-ing* for sustainability.

Timeline of Notable Economic Theories and Authors



There are those looking for *new metrics*. One of the first innovators, already in 1972, was Buthan, with the *Gross National Happiness Index (GNH)*, which in turn inspired the UN, decades later, in 2012, to create the International Wellbeing and Happiness Conference and the International Happiness Day(Kamei et al., 2021; Ribeiro & Lemos Marinho, 2017). The World Bank talks about the comprehensive GDD+ metrics in its Changing the Wealth of Nations report (World Bank, 2021).

The Wellbeing Economy Alliance (WEAll) countries (New Zealand, Iceland, Finland, Scotland, Wales) as well as the EU and Canada, started the coalition in 2018 looking to involve more broad-based metrics in developing their societies(CEPR, 2022; David Suzuki Foundation, 2021; Ellsmoor, 2019; Scottish Government, 2022; Wellbeing Economy Alliance, 2022).

Giacalone et al. (2022) looks at wellbeing of Italian communities and proposes a new composite index.

There's work ongoing on macroeconomic modeling, aiming to create a *digital twin* of the economy. Some of the most complex computer models of the economy include the Global Integrated Monetary and Fiscal Model (GIMF) (Laxton et al., 2010) and DSGE (Dynamic stochastic general equilibrium).

10.2.4 Hidden Costs: Pricing Externalities

Markets mis-price “home maintenance.”

Co-founder of Generation Capital with 50 Billion under management David Blood “the most significant thing we can do as capital allocators is to price in those difficult to price externalities” Liebreich (2025)

In the simplest sense, prices do not capture all costs. “Consumption, production, and investment decisions of individuals, households, and firms often affect people not directly involved in the transactions” (Helbling, 2012). Externalities as an economic concept was implied by Alfred Marshall, one of the founders of neoclassical economics, in his 1890 treatise “Principles of Economics,” and further developed by Arthur Cecil Pigou in his 1920 book “The Economics of Welfare” (Marshall, 1997; Pigou, 2002). As of 2023, the value of unpriced externalities which are not included in the GDP is 7.3 trillion USD per year (Trucost & TEEB for Business Coalition, 2023). The award-winning economist Mariana Mazzucato argues in (A. H. Gupta, 2020) we should include more into how we value unpaid labor, relating to the social (S in ESG) (Mazzucato, 2018) as part of our metrics.

10.2.5 Financialization

(Yüksel et al., 2023) criticizes excessive financialization where the real economy and financial markets disconnected, blaming it for the the 2008 economic crisis, proposing a new index for *participation finance* aiming to ground the financial economy in the real economy; rooted in Islamic banking, participation finance avoids highly speculative activities, which are seen as exploitative, looking to promote stability, transparency, and fairness.

10.2.6 Ecological Economics Builds Upon Classical Economics

While Adam Smith is most famous for his concept of the *invisible hand* first appearing in *The Theory of Moral Sentiments* (1759) and further developed in his seminal work *The Wealth of Nations*, published in 1776, his writings also highlight the interdependence of economic actors, who through specialization

increase productivity, but also increasingly dependent on each other as well as the role of empathy in individual actions (Atal et al., 2024).

Ecological economics doesn't necessarily argue with the foundation of classical economics, rather ecological economics finds the classical economics model and by extension neoclassical economics are *incomplete*, ignoring the physical limits of natural resources. Ecological economics draws attention to the interdependence of economy and the ecosystem; there are physical limits to economic growth on a planet with finite resources.

The biggest point of contention is the necessity of *economic growth*. The founder of ecological economics Herman Daly was talking about *prosperity without growth* more than two decades ago, focusing on the diminishing natural resources (Daly, 1997). Daly was teaching economics to undergraduates at Louisiana State University when he grew dissatisfied with the standard model of the market, which didn't include any inputs (resources) or outputs (pollution), and later modeled his work by placing the economy *within* the larger system of the ecosphere (Ketcham, 2023). More recently.(Jackson, 2009, 2017) have expanded on these ideas with recipes for a *post-growth* world, making the ideas seem more tangible and precise, yet mostly untested in the real world.

Writing in 1973, E. F. Schumacher argued economics overlooks both natural resource depletion and environmental degradation and draws on religion (particularly Buddhism) to suggest a simpler way of life:

"Simplicity and non-violence are obviously closely related. The optimal pattern of consumption, producing a high degree of human satisfaction by means of a relatively low rate of consumption, allows people to live without great pressure and strain and to fulfil the primary injunction of Buddhist teaching: 'Cease to do evil; try to do good.'" (Schumacher, 1985)

New economic thinkers are asking how can economic growth and sustainability be compatible. Some even ask if *economic growth* itself is the wrong goal? (Diduch, 2020). Degrowth is the most famous contender in that branch of economics. Is Decoupling Economic Growth and CO₂e Emissions Possible? Is Green Growth an oxymoron? No-one knows as it hasn't been done before. Degrowth proponents are pessimistic it's possible to decouple greenhouse gas emissions from economic growth; historical data shows does not show any decoupling. Some data from China shows decoupling?

The original Ramsey model introduced by Frank P. Ramsey in 1928, becoming foundational for traditional economic growth theory, does not assume infinite economic growth (Attanasio, 2015). (Marc Germain, 2016) has adopted the Ramsey Model and introduced constraints such as pollution, distinguishing renewable and non-renewable capital.

10.2.7 Doughnut Economics and Regenerative Capitalism

Doughnut Economics, introduced in the eponymous book uses a simple visualization of a doughnut (donut) to help us grasp the big picture of the economy *embedded* inside the physical and social worlds (Raworth, 2017). It allows one to see the social shortfall and ecological overshoot of nations at the same time (A. L. Fanning et al., 2021). The doughnut concept is simple and deep at the same time, a useful as social object to enable starting conversations with people from all walks of life, independent of their politics leanings. As Raworth calls it, it's a "*self-portrait of humanity in the beginning of the 21st century*". Combining the *SDGs (Sustainable Development Goals)* inside the doughnut and the *Planetary Boundaries* (Earth's

ecological ceiling) outside the doughnut, leaves a space inside the donut represents a state of equilibrium and balance on spaceship Earth.

In some ways this Doughnut Economics can be described as a movement. Doughnut Action Labs enable local communities to build local donuts customized to local problems. While the ideas have not yet been implemented on a country-level, smaller scale doughnut economics' success stories have inspired cities to take a comprehensive view of the doughnut of their own city with several EU cities adopting the vision (Jordan G. Teicher, 2021). While critics say doughnut economics would expand the role of the government (Horwitz, 2017), doughnut practitioners in Brussels believe everything can be adapted to the place and context (BrusselsDonut, 2022; Oikos Denktank, 2021).

The city of Amsterdam is developing shorter food chains (which save CO₂e) and linking residents with food production and reconnecting people to the food which foster collaboration in the community (Circle Economy, 2021). Amsterdam has also built comprehensive dashboards called the Circular Economy Monitor which makes it easy for anyone to see the progress being made towards the Dutch goal to be a circular economy by 2050 (Gemeente Amsterdam, 2022; [waterstaatCircularDutchEconomy2019?](#)).

Table 68: From (Circle Economy, 2021).

Shortening Food Chains in Amsterdam
Spatial planning for food place-making in the city
Circular agriculture
Regionally produced food
Collaboration between chain members
Food education

In his 2015 paper Regenerative Capitalism, John Fullerton, an investor and a capital markets and derivatives expert, builds his economic theory on the ideas of Club of Rome and the Limits to Growth (Meadows & Club of Rome, 1972) as well as taking inspiration from R. Buckminster Fuller.

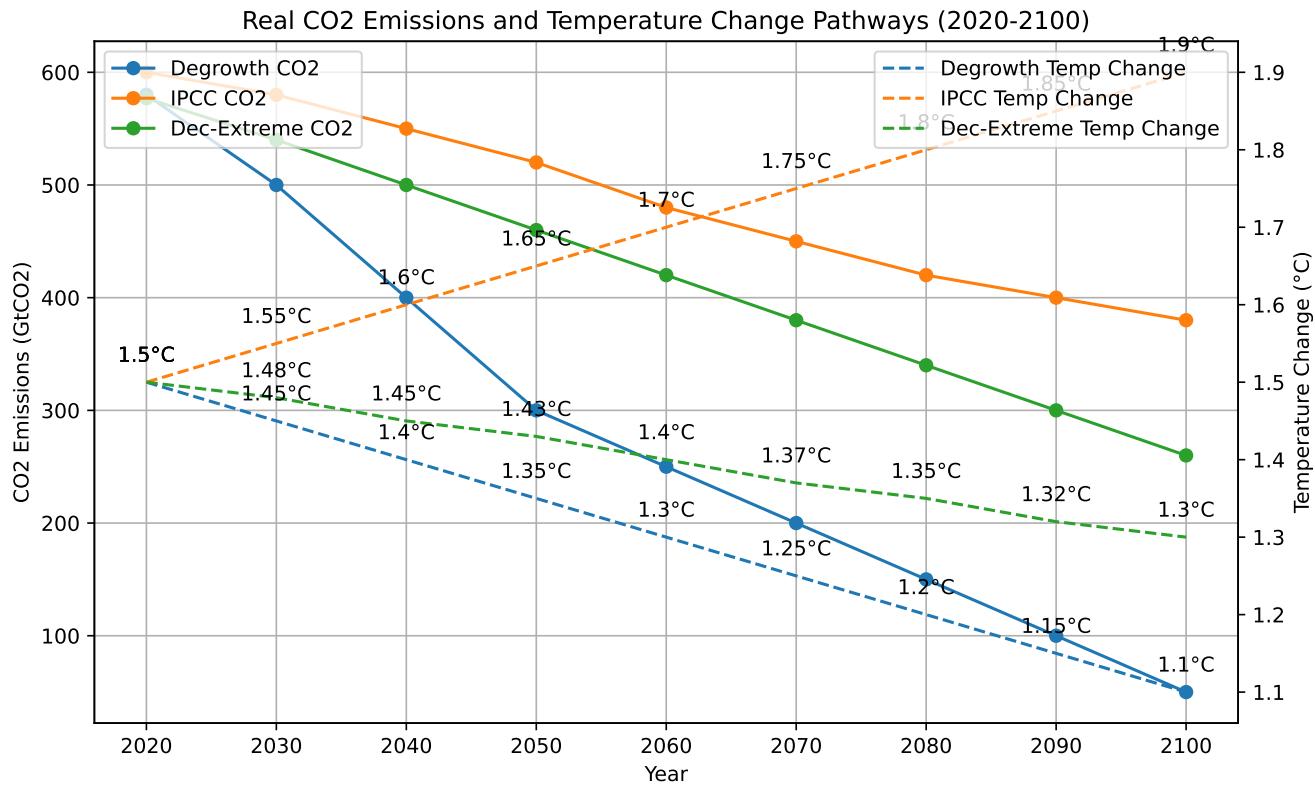
“Nature is a totally efficient, self-regenerating system. If we discover the laws that govern this system and live synergistically within them, sustainability will follow and humankind will be a success.” (Fuller, 1983)

“[H]uman civilization is embedded in the biosphere,” Fullerton’s ideas aim to balance efficiency with resiliency so the whole system doesn’t become brittle and break (Confino, 2015; John Fullerton, 2011, 2022). While regenerative capitalism recognizes the need for economic growth it also deems “[t]he quality of growth matters” (“Regenerative Capitalism,” 2023). For example, he cites the example of Triodos Bank which already in the 1980s focused on sustainable banking championing responsibility, transparency, and business ethics. A member of the Global Alliance for Banking on Values, Triodos finances projects in nature preservation and restoration (GABV, 2023).

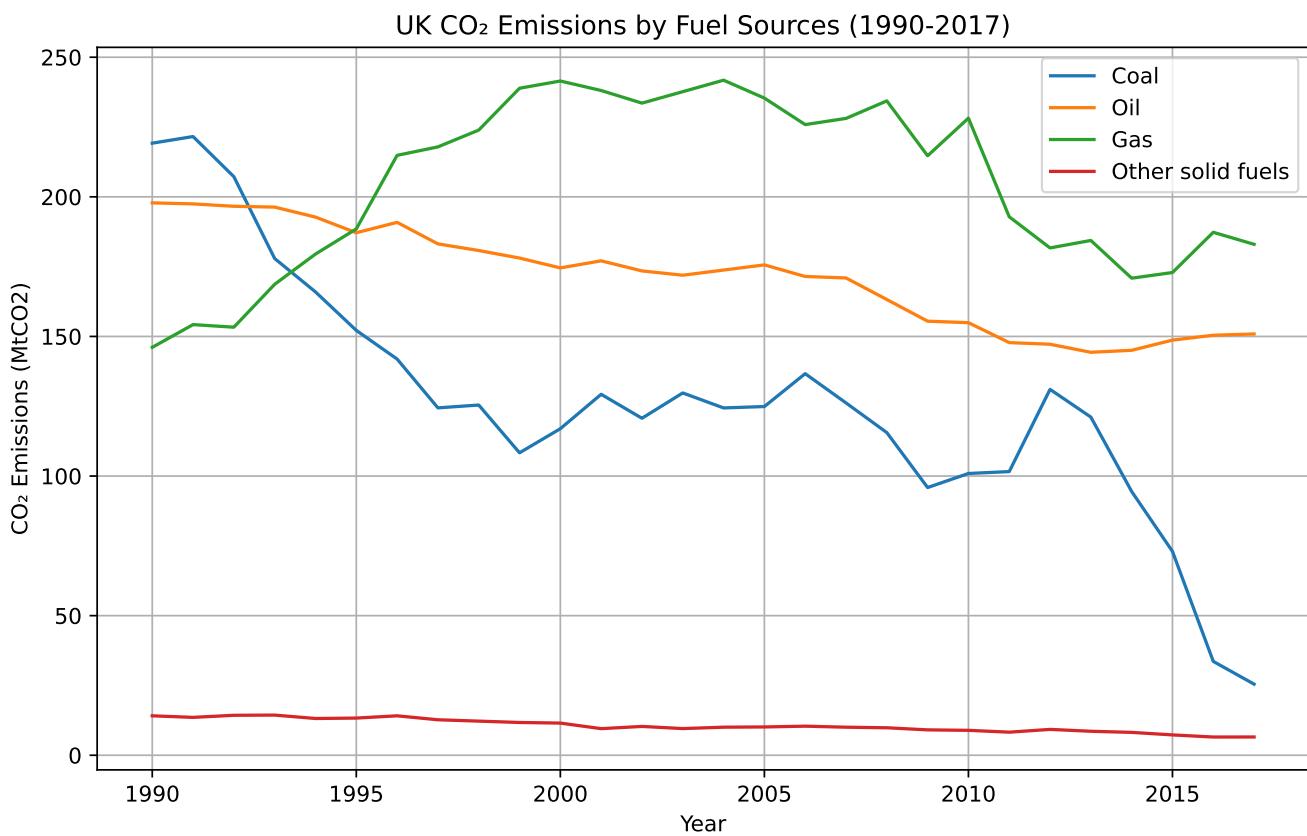
10.2.8 Decarbonization Scenarios

The possibility of decoupling economic growth from CO₂e emissions (also known as decarbonizing the economy or eco-economic decoupling) or is hotly debated (pun intended) among scientists. (Keyßer &

Lenzen, 2021) provides several scenarios for low, medium, and high levels of decoupling titled Degrowth, IPCC, and Dec-Extreme.

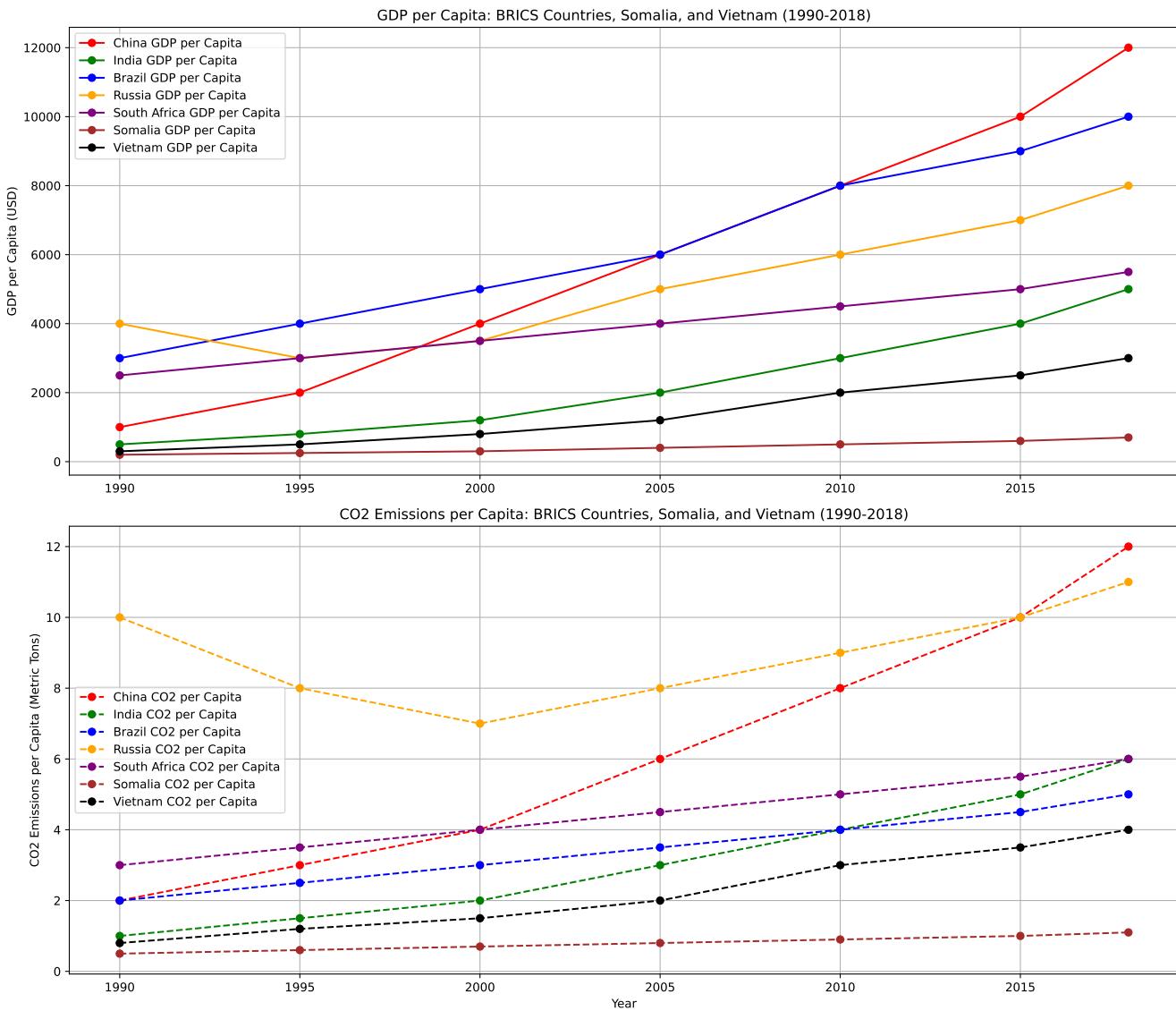


Looking at the United Kingdom, (Harrisson, 2019) concludes UK's CO_{2e} emissions have fallen 43% from 1990 to 2017 through the use of less carbon-intensive energy sources and argues for moderate policies in (Hausfather & Peters, 2020).



Meanwhile the cumulative CO_{2e} emissions trend in the UK in the same timeframe show the historic responsibility of UK (Global Carbon Budget, 2023).

CO_{2e} emissions and GDP growth per capita follow a similar path in the BRICS countries (Brazil, Russia, India, China, South Africa) as well as in Vietnam and Somalia (Raihan et al., 2024; Viana Espinosa De Oliveira & Moutinho, 2022; Warsame et al., 2024).



10.2.9 Reducing the Gap Between Climate Science and Climate Economics

William Nordhaus won a Nobel Prize in 2018 for attempting to combine climate change and economics in a single, integrated assessment model, named *Dynamic Integrated Climate-Economy (DICE)*, however his predictions are considered inaccurate by climate scientists, underestimating the risk of catastrophic warming, tippings points, and the probability of higher temperatures leading to mass death (Jones & Steffen, 2019; Kemp et al., 2022; Ketcham, 2023; Stern et al., 2022; Stern, 2022a; Y. Xu & Ramanathan, 2017).

Energy and climate change economist Noah Kaufman says economists don't understand climate and climate scientists don't understand economics; and calls out economic calculations which try to estimate climate damages over hundreds of years or find a price for climate equilibrium, as nonsensical (dessler2, 2024). Instead, in a recent paper, co-written with another Nobel prize-winning economist, Joseph Stiglitz,

they argue economics can solve climate change though a risk-management approach for policy support, focusing on lowering climate risk by achieving net-zero carbon emissions (Stiglitz et al., 2024).

While Nordhaus has been criticized for his numbers, the general idea of his early book titled “The Climate Casino” doesn’t disagree. Nordhaus himself likens the current trajectory of climate change to humanity entering a “climate casino,” where we’re gambling with the planet’s future (Nordhaus, 2013). Written a decade later, Nordhaus asks if we can still exit the casino, and is much more pessimistic than in his early work (Institute of International and European Affairs (IIEA), 2023).

Although over 100 different scientific journals now publish work on sustainability economics, the field remains highly fragmented, with little interaction between research clusters. A bibliometric study of 1987–2013 publications found 11 largely self-contained research clusters, with minimal cross-citation; for example the Nordhaus-style integrated-assessment-modeling literature had almost no overlap with another prominent researcher, Elinor Ostrom, whose work focuses on commons governance within sustainability economics (Drupp et al., 2020).

Kaufman decries the lack of real-world data in the economic-climate models, and believes the simple assumptions should be replaced with much more complex scientific analysis (dessler2, 2024).

10.3 Efforts to Curb Greenwashing: Data-Driven Benchmarks and the Fight for Transparency

Corporate hypocrisy is an important blocker of sustainable action. Both the European Commission and the Chair of U.S. Securities and Exchange Commission (SEC) Gary Gensler have called for more legislation to curb business greenwashing practices. *“If it’s easy to tell if milk is fat-free by just looking at the nutrition label, it might be time to make it easier to tell if “green” or “sustainable” funds are really what they say they are”* says Gensler (US Securities and Exchange Commission, 2022). EU regulation for standardizing sustainability reporting is called the Corporate Sustainability Reporting Directive (CSRD) entered into force in 2023 as is being gradually ramped up until 2027.

Green investing only makes sense if it’s possible to distinguish sustainable investments from not sustainable ones. Humans feel as if choosing green is useless and give up. Sustainable investing is firstly about changes in legislation which set stricter sustainability standards on companies (as discussed above). Secondly, increased transparency, new metrics, and new tools make it feasible to differentiate more sustainable companies from less sustainable ones.

Upcoming EU greenwashing legislation hopes to curb misleading communications by companies. *“Make benchmark methodologies more transparent when it comes to ESG & put forward standards for the methodology of low-carbon and ESG benchmarks in EU”* (European Commission, 2019b). Until new legislation is ramped up (2030 in the EU), building consumer awareness is crucial as currently most emission-reduction programs are voluntary and thus affected only by consumer demand (André & Valenciano-Salazar, 2022). Greenwashing is widespread in company social media communications (Geoffrey Supran, 2022). A number of new AI-based tools aim to find instances of greenwashing. ClimateBert AI finds rampant greenwashing (Bingler et al., 2021; Sahota, 2021).

While the EU has proposed legislation to curb greenwashing, EU climate policy itself has been criticized for greenwashing. Sometimes greenwashing comes under legislative protection Kira Taylor (2021). (Booth, 2022) describes how “A recent investigation shows illegal logging of protected areas in eastern European countries that supplies residential wood pellets in Italy. Belgium, Denmark, and the Netherlands are

importing pellets from Estonia, where protected areas are logged for pellets and the country has lost its forest carbon sink, despite large-scale wood pellet plants being certified ‘sustainable’ by the Sustainable Biomass Program”.

In recycling systems,(Purkiss et al., 2022) highlights the confusion between compostable and biodegradable plastics and public misunderstanding what happens to these plastics when they reach the landfill: “[m]ost plastics marketed as “home compostable” don’t actually work, with as much as 60% failing to disintegrate after six months”. Shopping bags marketed as *biodegradable* don’t show deterioration after 3 years in salt-water sea environment (Napper & Thompson, 2019).

10.3.1 Anti-greenwashing Efforts in Taiwan

The Taiwanese Green Citizens Action Alliance published a comprehensive report in 2024 tracking Taiwanese Corporate Sustainability Reporting focused directly at fighting corporate greenwashing (綠色公民行動聯盟, 2024).

The Taiwanese Corporate Governance 3.0 - Sustainable Development Roadmap 3.0, published by the Corporate Governance Reform Task Force established by the Executive Yuan (Taiwanese Government), identifies *lack of diversity and independence in boards* and *insufficient ESG and financial information transparency* as key issues (Taiwan Stock Exchange Corporation, 2023).

The Taiwanese Financial Supervisory Commission, the Ministry of Environment, the Ministry of Economic Affairs, the Ministry of Transportation and Communications, and the Ministry of the Interior collaborated on the “*Reference Guidelines for the Identification of Sustainable Economic Activities*” to encourage the financial industry to assist enterprises in their transition to sustainable carbon reduction” (金管會 & Financial Supervisory Commission, 2022)

10.3.2 Traceability Curbs Corruption

EU Deforestation Regulation (EUDR)

Know your suppliers’ suppliers (Sourcemap, 2025)

The founder of Sourcemap Leonardo Bonanni **started with doing product autopsy in 2015 to assess products (« *Fast fashion* », 2023)

What data should be surfaced to the consumer?

Supply Chain Mapping

Transaction Traceability

To put it very simply (knowingly oversimplifying), in traditional finance legislation is an enabler of corruption as in the case of Swiss privacy laws, where illegal funds can be hidden, while in cryptocurrencies, the lack of clear and comprehensive regulation is an enabler of corruption.

10.3.3 Product Databases as a Precursor for Traceability and Supply Chain Mapping

In order to consider the sustainability on a product level, there should be a directory of all the world's products - a world product database. GS1 is the organization responsible for issuing EAN/UPC barcodes found on most consumer products worldwide (GS1, n.d.). However, while the UPC stands for Universal Product Code, there is no truly centralized, authoritative database of all UPCs, which has led to duplication and inconsistency across products sharing the same codes, especially with the rise of e-commerce marketplaces (Semantics3, 2017). As early as 2016, (Håkon Bogen, 2016) raised questions whether a global database of all EAN (European Article Number) barcoded products could be created. Barcodes help identify products within supply chains and retail systems, but they do not alone create a central product registry. On a basic level, standardized product codes ensure product inventory, traceability, automated checkout, and support global trade. All of the world's products already are subject to one or another standard and although they are not uniform, some documentation does exist about every product.

A number of specialized product databases have been created to fill specific needs. The Open Product Database maintained by Datakick (*Datakick*, n.d.) aimed to crowdsource product information but faced limitations and is no longer widely active. WIPO GREEN, the global green technology database, catalogs environmentally sustainable innovations (*WIPO GREEN*, n.d.). The World Packaging Database provides detailed information about product packaging worldwide, important for understanding material impacts (“Packaging World,” n.d.).

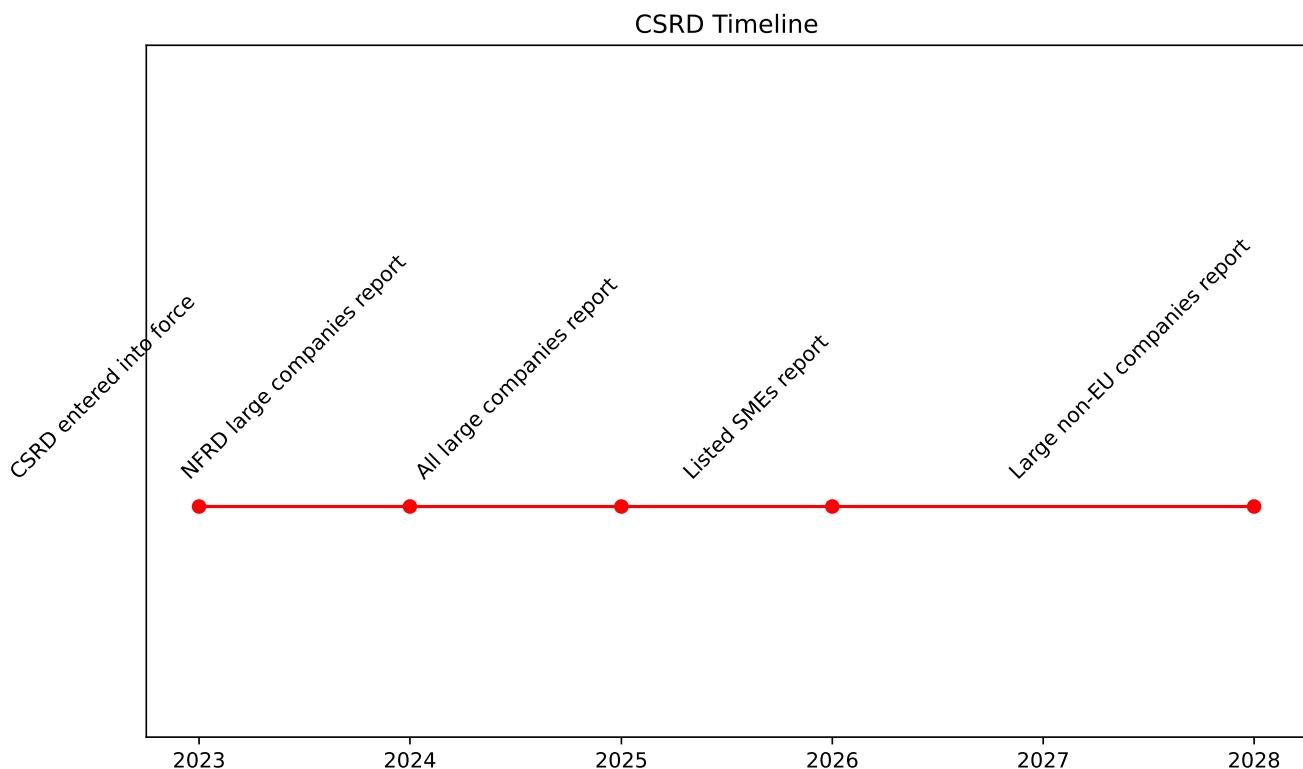
In a similar vein, Konrad (n.d.) imagines the possibility of an internet-wide directory of purchasable products, akin to how platforms like Spotify have made nearly all of the world's music easily searchable and accessible. However, despite the obvious need, attempts to build such directories have faced significant challenges. For example, the Open Knowledge Foundation's Open Product Data initiative (“Open Product Data” (n.d.)) was eventually shut down, highlighting how difficult it is to maintain open, comprehensive, and up-to-date product information at a global scale.

While some infrastructure exists, including bar and qr-codes, standards, and partial databases, the world still lacks a unified, reliable, open-access product database. Building such a system could improve sustainability assessments, supply chain transparency, and informed consumer choices at the global scale.

10.3.4 Indices, Certifications and Sustainability Standards Enable Product Comparisons

Research shows certification does matter. In Europe, consumers are willing to pay more for bio-based products “*72% of Europeans are willing to pay more for environmentally friendly products. The study identifies a “green premium” and a “certified green premium,” indicating increased WTP for bio-based and certified bio-based products*” (Morone et al., 2021). Particularly in Italy, a study of consumer awareness of sustainable supply chains shows Italian consumers have a strong preference for antibiotic-free meat (Mazzocchi et al., 2022).

Open ESG data platform Wikirate currently lists 4316 different metrics, essentially questions which companies should answer (Wikirate, 2025).



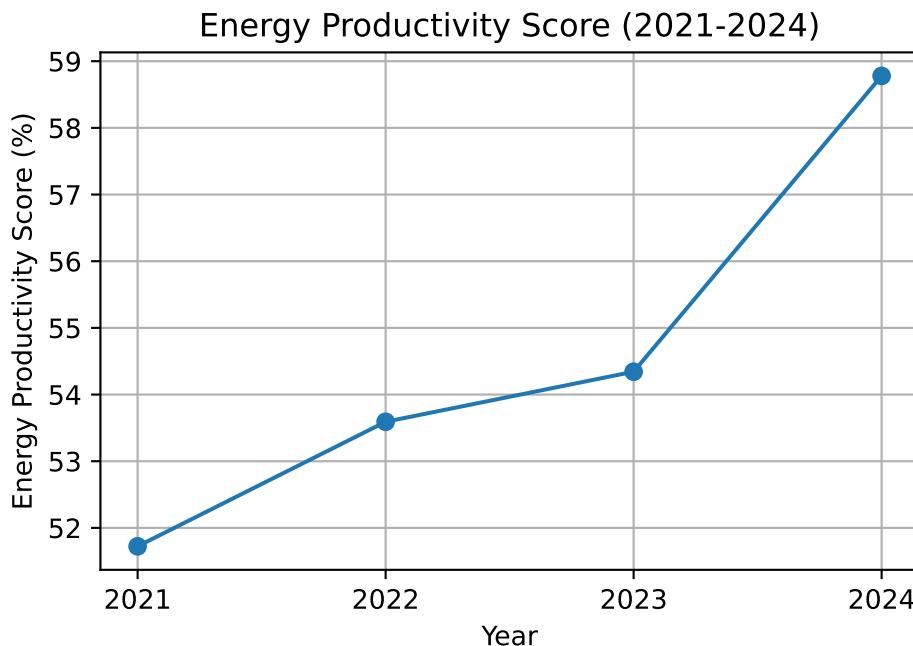
Companies assess customer's credit score to decide credit-worthiness, however inversely, how can customers rate companies? Indices make comparing companies possible. There are many-many indexes, scoring systems, ratings, certifications, etc.

Sustainability indices need transparency and standardization (Bolognesi et al., 2024).

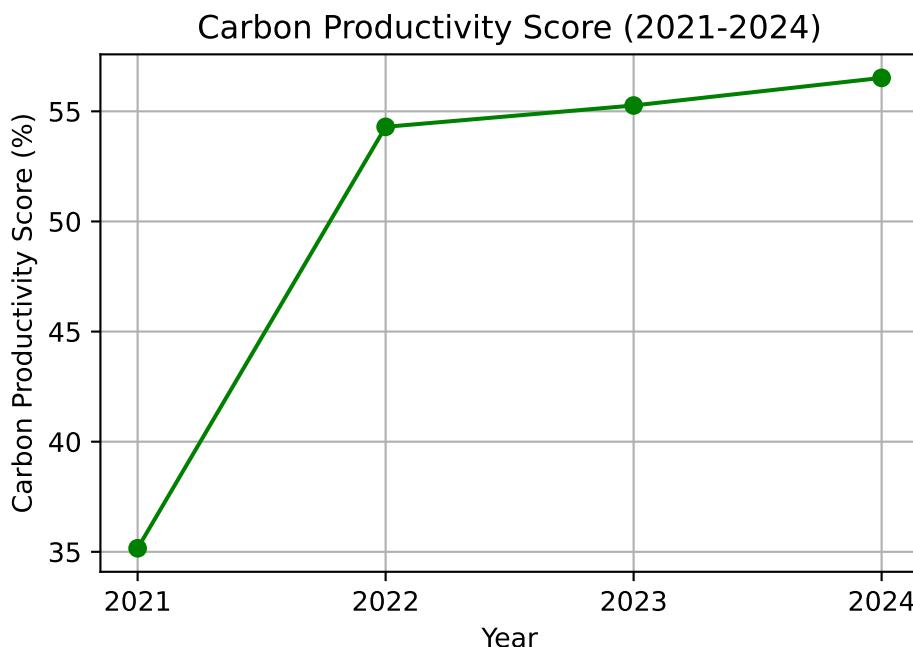
Based on Corporate Knights data (Corporate Knights, 2024)

Energy productivity and carbon productivity are a measure how intensive the product is per unit of productivity.

Energy productivity



Carbon productivity



(International Trade Centre, 2022) currently lists 334 different sustainability standards: “Towards a meaningful economy” “The world’s largest database for sustainability standards”, “We provide free, accessible, comprehensive, verified and transparent information on over 300 standards for environmental protection, worker and labor rights, economic development, quality and food safety, as well as business ethics.”

- There are many standards.

- Most sustainable companies. Make a database?

Type	Rating System	What it does
Certification	B Corporation ESG	B Impact Assessment
Certification	Fair Trade	
Ranking	Responsible Business Index	<i>Estonian Responsible Business Index</i> (n.d.) Responsible business index
Index	Greenly Science-Based Targets	Greenly Decarbonization Index Greenly (2023) Science-Based Targets initiative (SBTi) provides step-by-step guidance per economic sector help companies get started with meeting climate criteria and emission reduction requirements.
Certification	Green Web Foundation	“The Green Web Foundation” (2023) For example, the Green Web Foundation certifies how sustainable is the web hosting used by websites. Testing website CO ₂ emissions Wholegrain Digital (2023)
Rating	Leafscore for product	LeafScore (2023)
Rating	Ethical consumer ratings 1% For the Planet	“Ethical Consumer” (n.d.)
Standard	Climate Neutral Certified Standard	
Standard	The Conservation Alliance	(Climate Neutral Certified, 2023).
Index	Impakter Sustainability Index	

There are many different certifications

- “Ethical Consumer” (n.d.)
- sustainable brands
- Product-level reporting can be a basis for investing in companies. “Product-investing”. I want to invest in particular products.
- WikiRate, started in 2010, is a tool for checking green credentials and “[t]he largest open registry of corporate sustainability data in the world” (Mills et al., 2016; WikiRate, 2023).
- Transparency is about culture but also mechanisms and tools, which is why WikiRate defines Data Sharing Archetypes (WikiRate, 2021).

- OpenCorporates attempts to map all the companies around the world - “*the largest open database of companies in the world*,” - as per their tagline, launched a collaboration with the UNSD (United Nations Statistics Division) and the OECD (Organisation for Economic Co-operation and Development) to close the information gap on the 500 largest multinational enterprises (termed *MNEs*) to tackle the problem (as per their tweet on X, formerly known as Twitter): “*Hidden data is a big problem, and it’s limiting our understanding of the world’s largest #Multinational enterprises*” (Communications, 2023; opencorporates [@opencorporates], 2024)

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

- Laureen van Breen et al. (2023)
- Wikirate (2022a)
- *Home - ChainReact* (n.d.)
- Ray (2023) comprehensive overview of Web3.
- Rehash: A Web3 Podcast (2022) human-centered web3
- Web3 users are privacy-conscious and won’t answer questions, making it challenging to create good personas Crabb (2023)

Existing rankings

- Earth.Org (2022)
- Staff (2021)
- Fashion brand ratings
- Ethical Shopping
- “Top 100 Consumer Goods Companies of 2021” (n.d.) Largest consumer goods companies

B Corporations undergo strict assessment and adhere to stringent sustainability practices.

- B Impact Assessment
- *Find a B Corp* (n.d.) BCorporation listings by country
- “Etsy Made Mistakes, but Its Commitment to Social Responsibility Wasn’t One of Them” (2017)
- Citywealth (2021)
- “Social Enterprises, B Corps, Benefit Companies, ESG” (n.d.)
- RavenPack (2021)

10.3.5 Risk-Based Assessment of Sustainability Credits

“Companies in industries with the biggest carbon footprints aren’t reporting how their emissions feed into financial risk, according to an analysis of corporate reports by the Carbon Tracker Initiative.” (Frances Schwartzkopff, 2022b)

- BeZero is innovating in the voluntary carbon credit market (VCM) by providing risk-scoring, a language financial professionals are accustomed with (BeZero, 2022b; *Navigating Net Zero with Co-founder of BeZero Carbon*, 2023)

10.3.6

11 METHODOLOGY

Start with expert survey, then expert interviews (because so many questions from literature review).

Group	Task
Experts (Finance)	Interview
Experts (Design)	Interview
Experts (Sustainability)	Interview
Target Audience (College Students)	Survey + Prototype Testing

I adopted a face-to-face method to increase response rates distributing flyers to students on college campuses, canteens, and classrooms getting verbal permission from educators in their classrooms to distribute the survey flyer. The flyer included a colorful AI-generated visual with a futuristic game-link female figure, the title “climate anxiety survey”, a website link (ziran.tw) and scannable QR-code.

Similarly to (C.-H. Liu et al., 2023) I distributed the survey in schools in the Northern, Southern, Central, and East regions of Taiwan.

The survey only included questions and descriptions in Chinese. I have used the Claude 3 Opus model to translate them to English for this table.

Table 72: 36 Likert Fields included in the survey

Original Question in Chinese	English Translation
如果你/妳懷疑你/妳要買的番茄可能是由強迫勞工（現代奴隸）採摘的，你/妳仍然會買它嗎？	If you suspect that the tomatoes you are going to buy may have been picked by forced labor (modern slaves), would you still buy them?
你/妳關心食安嗎？	Do you care about food safety?
你/妳 7 年內買車嗎？	Will you buy a car within 7 years?
你/妳 7 年內買房嗎？	Will you buy a house within 7 years?
你/妳購物時知道產品環保嗎？	Do you know if the products are environmentally friendly when you shop?
你/妳覺得認證環保的公司更好嗎？	Do you think companies certified as environmentally friendly are better?
你/妳支持肉稅嗎？	Do you support a meat tax?
你/妳關心食用雞的生活嗎？	Do you care about the lives of chickens raised for food?
你/妳避免吃肉嗎？	Do you avoid eating meat?
你/妳覺得你/妳花錢會影響環境嗎？	Do you think your spending affects the environment?
你/妳會對金錢感到焦慮嗎？	Do you feel anxious about money?
你/妳會對金錢很節儉嗎？	Are you very frugal with money?
你/妳會經常存錢嗎？	Do you often save money?
你/妳對自己的財務知識滿意嗎？	Are you satisfied with your financial knowledge?
你/妳投資會考慮環保嗎？	Do you consider environmental protection when investing?
你/妳覺得台灣的經濟目標是增長嗎？	Do you think Taiwan's economic goal is growth?

Original Question in Chinese	English Translation
你/妳覺台灣的得環境退化是台灣的經濟增長的前提嗎?	Do you think environmental degradation in Taiwan is a prerequisite for Taiwan's economic growth?
你/妳覺得台灣的經濟增長有助於保護環境嗎?	Do you think Taiwan's economic growth helps protect the environment?
你/妳覺得經濟能不排 CO ₂ 也增長嗎?	Do you think the economy can grow without emitting CO ₂ ?
你/妳覺得經濟增長有物質限制嗎?	Do you think there are material limits to economic growth?
你/妳會每天都用 AI 嗎?	Do you use AI every day?
你/妳會信任 AI 嗎?	Do you trust AI?
你/妳想要 AI 有個造型嗎?	Do you want AI to have a specific appearance?
你/妳喜歡待在大自然嗎?	Do you like being in nature?
你/妳擔心氣候變化嗎?	Are you worried about climate change?
你/妳對環境污染情況會感到焦慮嗎?	Do you feel anxious about environmental pollution?
你/妳知道許多植物和動物的名字嗎?	Do you know the names of many plants and animals?
你/妳感覺自己和大自然很接近嗎?	Do you feel close to nature?
你/妳努力實踐低碳生活嗎?	Do you strive to live a low-carbon lifestyle?
你/妳想做更多環保事嗎?	Do you want to do more for environmental protection?
你/妳對環境相關政治議題有興趣嗎?	Are you interested in environmental political issues?
你/妳信任碳排放抵消額度嗎?	Do you trust carbon offset credits?
你/妳的環保行動對環境保護有效果嗎?	Do your environmental actions have an effect on environmental protection?
你/妳想在行業內推環保嗎?	Do you want to promote environmental protection within your industry?
你/妳得自己對新觀念開放嗎?	Are you open to new ideas?
你/妳的大學對可環保性支持嗎?	Does your university support environmental sustainability?

Respondents who remained outside the survey parameters were disregarded from the data analysis.

- References were stored in the Zotero paid version with 6 GB storage.
- Bibtex and Better Bibtex were used to export the references to the .bib format consumable by Quarto.

11.1 Research Design

When developing my research design, I relied on the advice of (Christian Rohrer, 2022) to decide when to choose which User-Experience Research methods.s

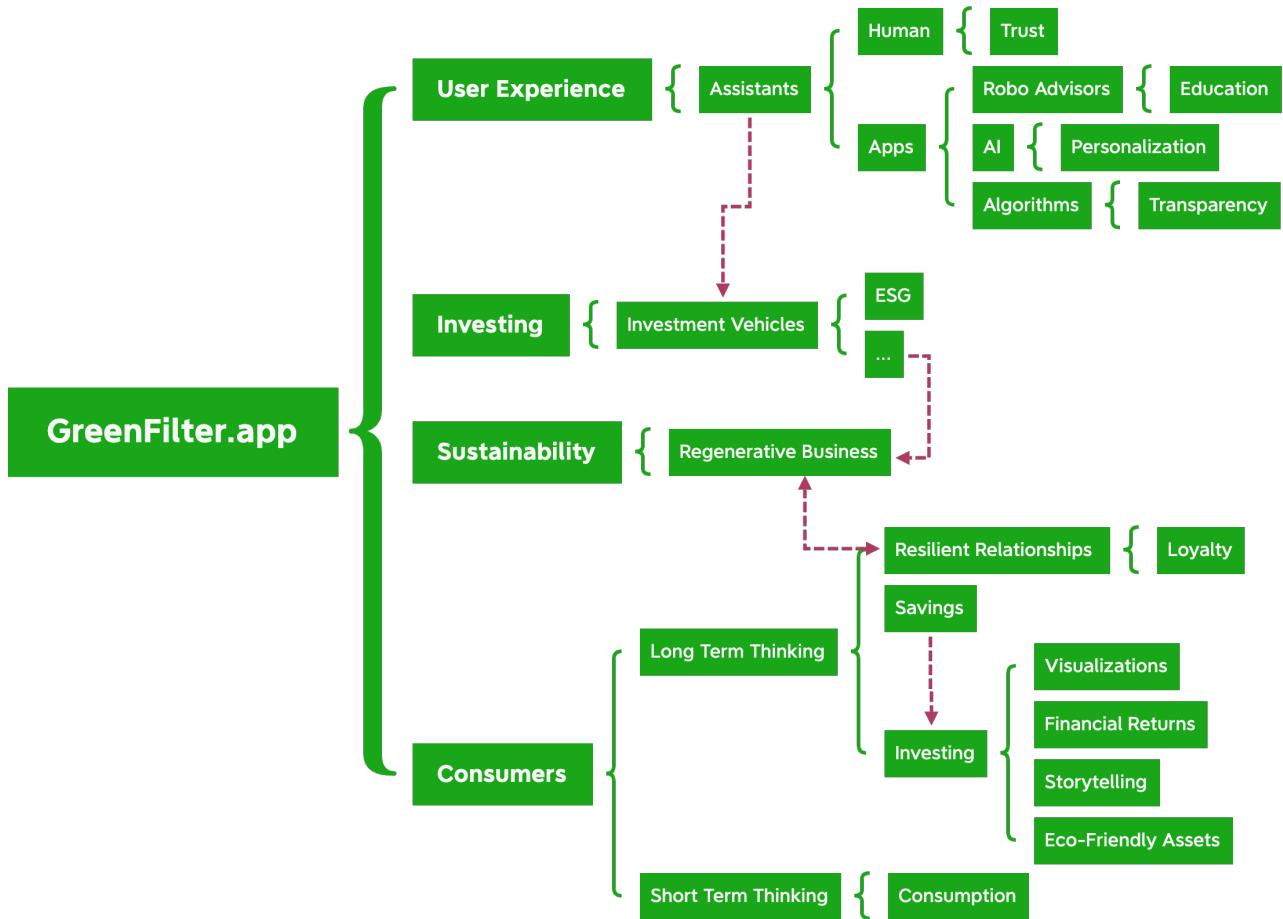
The research design of this study consists of 3 steps.

- Qualitative research targeted at financial and interaction design experts, leading to a *wish list* of features.
- Survey potential users' preferences, including a choice experiment of the proposed features.

- Design a prototype of the personal sustainable finance AI assistant, tested using qualitative methods in a focus group.
- This mixed-method research design is divided into three stages (fig. 11).
- My purpose for the first qualitative stage is to explore the general themes arising from the literature review related to the design of AI advisors for investing. I will identify specific user experience factors, through interviewing experts in financial technology and user experience design and reviewing existing applications on the marketplace. At this stage in the research, the central concept being studied is defined generally as expectations towards a sustainable investment AI advisor.
- I will then proceed to the second, quantitative stage, informed by the previously identified factors, and prepare a survey, including a Likert scale, and a choice experiment, focusing on the preferences of the potential users in generation-z aged 18-29, living in Taiwan (see fig. 12 on next page), exploring the relationship between independent variables: - “Interest in Sustainability” - “Interest in Investing” - “Preferred Features” - and the dependent variable “User Sign-ups”.
- In the third stage, I will return to the qualitative methods, by building a prototype of the sustainable investing AI companion, taking into account insights gathered in the previous stage. I will use a focus group to discuss the prototype, and conduct a thematic analysis of the discussions’ recordings, leading to further validation of previously gathered data and possible changes in the prototype. The gained insights, accompanied by the app prototype, which embodies my findings, will be the final outcome of my research.

11.2 Conceptual Framework

- The conceptual framework map presents the key concepts arising from the literature review thus far in the research process. I’m using these concepts when developing interview strategies for phase one of the research, developing the survey questionnaire for phase two, as well as for building the Personal Sustainable AI Financial Advisor (PSAA) for young adults at the final stage of the process. However, I expect the conceptual framework to further evolve with additional findings while conducting my research.



Presented with xmind

Figure 23: Concept map

Conceptual Model

11.3 Research Methods

11.3.1 Phase One - Qualitative Research

The qualitative research methods employed in the first stage of the research design enables me to explore concepts arising from literature review further, using a more open approach, without limiting the conversation only to pre-scribed notions. The strength of the qualitative approach in the first stage is to encourage the discovery of new ideas, not yet common in literature and potential user experience factors related to sustainable investing and user experience.

11.3.1.1 Sampling

My qualitative sampling structure uses non-probability snowball sampling, with the following criteria: financial industry, fintech, and design experts everywhere, including in Taiwan and Sweden, but also Estonia, Portugal, and elsewhere.

Method: Semi-Structured Interviews

I will conduct exploratory research in English using semi-structured interviews recorded online and offline.

11.3.2 Phase Two - Quantitative Research

The strength of quantitative research is to enable me to access a larger sample of potential users in two countries, using online survey methods, and to validate some of the qualitative findings from stage one.

Sampling My quantitative sampling structure uses a judgmental criterion: adults aged in Generation-Z (18-29), located in Taiwan, surveyed using a Chinese-language online survey.

Method: Likert The survey includes a Likert scale between 1 to 5 to validate key findings from the first stage of the research by assessing responses to statements regarding the app's design, features, and other criteria that may still emerge.

Method: Choice Experiment The survey includes a choice experiment between different sets of potential features available when communicating with the sustainable finance AI companion.

11.3.3 Phase Three - Qualitative Research

In the last phase, I will return to the qualitative methods to further validate the quantitative findings from stage two. Here my focus will be on operationalizing the gathered insights into a prototype that users can experiment with and discuss with their peers in a focus group setting. Sampling

The phase three sampling structure uses a judgmental criterion: - age 18-35 - located in Taiwan - Using the Chinese language for discussion

Individual face-to-face interviews will be organized at universities around Taiwan. Because in-person presence is required in this stage, the prototype will only be tested by potential users physically present in Taiwan. To avoid convenience sampling, I will post online ads in Chinese and reach out to varied student clubs to invite people who I don't know personally, to participate in a "sustainable AI application testing" (wording may change).

Method: Focus Group The strength of a focus group is the ability to observe potential users in a social setting, where knowledge can be exchanged between the participants. The whole experience, including emerging conversations, will be recorded and transcribed.

Method: Thematic Analysis Finally, I will perform a thematic analysis of the focus group transcriptions in order to validate previous findings, and open avenues for future research.

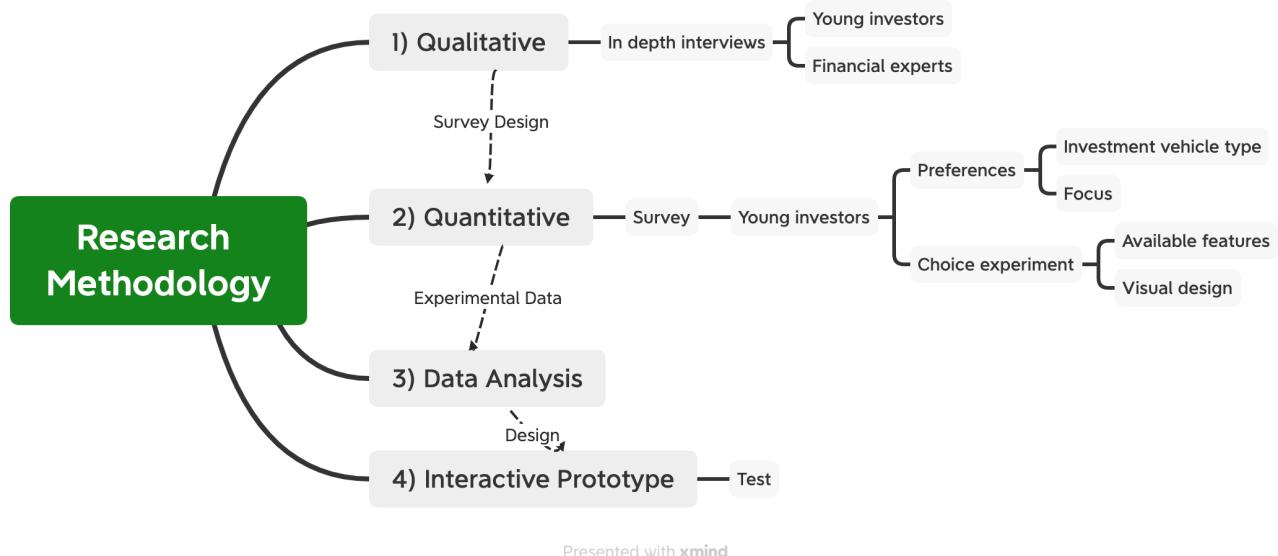


Figure 24: Overview of research methodology

- Interview transcript from Descript and Google Speech-to-Text model were combined using Gemini 2.5 Pro Experimental 03-25 (gemini-2.5-pro-exp-03-25) model.

11.4 Testing

Does the prototype match user needs?

Testing was the most difficult part of the thesis process.

- Testing with friends and acquaintances.
- Testing with experts.
- Testing with unknown people in the target audience.

11.4.1 App Testing Flow

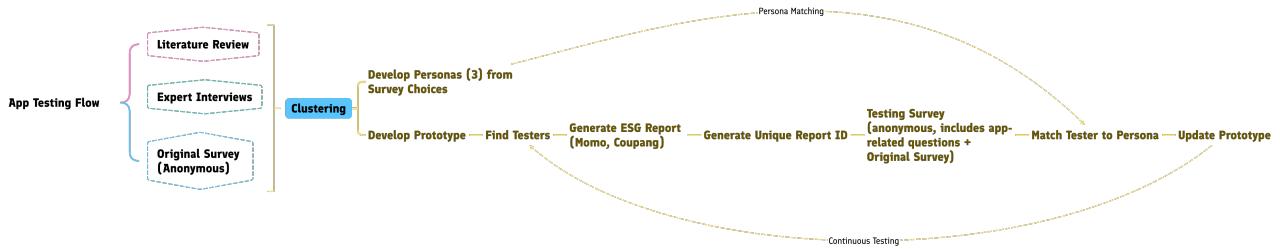


Figure 25: App Testing Flow

11.4.2 1st Wave of Testing (Spring 2024)

- 1 month from 2024 April 2 to May 2, 2024
- 8 anonymous participants at NCKU
- Participant observation
- No audio recording

Prototype Testing results

sun, 14. april. 22h at D24

- NCKU student, gen-z
- searches for lancome brand
- chooses LANCOME 蘭蔻 小黑瓶 100ml(買一送一/超未來肌因賦活露國際航空版) <https://www.momoshop.com.tw>
- notices 買一送一
- doesn't notice analysis button at first
- would only click on this if it's really expensive
- would not click on "continue chat button"
- asked "why is it so expensive in taiwan?"
- considers report result useful

note: there's dropoff on every step of the user journey

RQ: To what extend can shopping become an entry point for saving and investing. RQ: Can shopping serve as an entry point for sustainable saving and investing?

Testing overview

- Tested with 30 participants individually
- Testing is anonymous
- Generate
-

有意識的消費主義

- add carbon indicators, other labels to the analysis, add report code, calculate report code from URL? save as kv

may 8 czuta

- investment help useless.. needs simpler intro - wants to see real cows - very curious about companies - wants to see profit percentage. why is margin so high if pollution is bad. - real environmental impact of the company.

06 may - Seeing factory photos is useful only if they are trustworthy photos. Who will provide them? -

may 5
- user: it looks like an ad

may 3

- uses google to look for “fashion brand eco friendly”
 - thinks “goodonyou.eco” looks like a brand website
-

may3 - first looked for NET clothes but Momo doesn't sell it - Looked for Sony camera lens

1 may prof suggestion - make connection between biodiversity and production and consumption clearer - what is the incentive for companies to share their data?

my own idea: like the switch of going from traditional banking with ATM machines on the street (or even the physical bank office) to online banking with mobile payments

- hypothesis: esg accessibility can push companies to increase production standards
- what if you can see ESG in near-realtime such as the stock market price
- i can imagine esg derivative product like siemens gamesa
- ai can help integrate esg derivatives into daily life to drive esg adoption
- “effective altruism (EA)”
- “Blockchain technology can improve price transparency in product distribution by allowing consumers to know the exact pricing from raw materials to distributors to suppliers.”
-

Interviews and testing survey were conducted anonymously in hopes to have more honest responses from the responders.

- ziran chrome extension is unable to record activity due to browser security restrictions for plugins
- ai.ziran.tw record user activity
- semi-structured interviews were conducted in chinese
- the interviewer (me) took notes of the interviews
- some gaps in the data exist due to the limited chinese language skills of the interviewer (me)

basic interview script - momo: what is a brand that you like'd or would like to buy - search - please pick a product (or search again) - on product page: what do you notice on this page? - what kind of information is important for you on this page? - do you notice anything else - (if the user doesn't notice the green filter, direct their attention to it and ask: what do you think this does?) - would you click on it - if the user says yes, continue - if the user says no, make note and continue - as the extension generates a response: what do you think about this content? - is there any information that you consider important? - anything else you see that you think looks special - do you see anywhere you can click? - would you click on it? - if yes, continue - if no, make note, and continue - explain: due to the limitation of the prototype, the test will continue on a separate page where you can ask questions - is there anything you would like to ask the helper? - notice if the user picks from sample questions - remind the user they can come up with their own question - as the ai is generating content ask: do you see any information in this content - did you know this before or is there any info you didn't know before? make note. - front page: explain

the helper takes into account your personal info and goals. - ask: what kind of information do you think important to share with the helper?

Tuesday 30. April 14:05-14:45 - 7CYQ6

- Momo
- Looks for Levis pants
- Looks for recommendations on the sidebar
- Looks at the photos
- Looks at the price and options
- Didn't notice the helper as it looks like an ad
- When helped
- Ignores 社區支持: 購物 69% 儲蓄 80% 投資 65% as doesn't know what these mean
- on ai.ziran
- shares personal info: 四年後想考研究所, 還不想工作, 所以不會存到錢, 希望可以考到台北的學校, 每個月有兩萬生活費。
-
- DJmoney
- <https://www.moneydj.com/etf/x/basic/basic0004.xdjhtm?etfid=0050.tw>
- Still didn't notice the helper
- Doesn't understand investing (Understands it's Taiwanese stocks) so the helper is useful for explaining new concepts

Monday 29. april 10:10-10.25 - Momo - buy new balance sneakers

- DJmoney
- wants compare EFTs

Monday 29. april 14:50-15:10 - Momo - buy apple iphone - bad internet - app was slow - app crashed

- green filter analysis on DJmoney seems more trustworthy than other 2 eft sites
- button placement is important (too low on other sites than djmoney)

Sunday 28. april 16:00 - momo: wants to buy ice cream

sun, 14. april. 22h at D24

- ncku student, gen-z
- searches for lancome brand
- chooses LANCOME 蘭蔻 小黑瓶 100ml(買一送一/超未來肌因賦活露國際航空版) <https://www.momoshop.com.tw>
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RQ: To what extend can shopping become an entry point for saving and investing. RQ: Can shopping serve as an entry point for sustainable saving and investing?

Testing overview

- Tested with 30 participants individually
- Testing is anonymous
- Generate
-

有意識的消費主義

- add carbon indicators, other labels to the analysis, add report code, calculate report code from URL? save as kv

11.4.3 Expert Feedback

- Provide alternatives
- Simplify text
- Use images
- Put a “New Feature” ad on the front page
- Change 繼續討論 to something more actionable
 - I tried changing to “see alternatives”

11.4.4 2nd Wave of Testing (Autumn 2024 - Spring 2025)

In-Person Face-to-Face Testing

I conducted in-person testing individually with 32 students at 7 universities. Interviews were conducted in Chinese and transcribed and translated to English using Google Voice to Text AI as well as Describe AI. Face-to-face testing was concluded in several universities across Taiwan.

Region	University	No of Testees
Taichung	國立中興大學 National Chung Hsing University (NCHU)	7
	國立中正大學 National Chung Cheng University (CCU)	5
Chiayi	國立成功大學 National Cheng Kung University (NCKU)	6
	國立臺南藝術大學 Tainan National University of the Arts (TNNUA)	2
Tainan	長榮大學 Chang Jung Christian University (CJCU)	5
	南臺科技大學 Southern Taiwan University of Science and Technology (STUST)	5

12 RESULTS

Expected Findings

During the preparation of this research proposal I conducted a preliminary round of facetoface interviews using 21 openended probing questions using a convenience sampling of NCKU students on campus between ages 19 and 29 a total of 12 respondents The interviews lasted between 9 and 21 minutes and were conducted to get some initial feedback on my research idea the respondents daily routines app usage feelings towards financial questions including investing relationship with nature and environmental sustainability These preliminary conversations led me to emphasize more on the financial journey ie to consider the importance of the shopping savings and payments apps students already use daily which could serve as an entry point to becoming an investor I expect my future research findings to confirm this initial idea and offer diverse ways and examples of what that path could look like in practice

Survey Overview

A survey of Taiwanese college students excludes overseas Chinesespeaking students as well as foreign students covering attitudes towards shopping saving investing economy nature sustainability and AI

Survey Oct 13th Nov 3rd 2023

2000 cards with a QR code printed out

Distribution conducted at 8 universities handing out the cards

1289 people started the survey 518 quit

771 people completed the whole survey

Data after filtering 675 people aged 18-26 GenZ Taiwanese current students in BA large majority MA small minority or PhD level very few respondents

36 likert fields 5point scale used for clustering the students into 3 personas with Kmeans clustering

14 product features multiplechoice used for Kmodes clustering

4 choice experiments

2 option ranking questions

10 text fields used to enrich the personas

Data Analysis

KMeans clustering for survey data Kmeans clustering is similar to vector distances for similarity used in largelanguage models LLMs word embeddings and deep learning

Findings

Literature AI assistants should integrate with Digital Product Passports Literature AI assistants should show carbon label data Literature AI assistants should avoid taking ESG at face value because its a really low bar and integrate other metrics such as B Corp Literature AI assistants should Literature Do not make another investing app make a sustainability filter for excising investing platforms Literature College students can support extended producer responsibility

How might AI assistants empower regenerative shopping saving and investing

Display the ESG EPR BCorp etc etc credentials for each product and investment EPR and BCorp are success stories which should be highlighted while ESG is largely discredited There are many existing and ongoing approaches to sustainability The best approach might be to plug into existing system and communities and legislation to support and empower them

How might one design an intuitive sustainable shopping saving investing app

Apple Watch app

What app features might college students rate as the highest priority

Autopilot

How might one visualize ecological impact in digital product design

Accuracy is more important for human trust than actual impact

95,9% used a mobile device, 75,5% using an iOS device iPhone, 20,8% using an Android device design implication should design mobile app but apple is so restrictive

RQ 1

the AI companion is informed by the latest scientific insights and can provide accurate evidencebased recommendations The AI is designed to offer personalized guidance by analyzing complex environmental data and translating it into userfriendly information helping students make more sustainable choices in their daily lives It explores various AI interaction designs including chatbots voice assistants and virtual avatars to find the most engaging and supportive formats for college students address the attitudebehavior gap among college students by providing tools that make sustainable financial actions more convenient and impactful

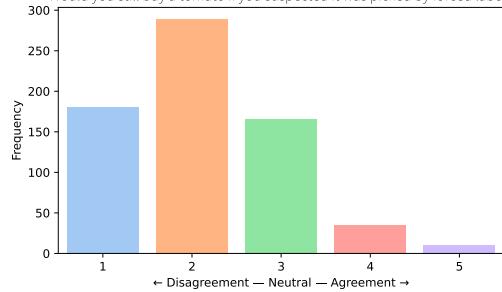
RQ 2

provide realtime information about the sustainability of products and companies AI companion includes features for identifying and investing in sustainable companies This involves providing data on companies environmental social and governance ESG practices and facilitating investments in green bonds and sustainable funds shoppingasinvesting where the AI links the act of purchasing sustainable products with investing in companies that produce these products effectively merging consumer and investor roles

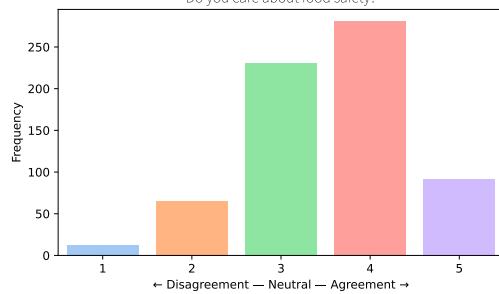
RQ 3 todo

12.1 Shopping

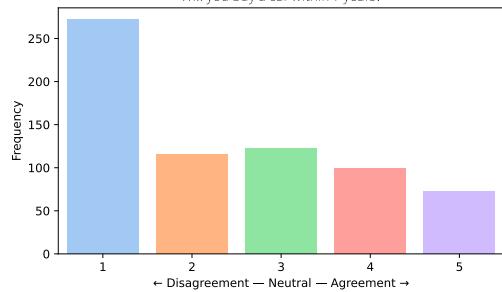
如果你/妳懷疑你/妳要買的番茄可能是由強迫勞工（現代奴隸）採摘的，你/妳仍然會買它嗎？
Would you still buy a tomato if you suspected it was picked by forced labor?



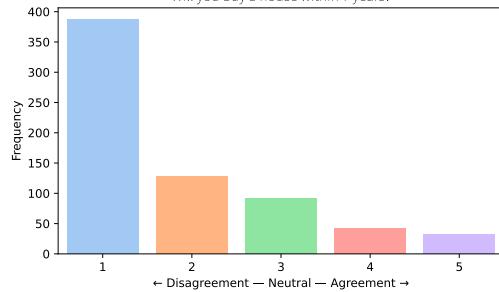
你/妳關心食安嗎？
Do you care about food safety?



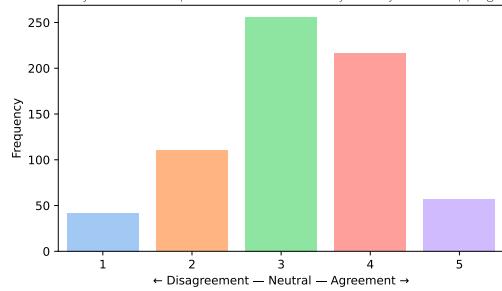
你/妳7年內買車嗎？
Will you buy a car within 7 years?



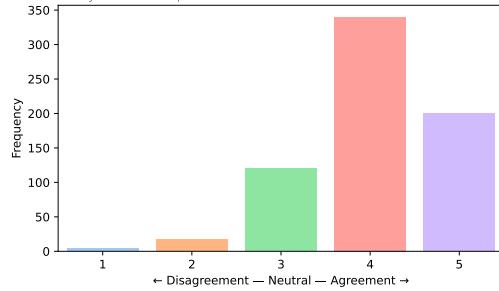
你/妳7年內買房嗎？
Will you buy a house within 7 years?



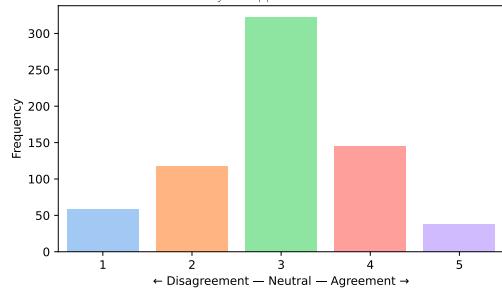
你/妳購物時知道產品環保嗎？
Do you know if the product is environmentally friendly when shopping?



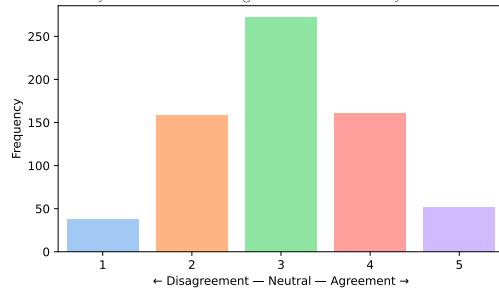
你/妳覺得認證環保的公司更好嗎？
Do you think companies with environmental certifications are better?



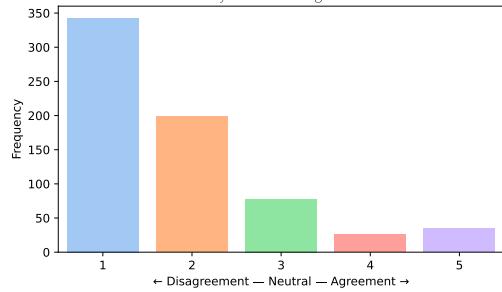
你/妳支持肉稅嗎？
Do you support a meat tax?



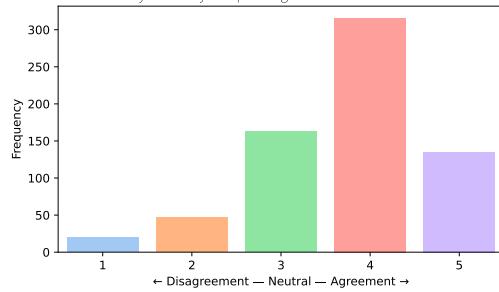
你/妳關心食用雞的生活嗎？
Do you care about the living conditions of chickens you consume?



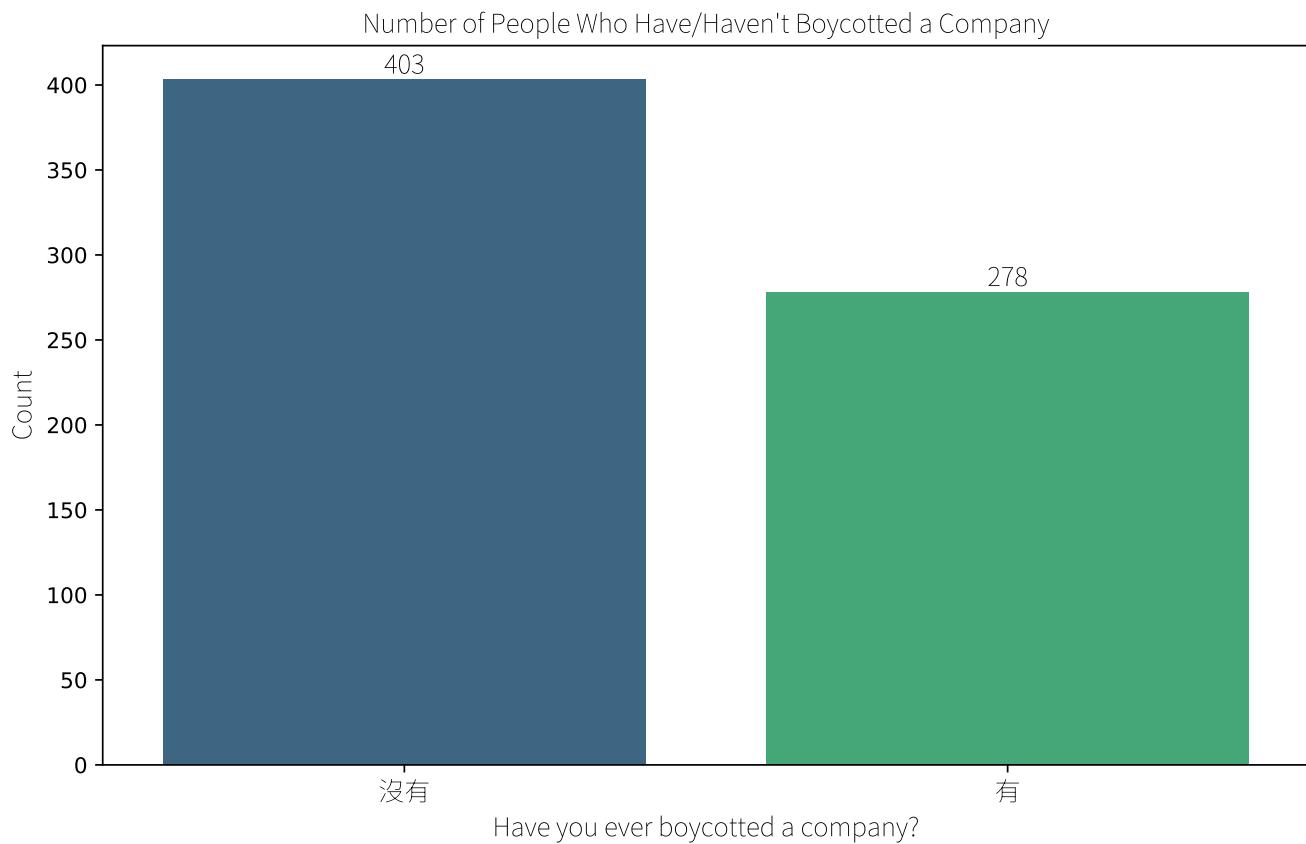
你/妳避免吃肉嗎？
Do you avoid eating meat?



你/妳覺得你/妳花錢會影響環境嗎？
Do you think your spending affects the environment?



12.1.1 Boycott Count (Overall)



12.1.2 Why Boycott

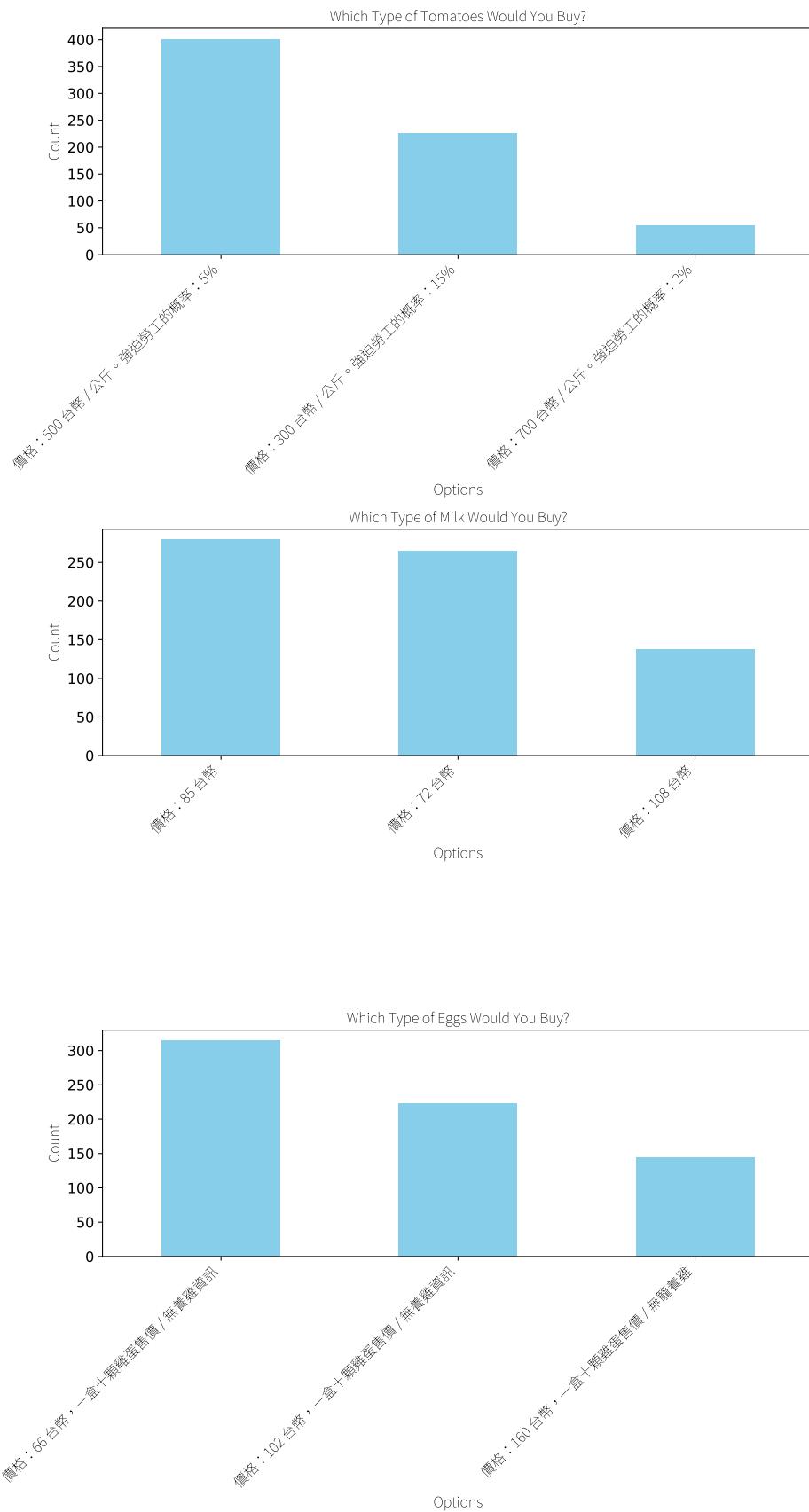
Reason	Count
0 食安問題	33
1 地溝油	10
2 黑心油	8
3 食安	5
4 政治因素	4
...	...
182 因為有出新聞	1
183 此公司危害食安，以抵制這種行為讓公司更能意識到執行此行為的後果	1
184 地溝油啊	1
185 不認同理念	1
186 因為這家公司壓榨員工	1

12.1.3 Trusted Brands

	Brand	Count
193	No trusted brand	329
194	Have but not specified	56
0	義美	42
1	Apple	9
2	光泉	7
...
83	自家種植	1
84	Casetify	1
85	Adidas	1
86	麥當勞	1
97	淨毒五郎	1

The following responses were counted as “no brand”: “無”, “沒有”, “沒有特別”, “□”, “目前沒有”, “No”, “沒”, “沒有特別關注”, “沒有特別信任的”, “不知道”, “無特別選擇”, “目前沒有完全信任的”, “沒有特定的”, “沒有特定”, “沒有特別研究”, “目前沒有特別關注的品牌”, “N”, “none”, “無特別”, “目前無”, “沒有特別想到”, “沒有固定的”, “x”, “沒在買”, “nope”, “一時想不到…”, “沒有特別注意”, “無特別的品牌”, “無絕對信任的品牌”, “不確定你說的範圍”, “還沒有”

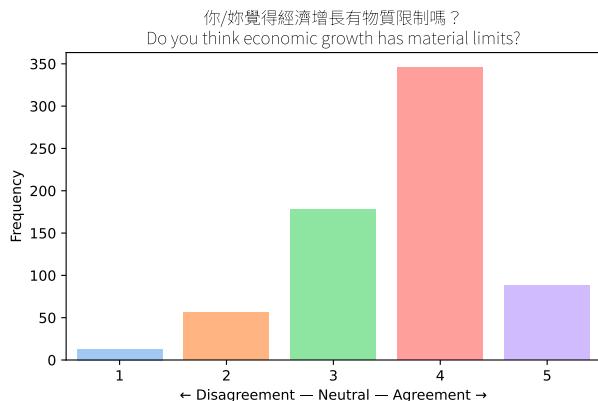
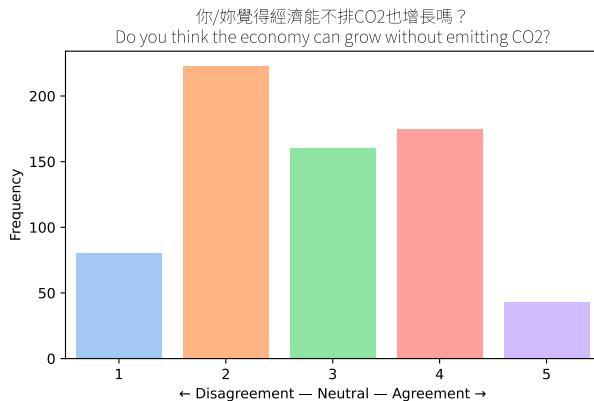
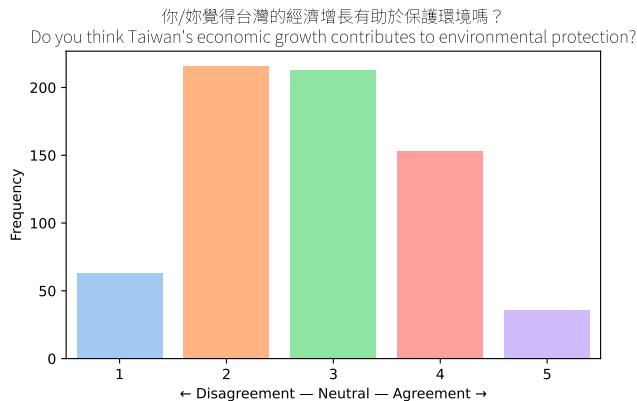
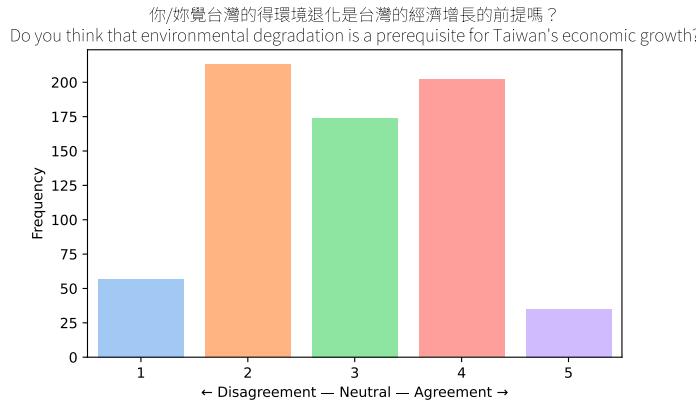
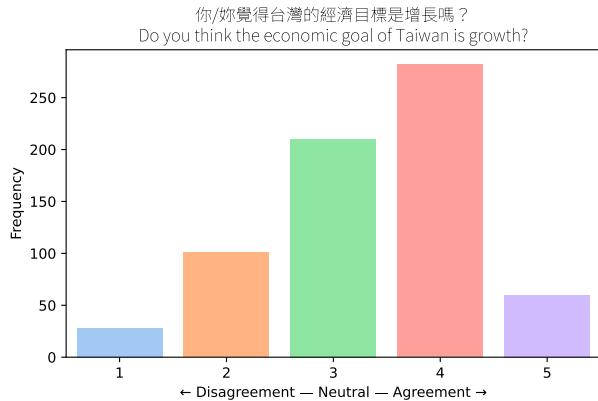
12.2 Choice Experiments



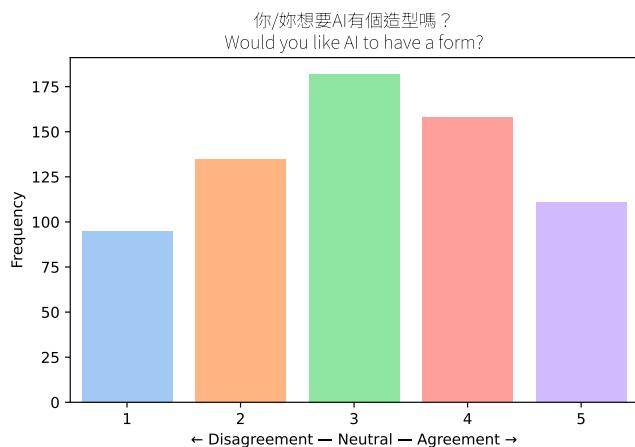
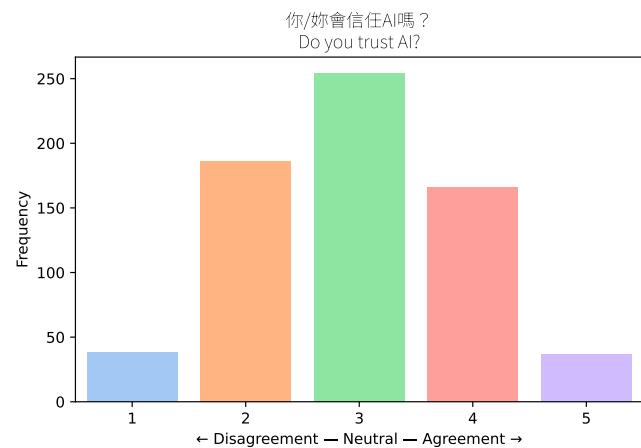
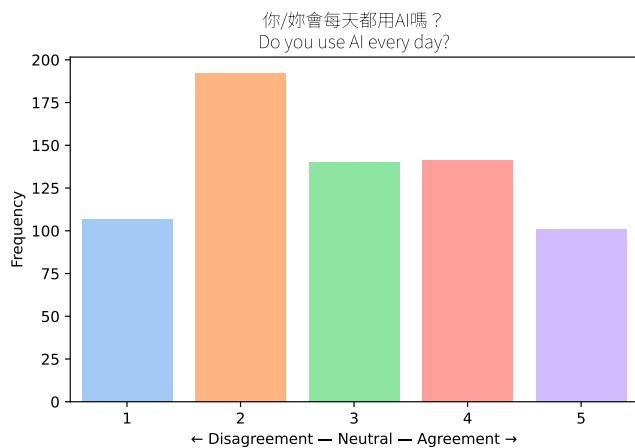
12.3 Taiwanese College Student Attitudes (Overall)

These are student attitudes across all 36 likert fields without clustering. Clustered results are available under the Personas section.

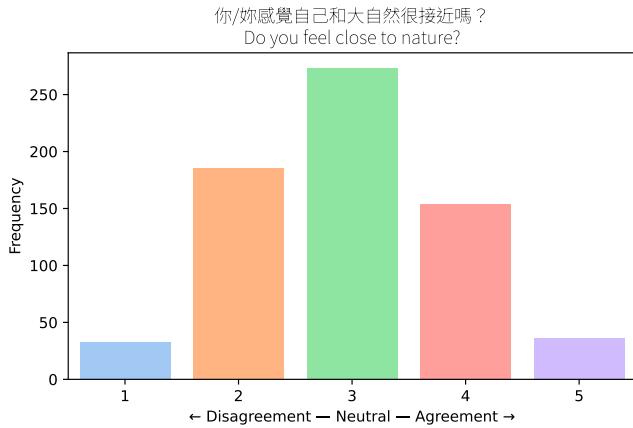
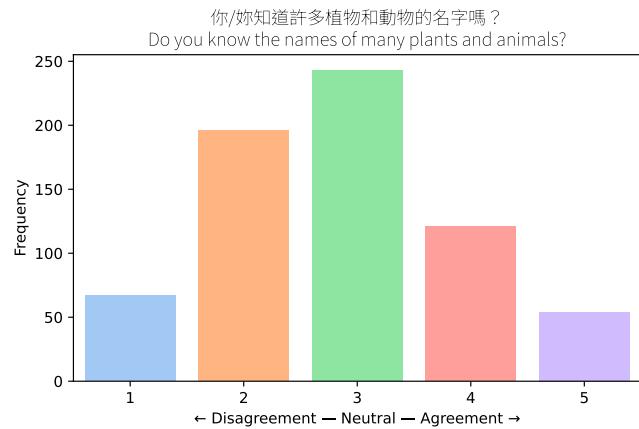
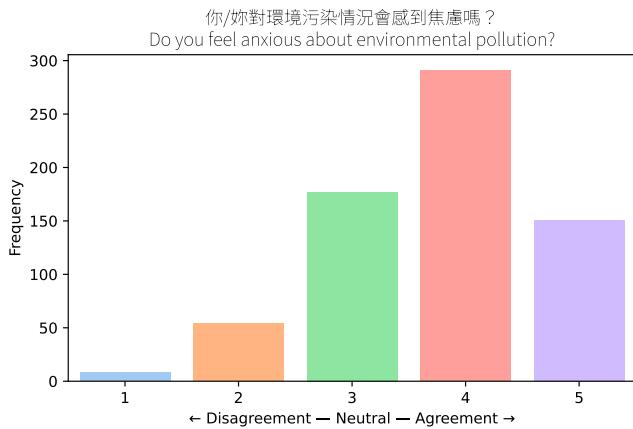
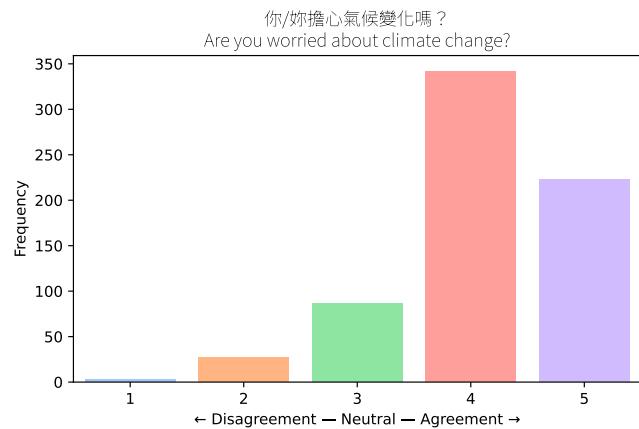
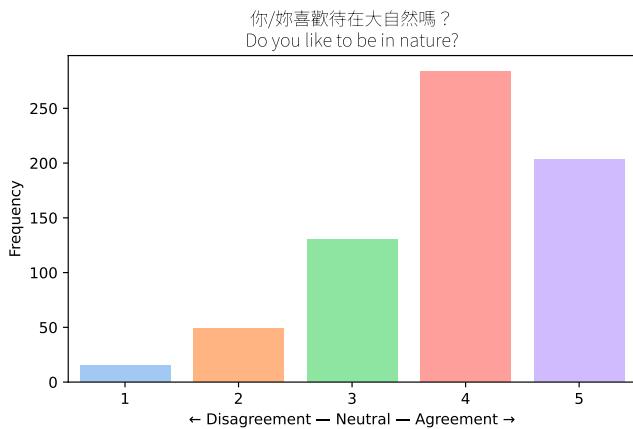
12.4 Economy



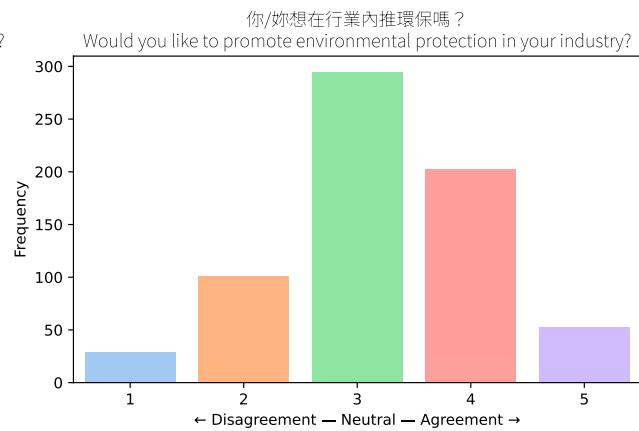
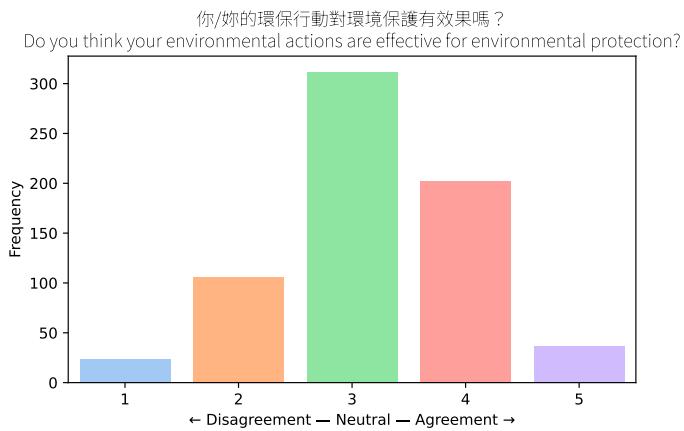
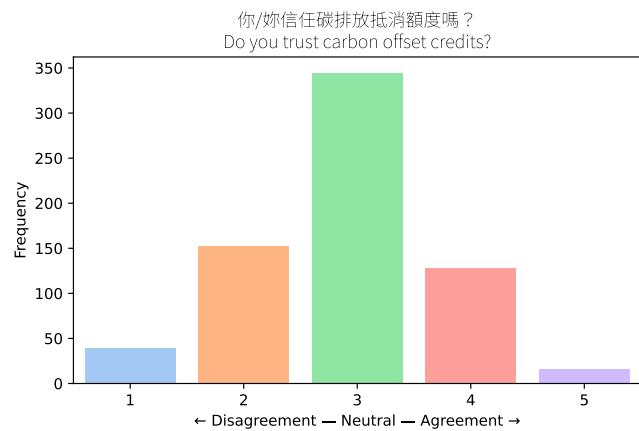
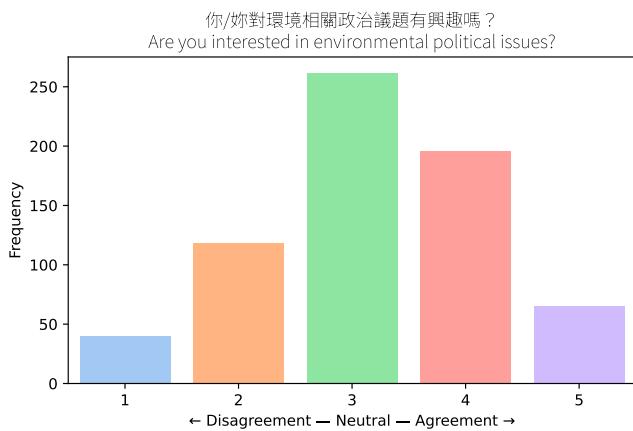
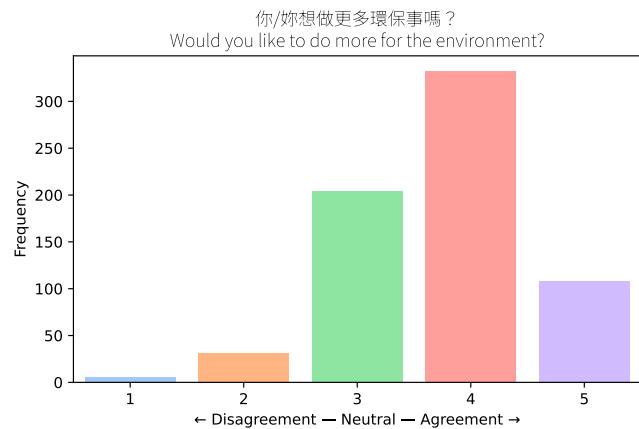
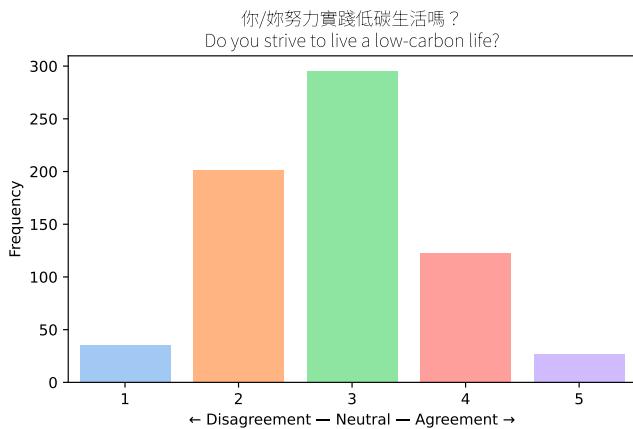
12.5 AI Usage



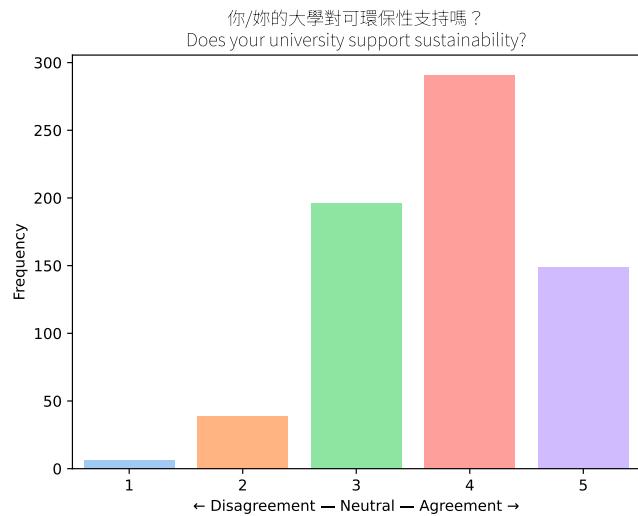
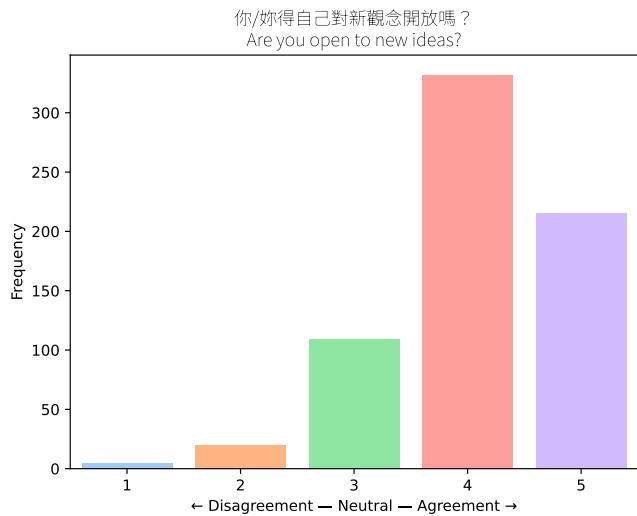
12.6 Nature



12.7 Environmental Protection

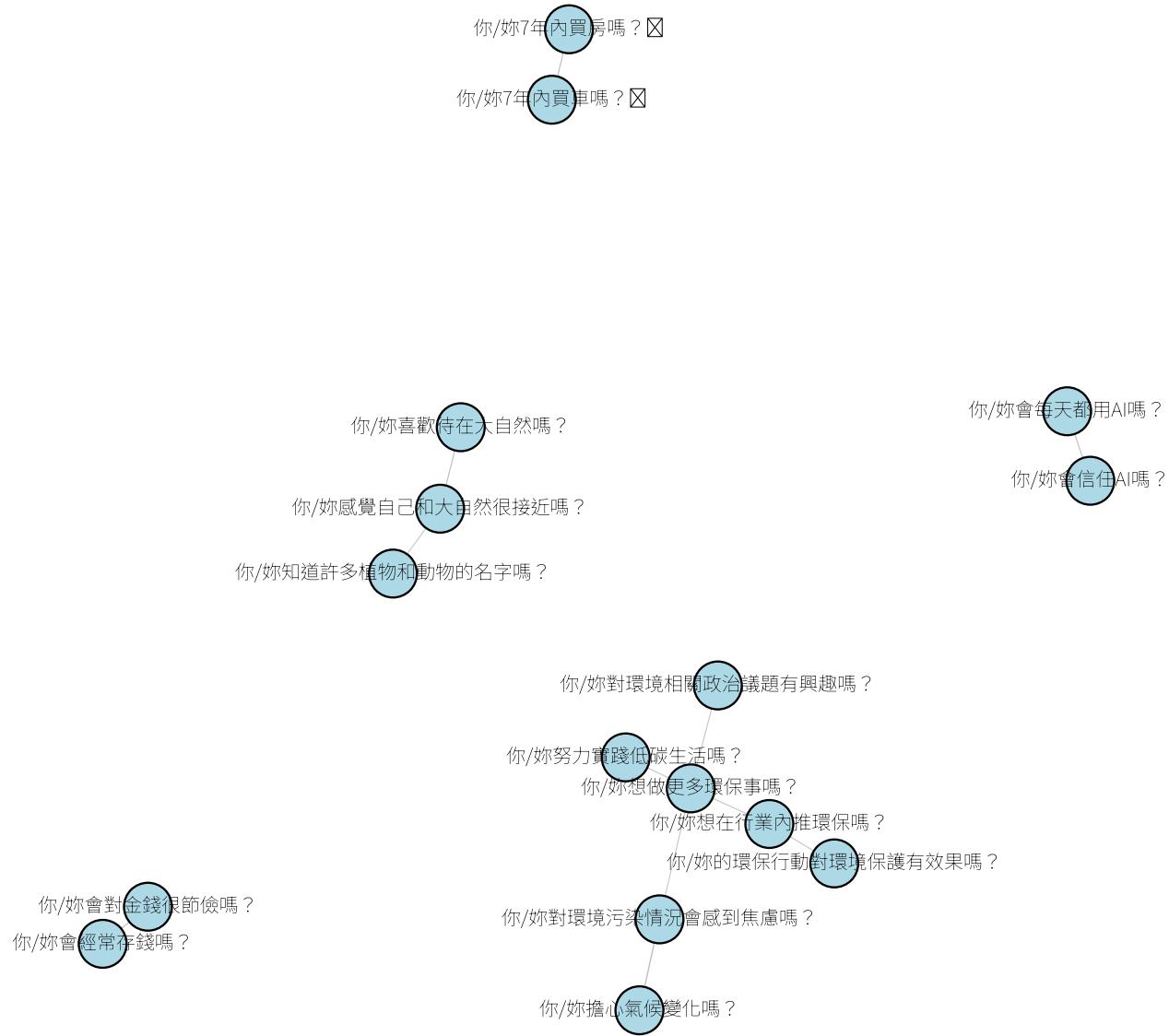


12.8 Learning Environment



12.9 Correlations Between Fields

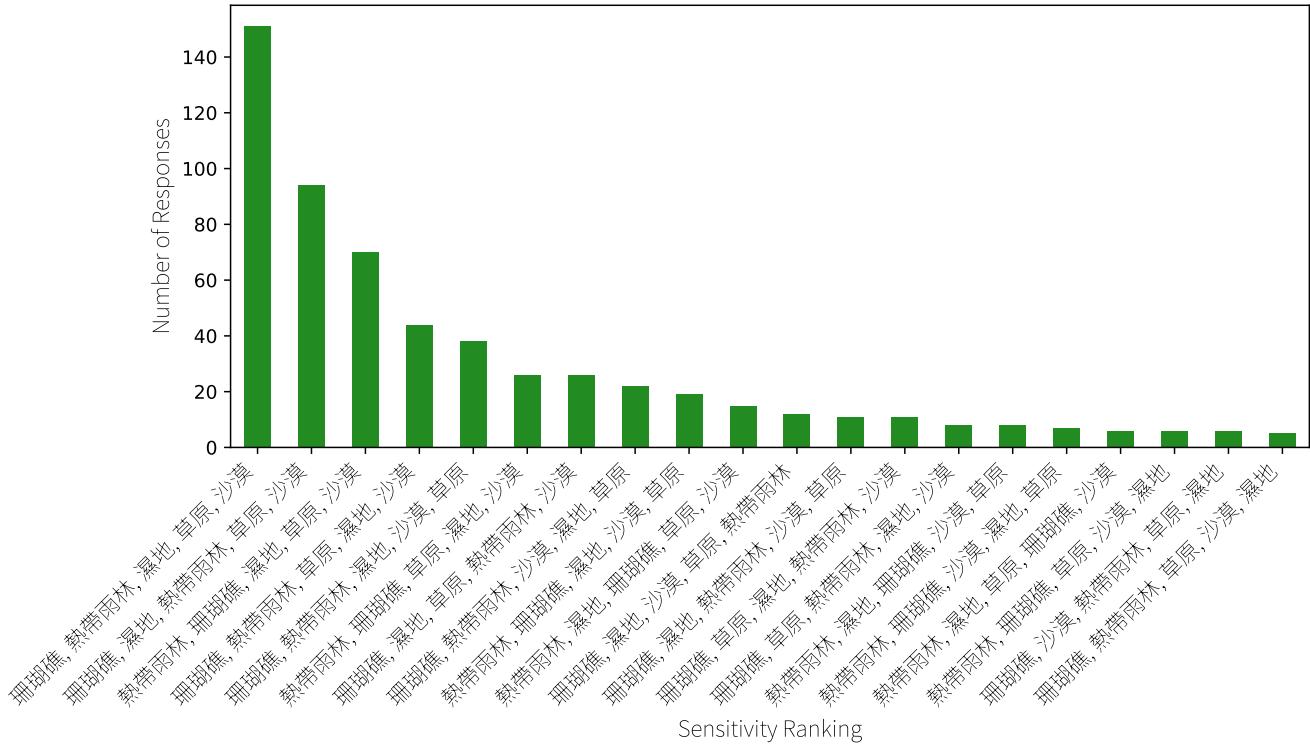
Correlation Network



12.10 Environmental Knowledge Ranking Experiment

Test knowledge about the environment.

Ecosystem Sensitivity to Environmental Degradation

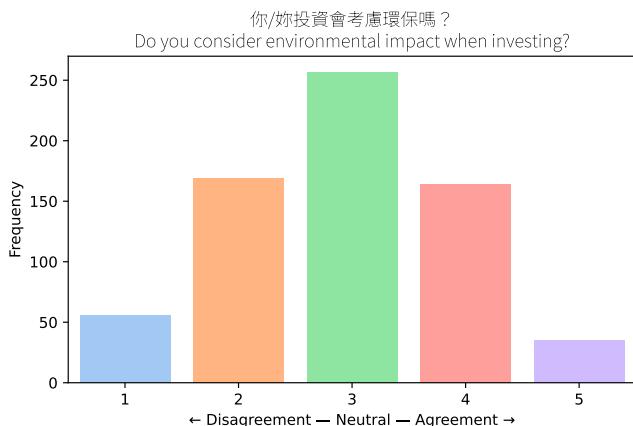
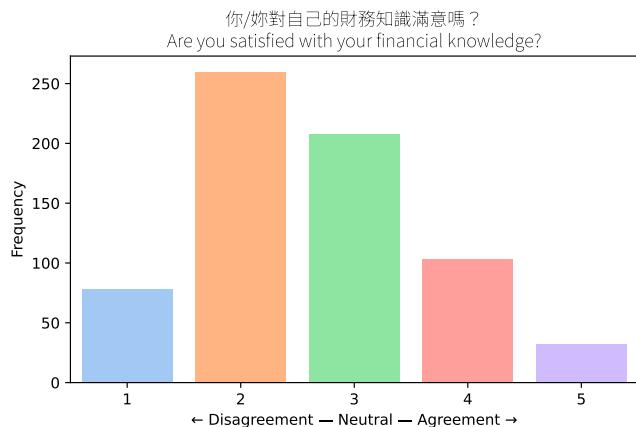
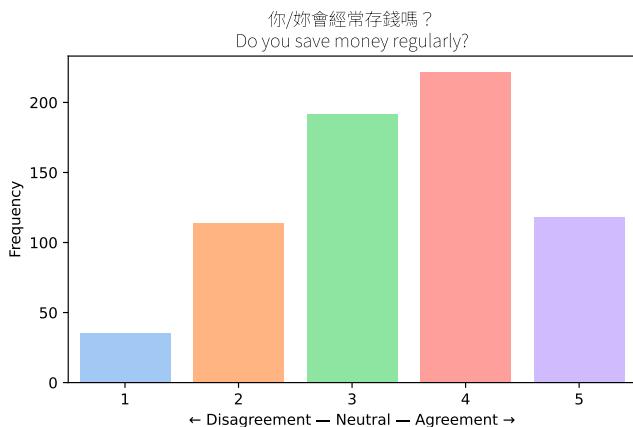
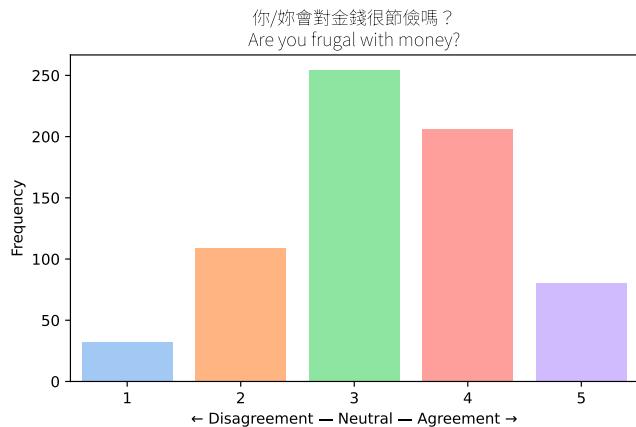
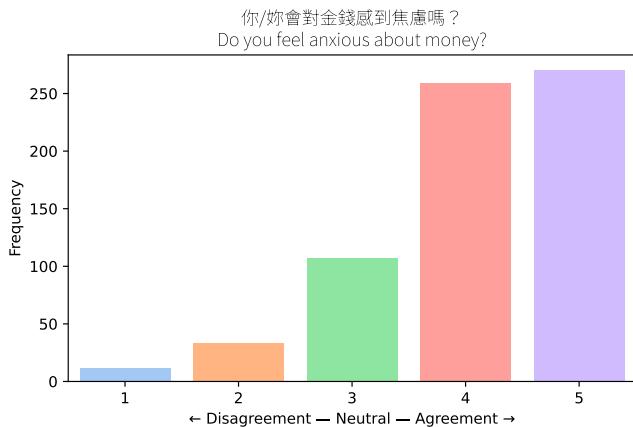


Design implications: majority don't plan to buy a house or car within 7 years, don't focus on these categories. Majority don't fly much, don't focus on flights.

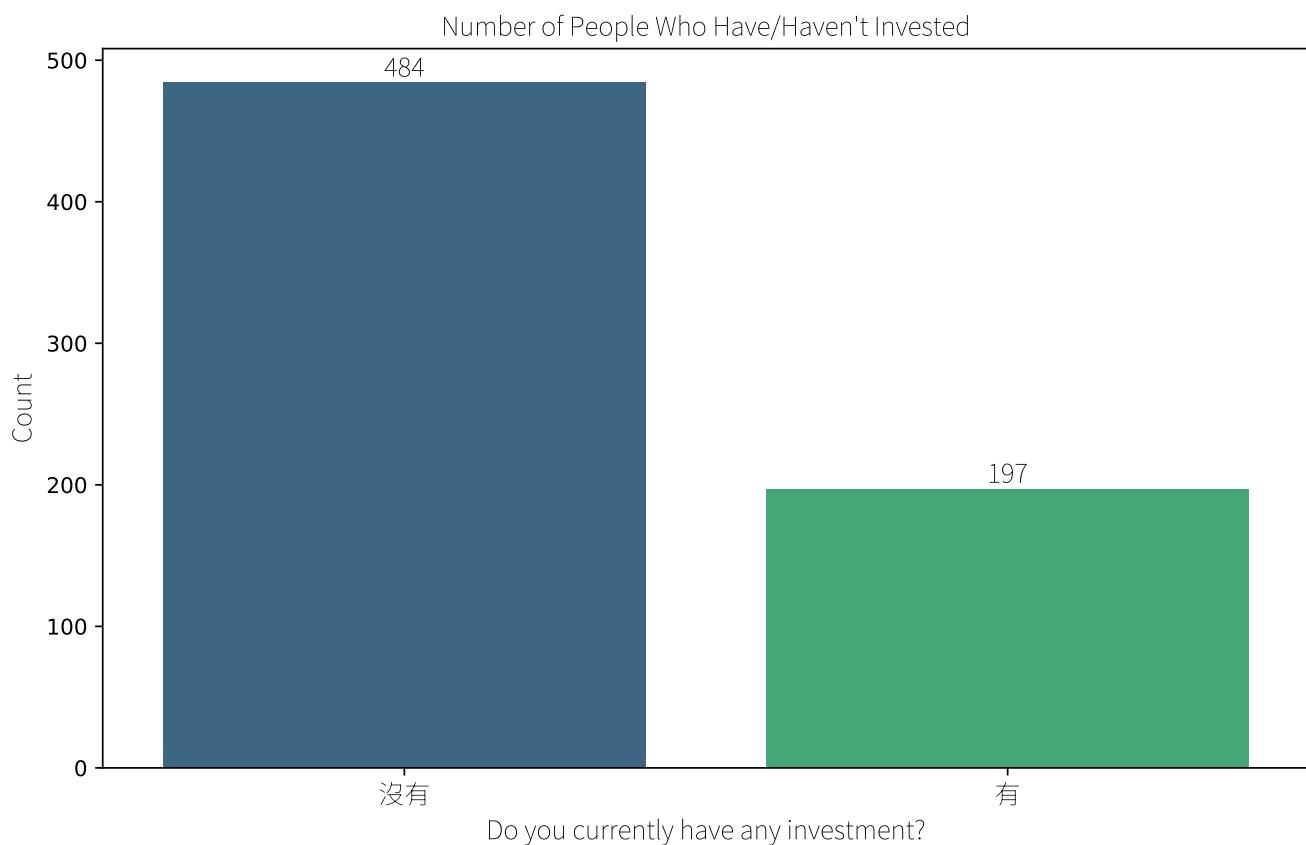
12.11 Investing

Student attitudes towards investing.

12.11.1 Saving and Investing



12.11.2 Investing Experience (Overall)



12.12 Choice Experiment

Question: 你/妳選哪個投資? Which investment do you choose?



12.13 Personas

12.13.1 Clustering Students to Build Personas

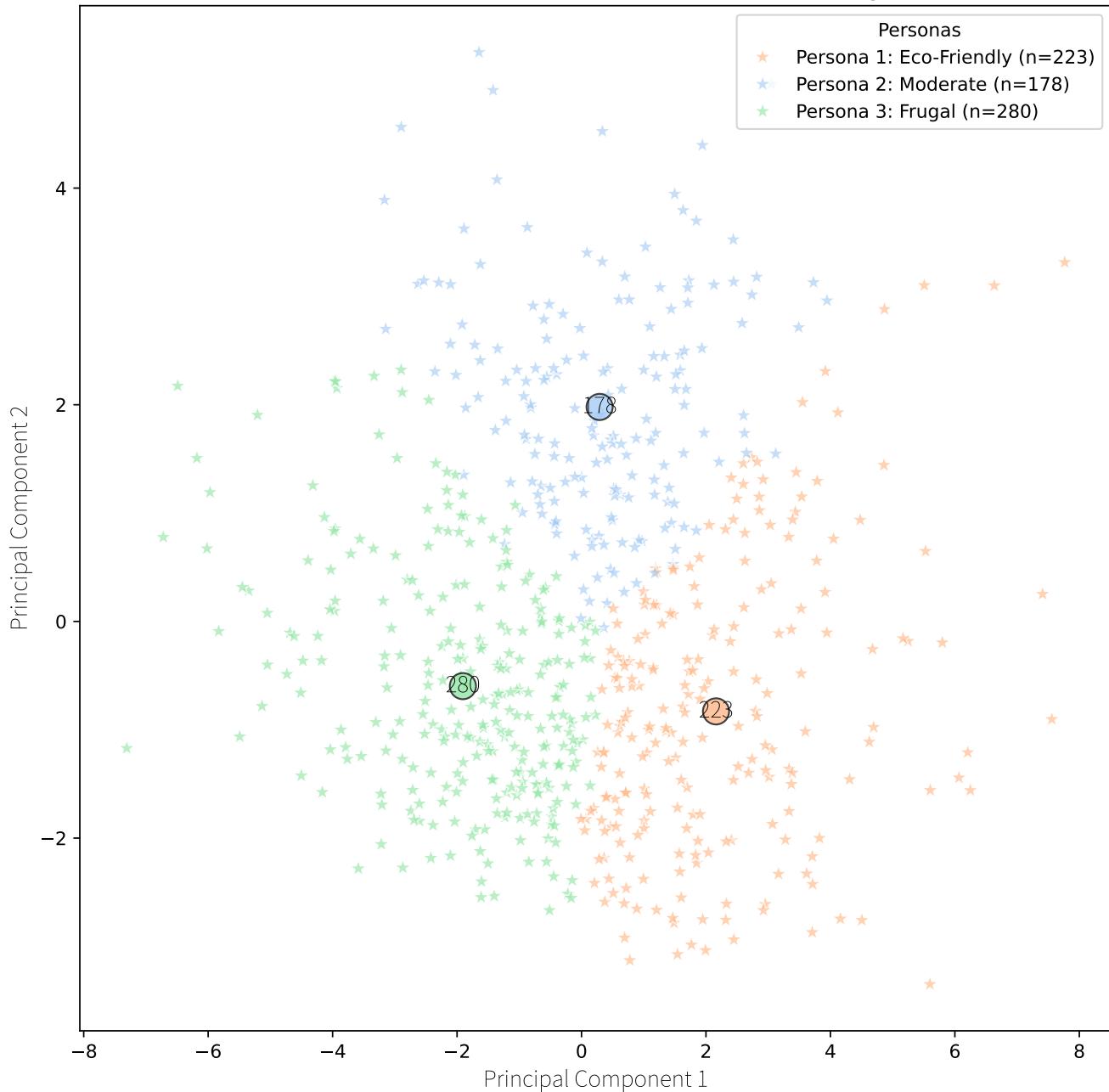
Customer segmentation

Personas are created using K-means clustering, an unsupervised machine learning algorithm, which clusters college students based on their responses across 36 Likert-scale fields in the online survey. Clusters are visualized using Principal Component Analysis (PCA), where the principal component loadings on the X and Y axes represent the weights of the original Likert-scale fields, transformed into the principal components that capture the most variance.

K-prototypes combines K-mean and K-modes unsupervised machine learning algorithms.

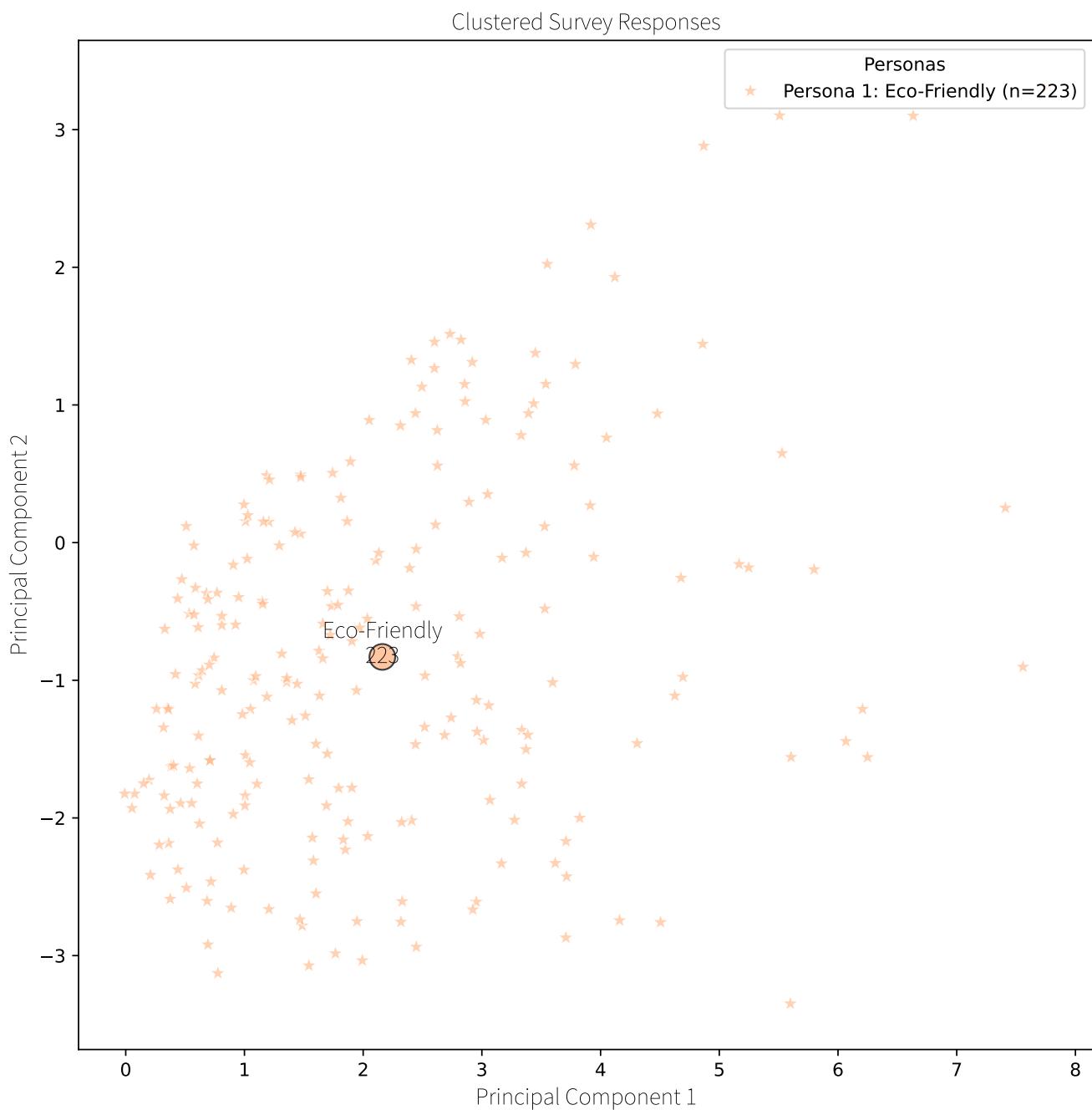
- There is some similarity between clusters. All 3 personas report a high level of financial anxiety and below-average satisfaction with their financial literacy.
- Principal Component Analysis (PCA) is used to convert data to lower dimension space. This is a predecessor of embeddings.

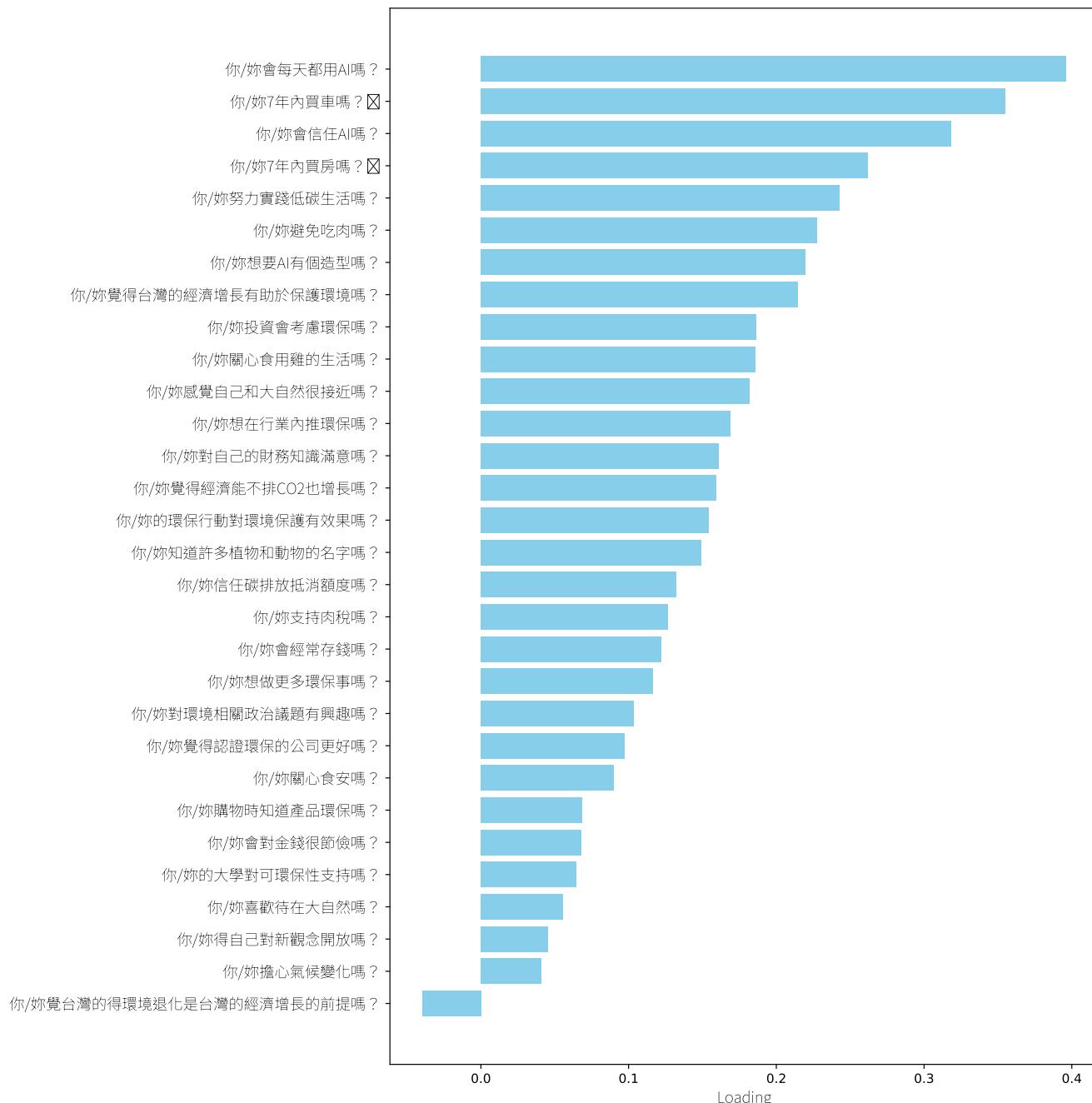
Distinct Respondent Profiles Based on K-means Clustering



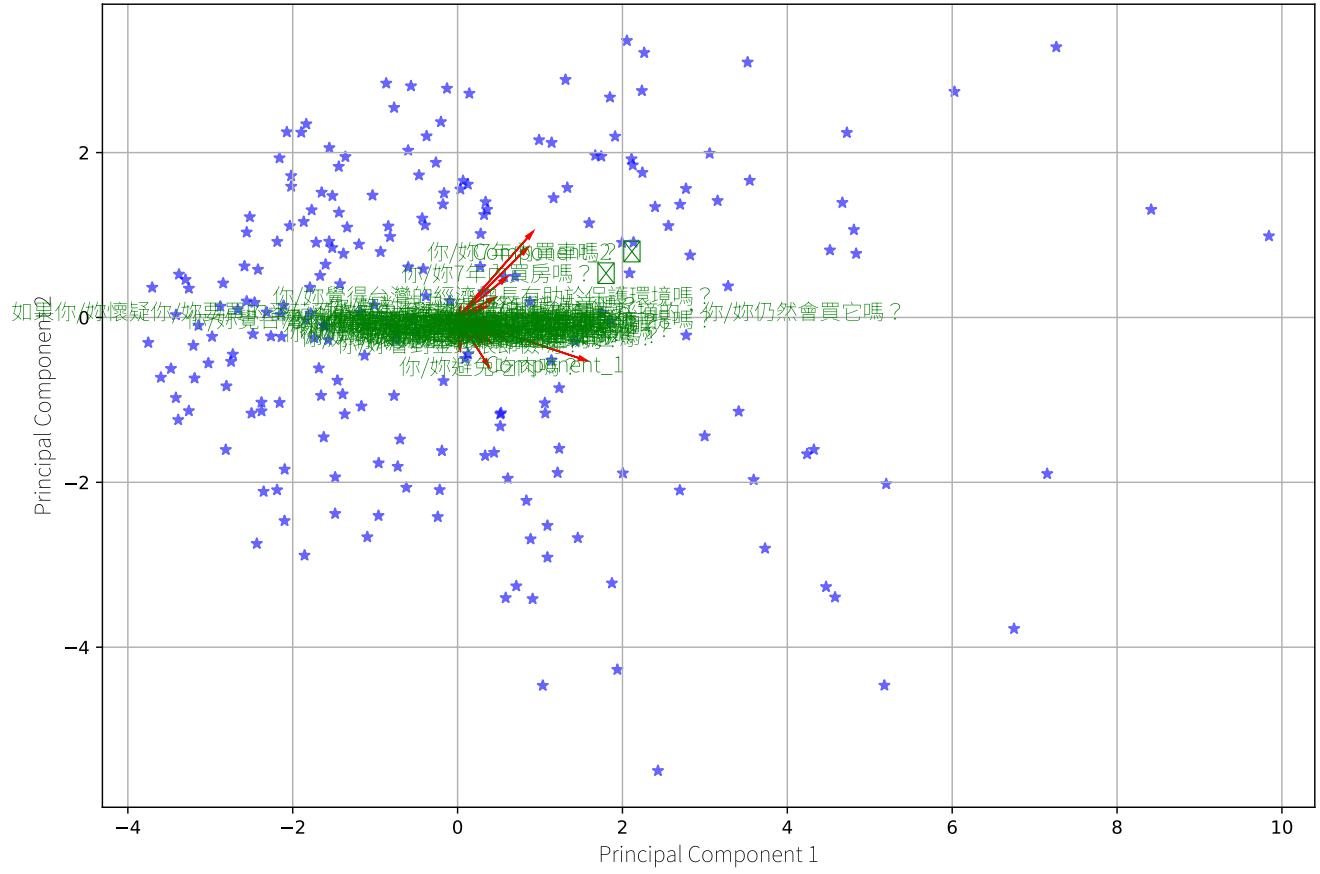
12.13.2 Persona 1: “Eco-Friendly”

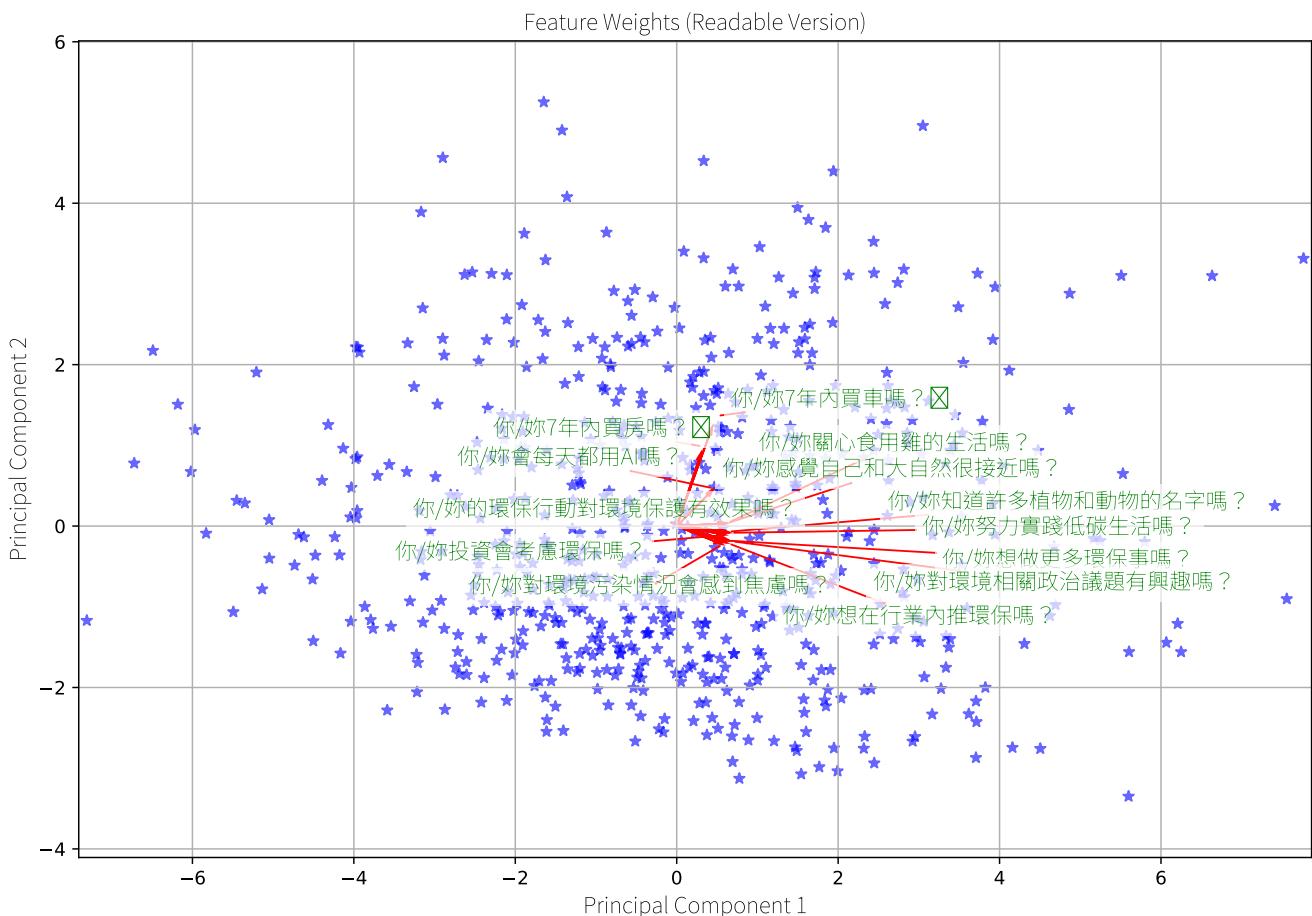
Questions Most Affecting Persona Creation include...





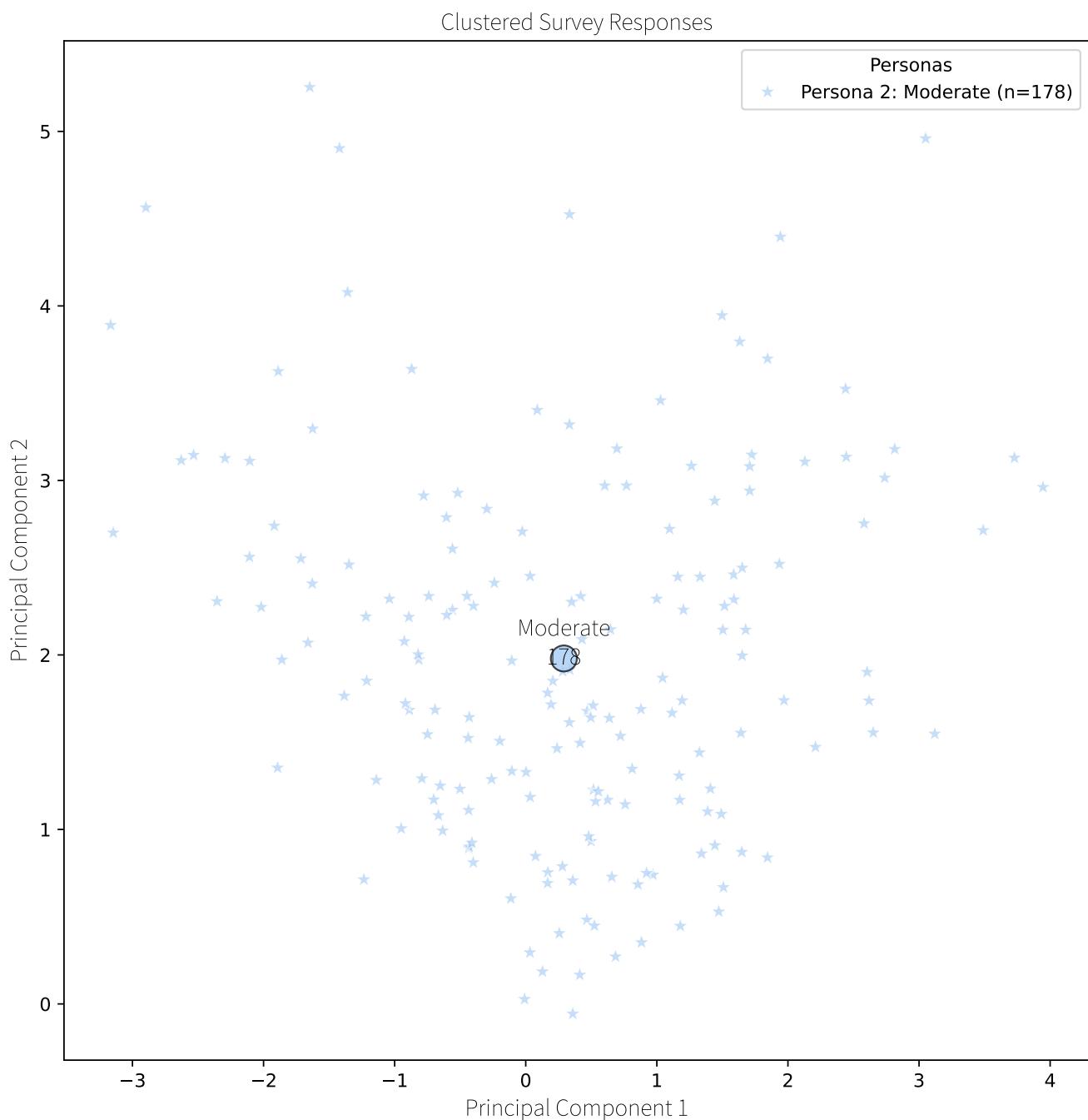
Feature Weights (Survey Questions)

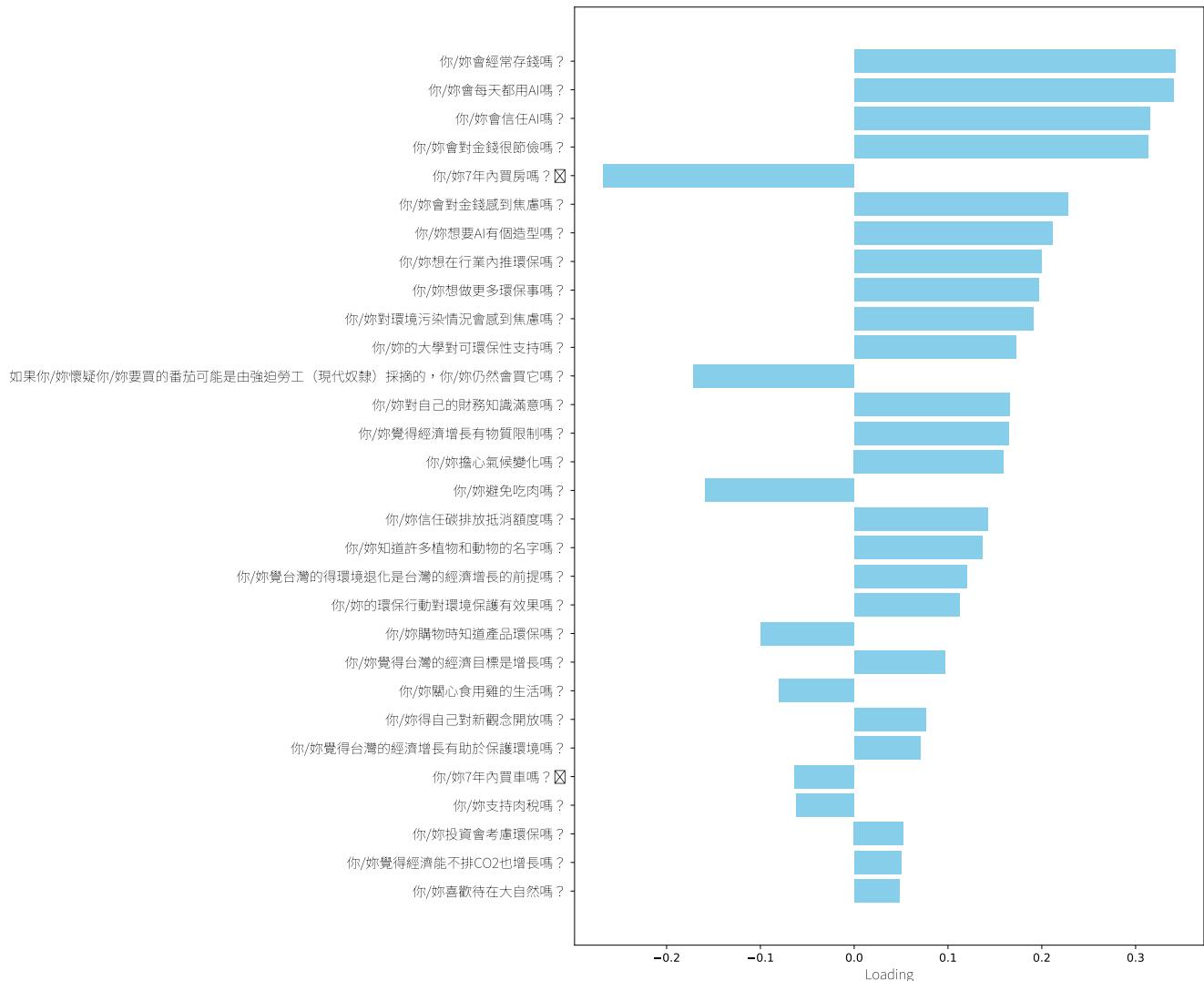


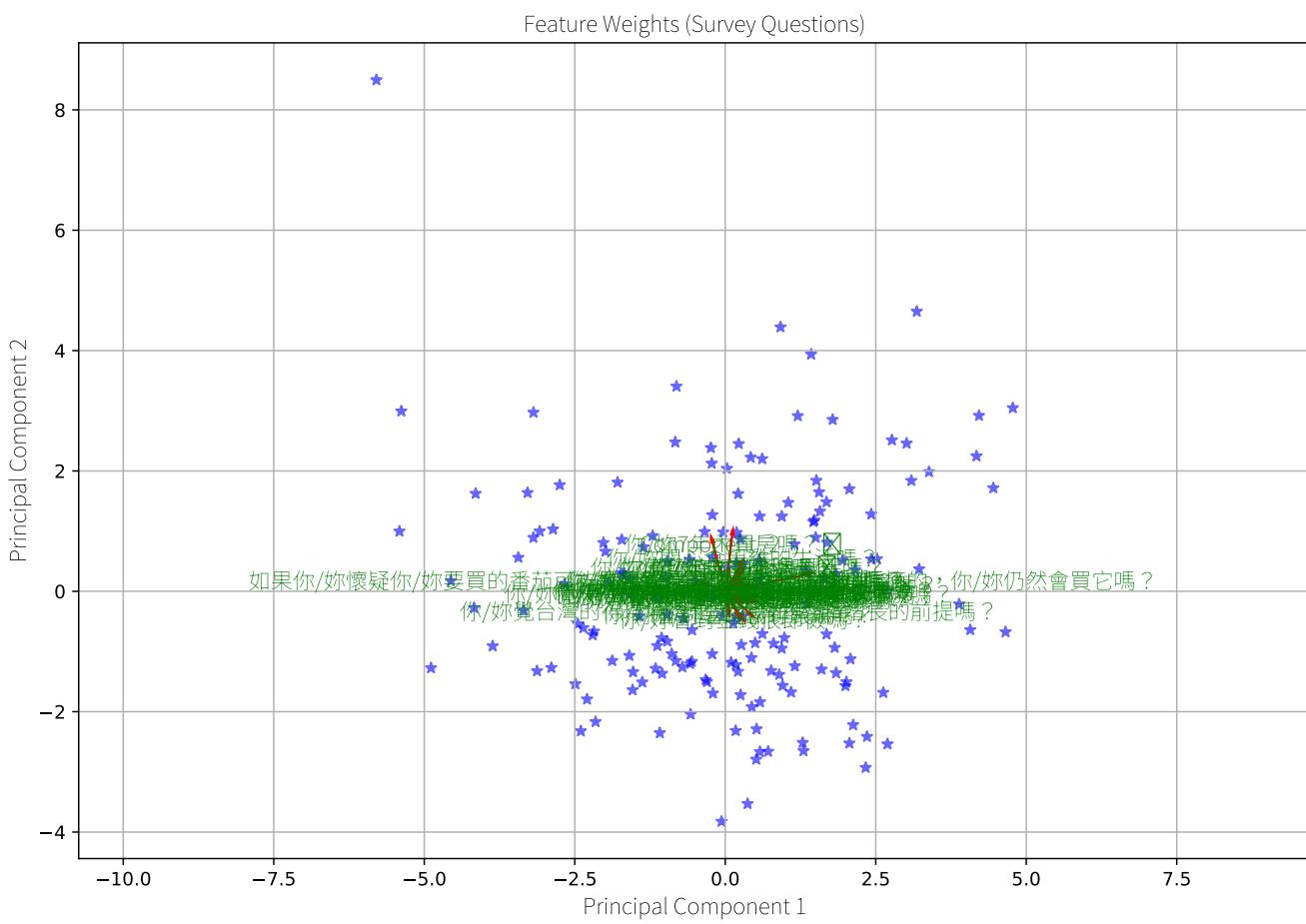


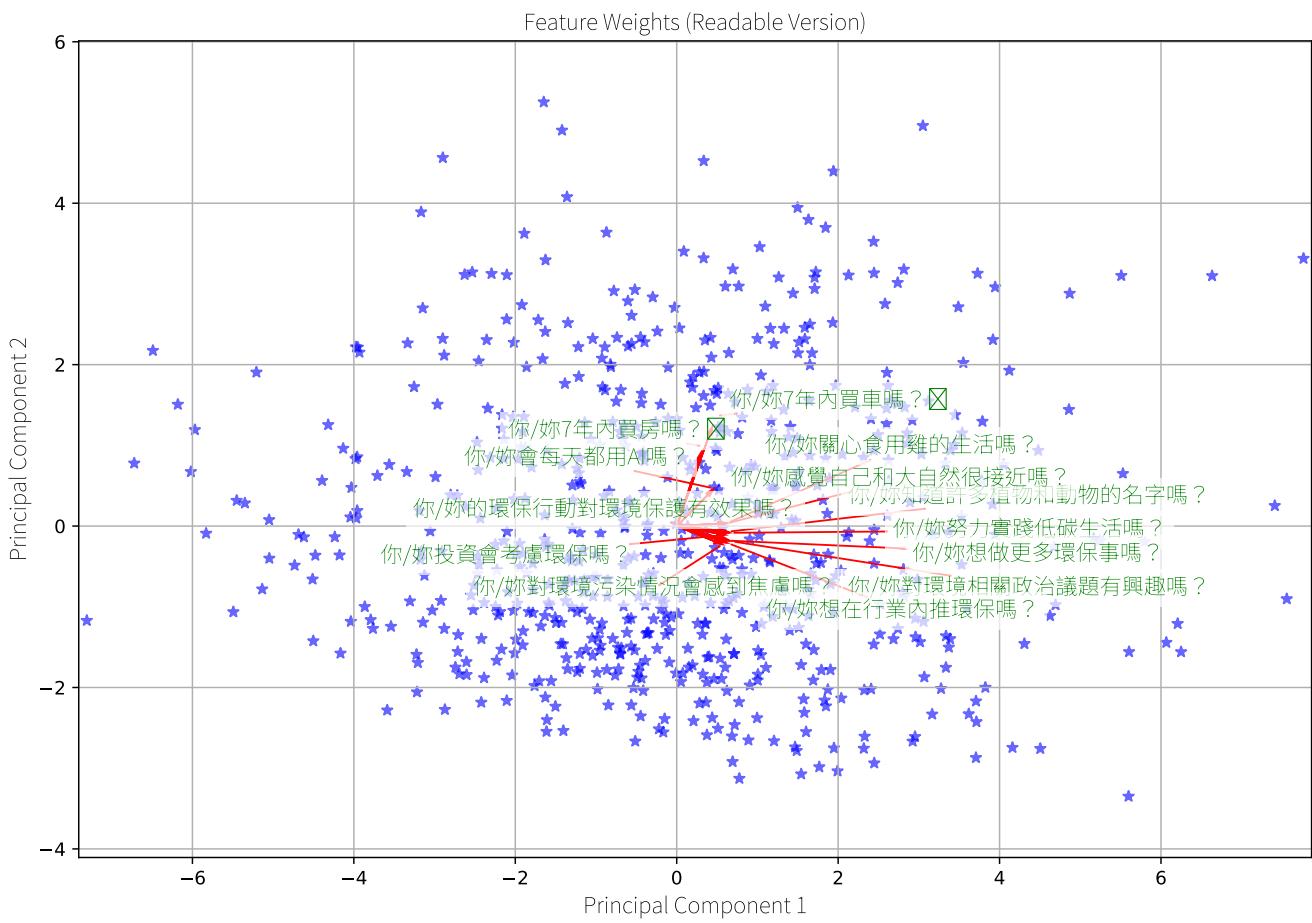
12.13.3 Persona 2: “Moderate”

Questions Most Affecting Persona Creation include...





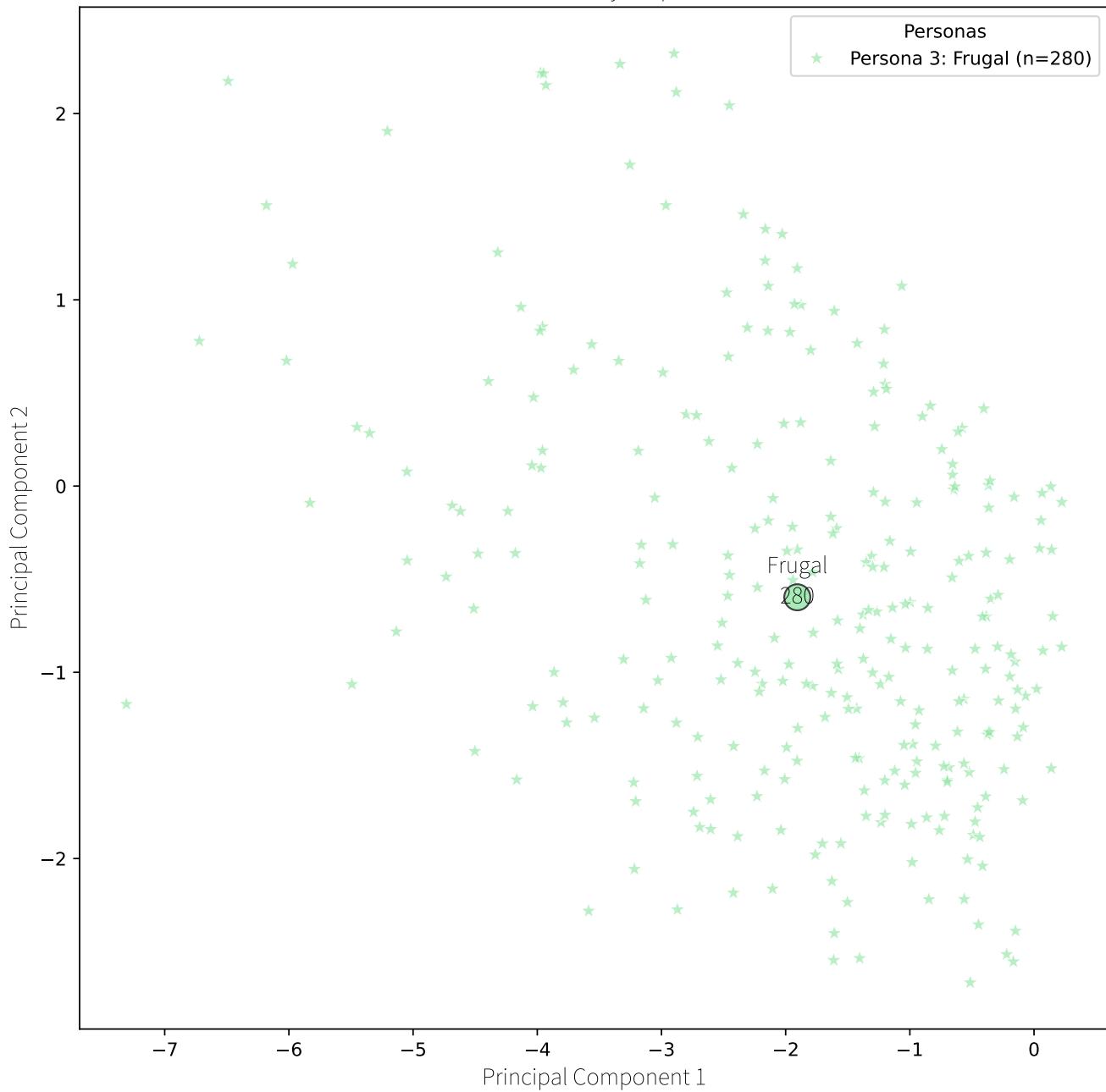


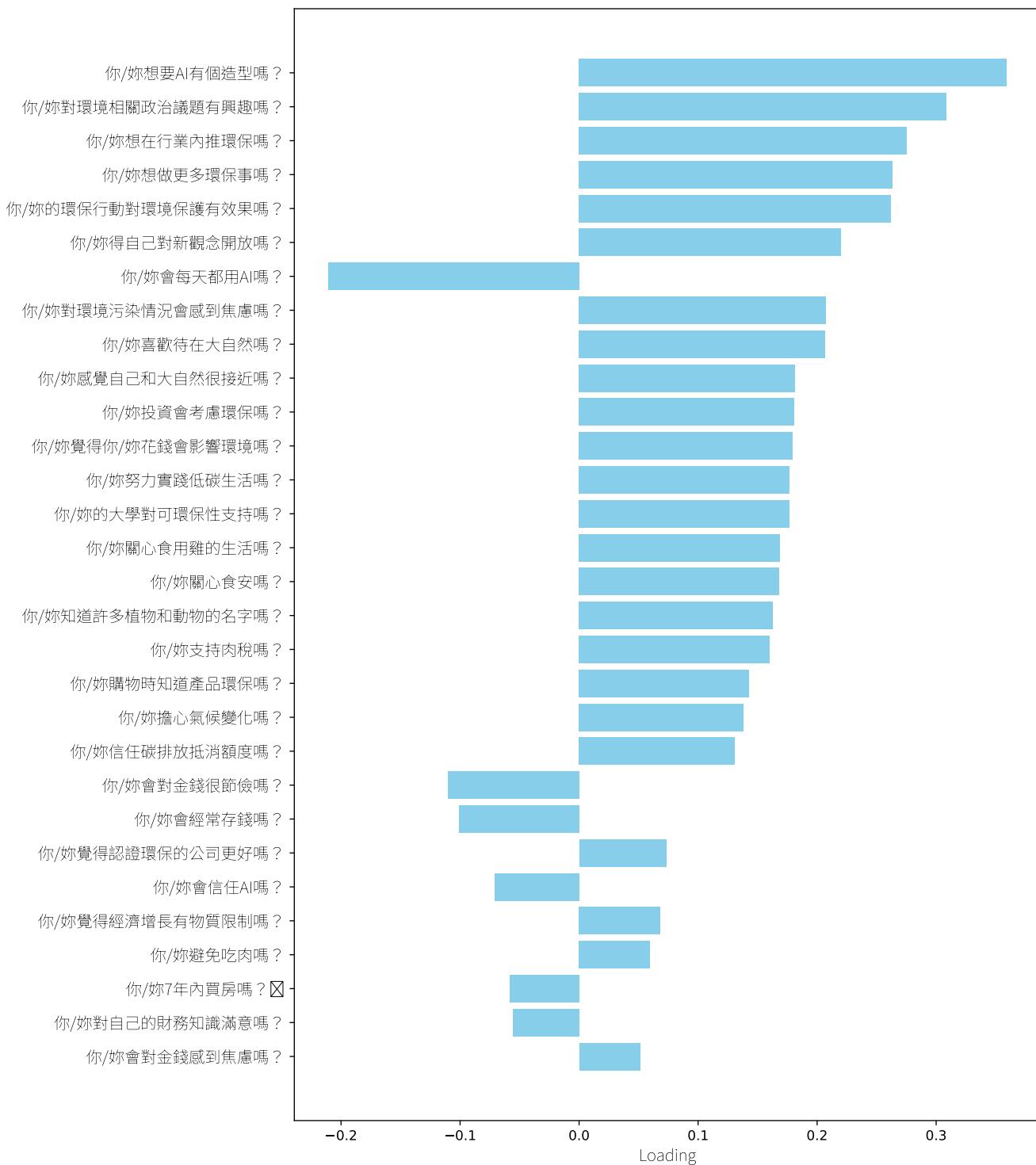


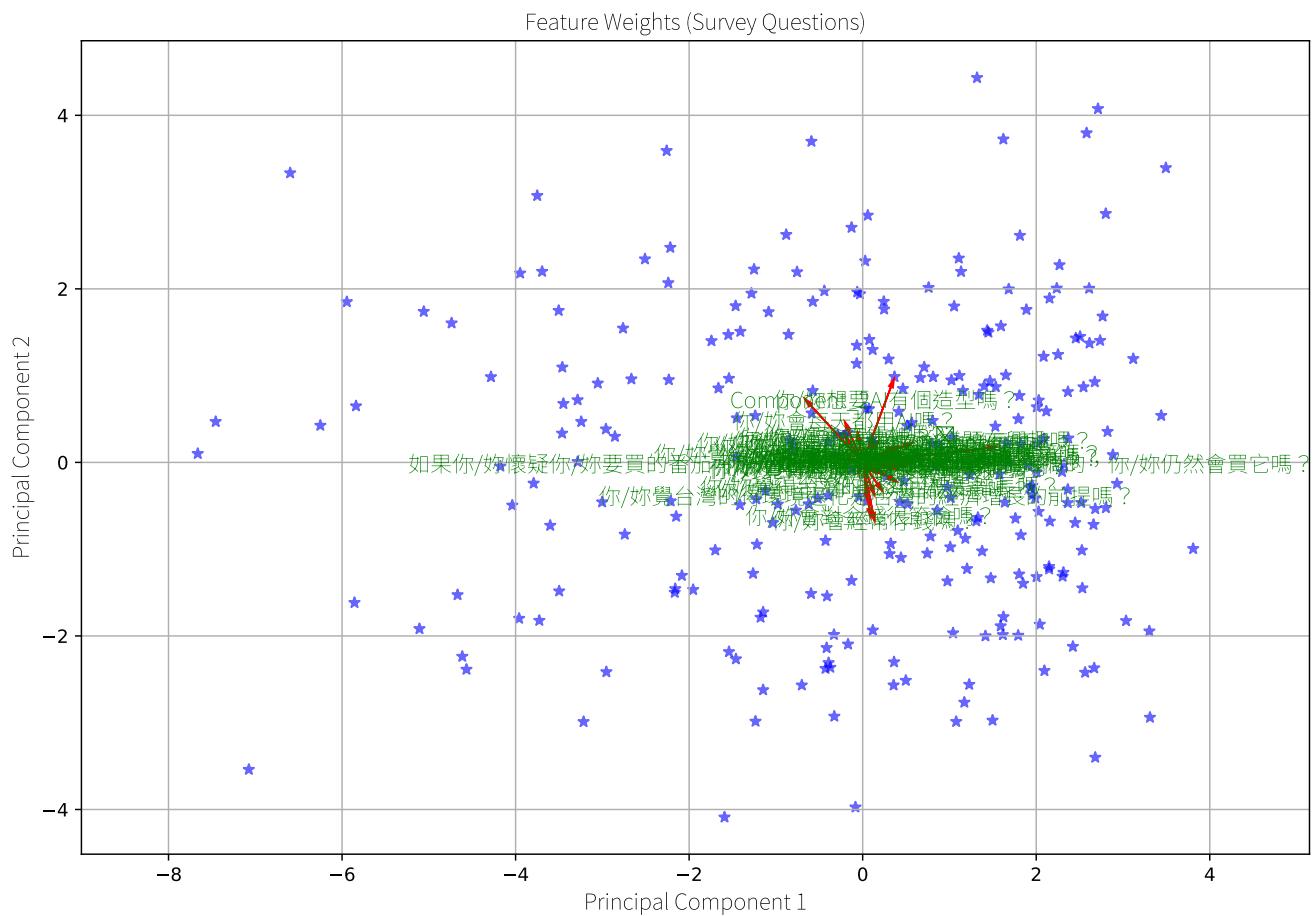
12.13.4 Persona 3: “Frugal”

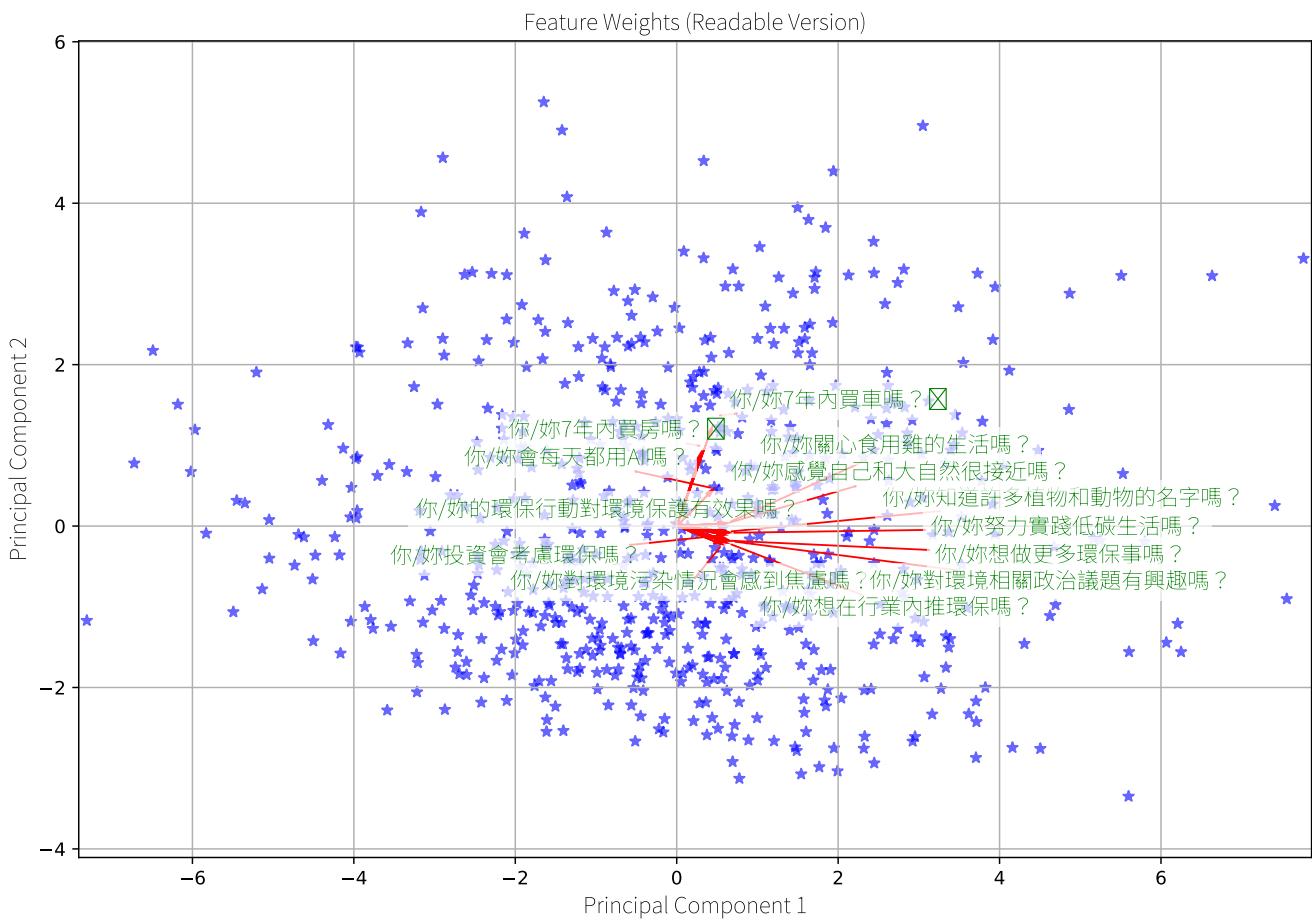
Questions Most Affecting Persona Creation include...

Clustered Survey Responses

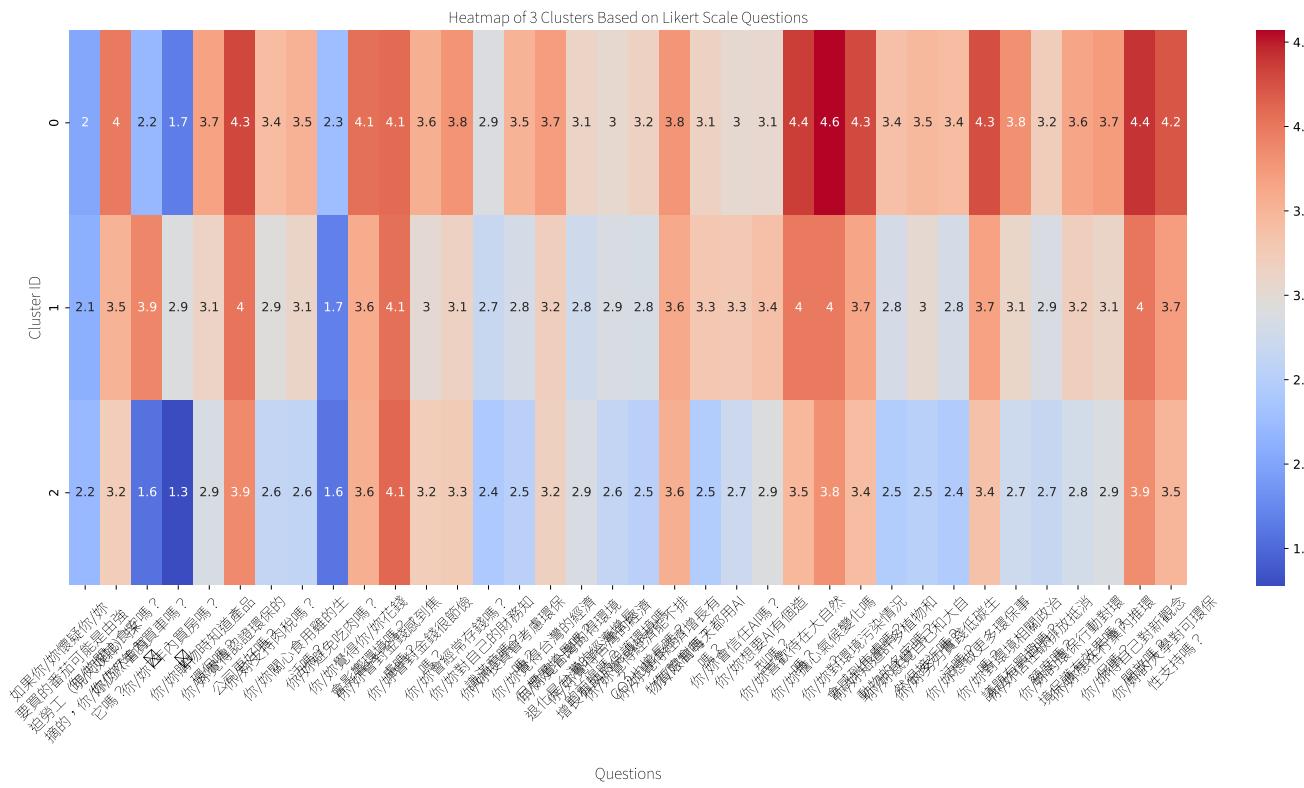








12.14 Clustering Heatmap



12.15 Mean Answer Scores

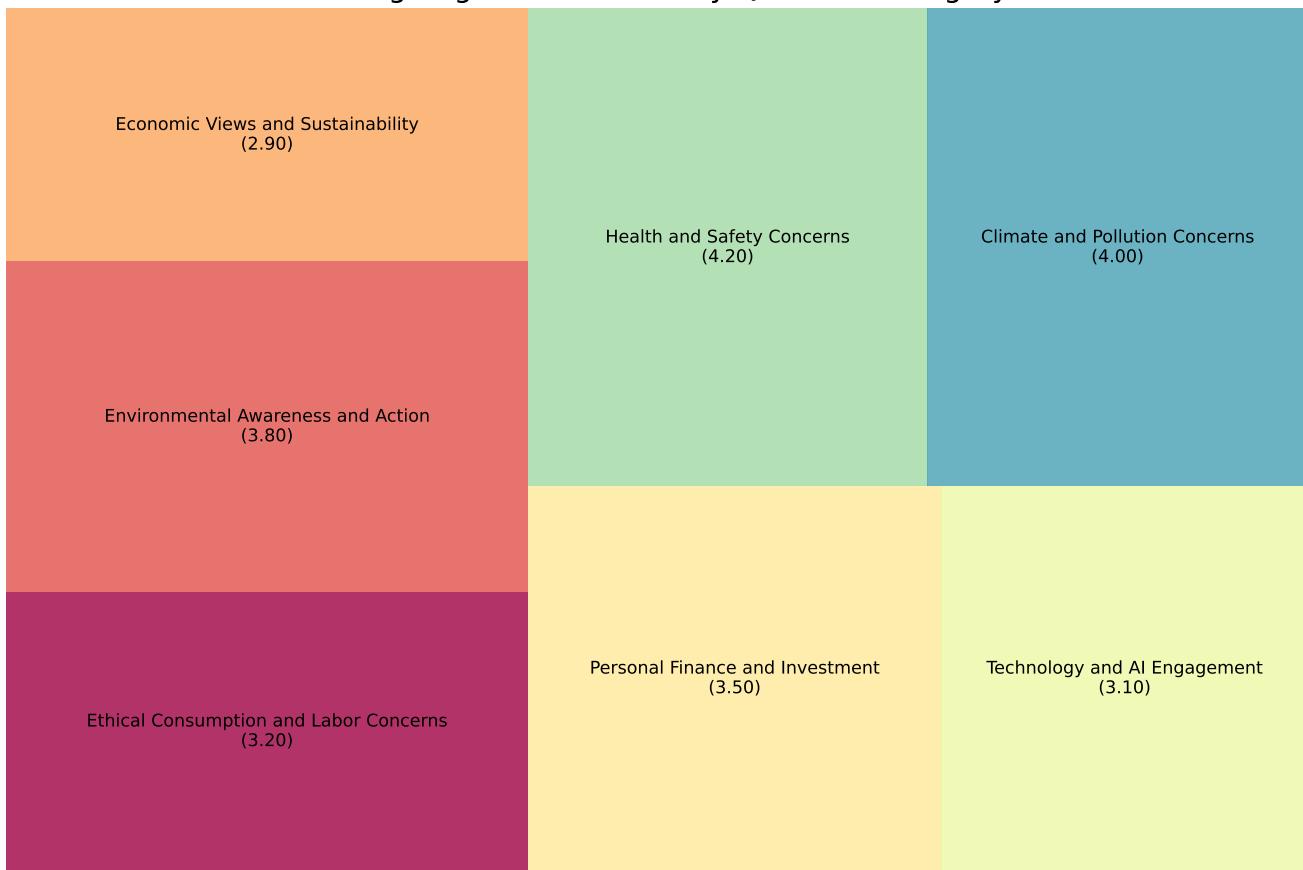
Mean response values for each Likert question in each cluster:

Cluster	如果你/妳懷疑你/妳要買的番茄可能是由強迫勞工（現代奴隸）採摘的，你/妳仍然會買它嗎？	你/妳關心
0	0	2.026906
1	1	2.106742
2	2	2.214286

12.16 Agreement between personas

Highest agreement between personas is about health, safety, pollution and climate concerns.

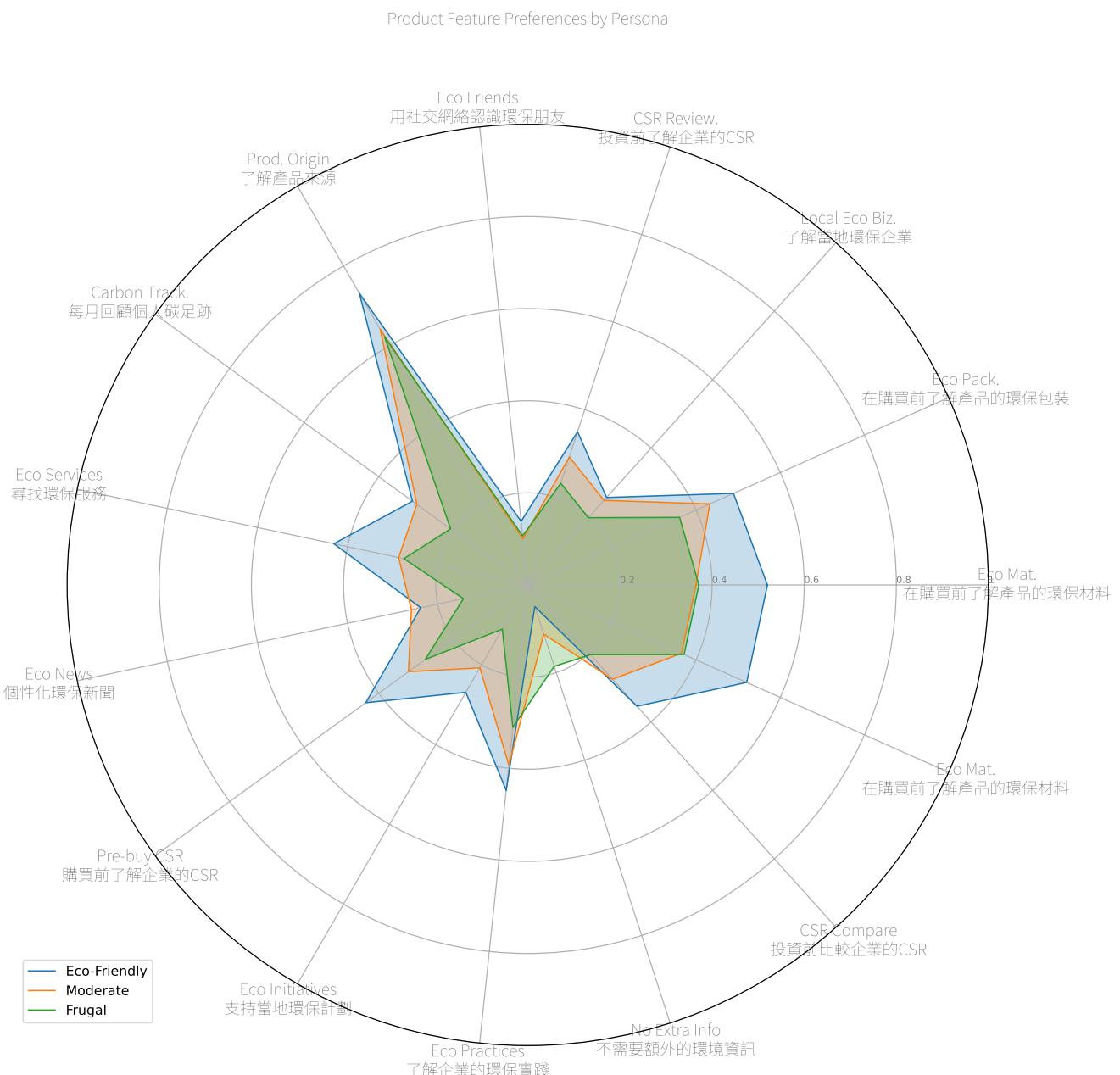
Average Agreement Level by Question Category



12.17 AI Companion

12.17.1 Likert-Based Clustering

AI-assistant feature choices per Likert-based Personas



Want: - Product origin - Product materials - Product packaging

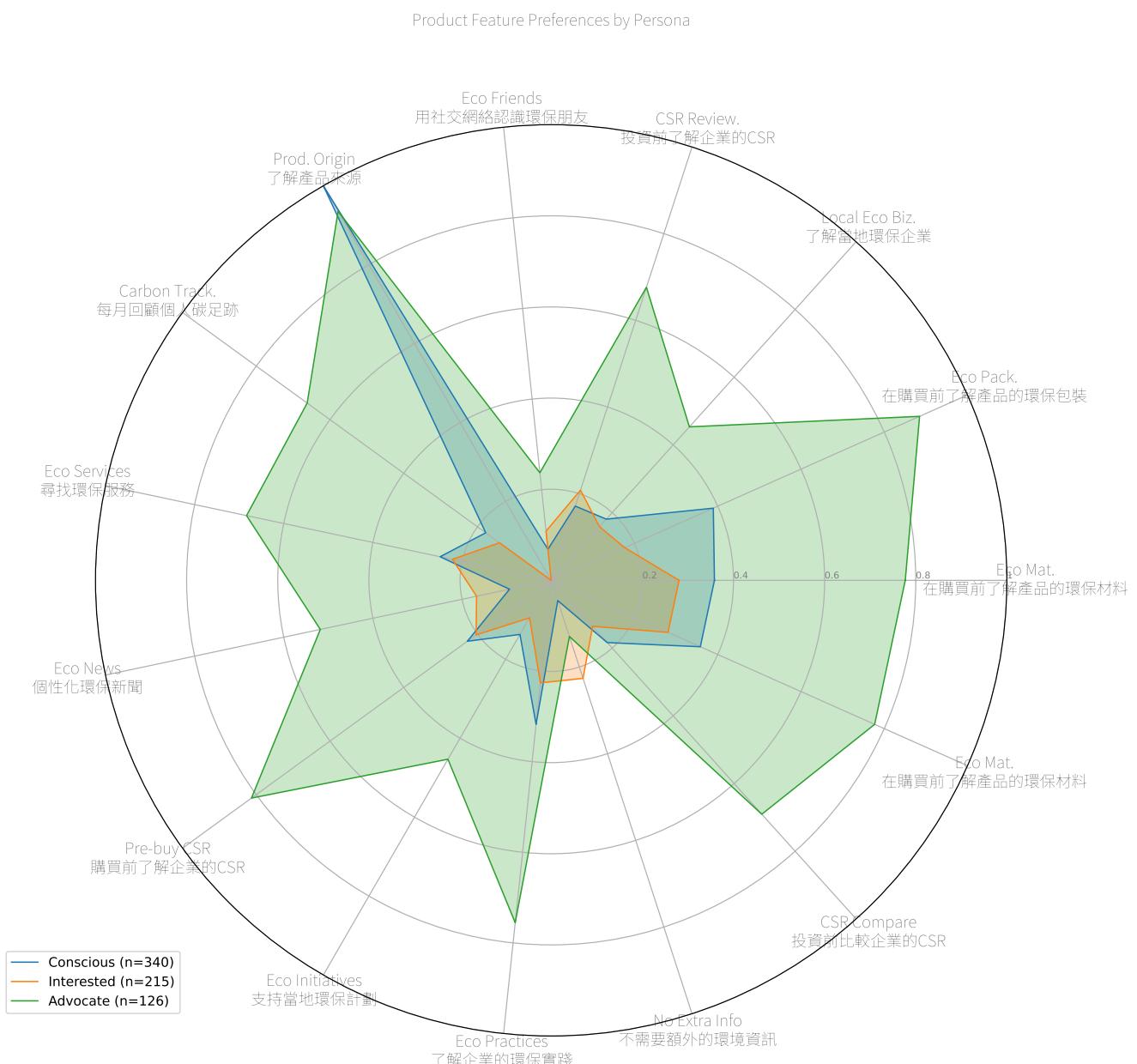
Don't Want: - News - Carbon tracking - Eco-friends - ...

12.18 Feature-Based Clustering

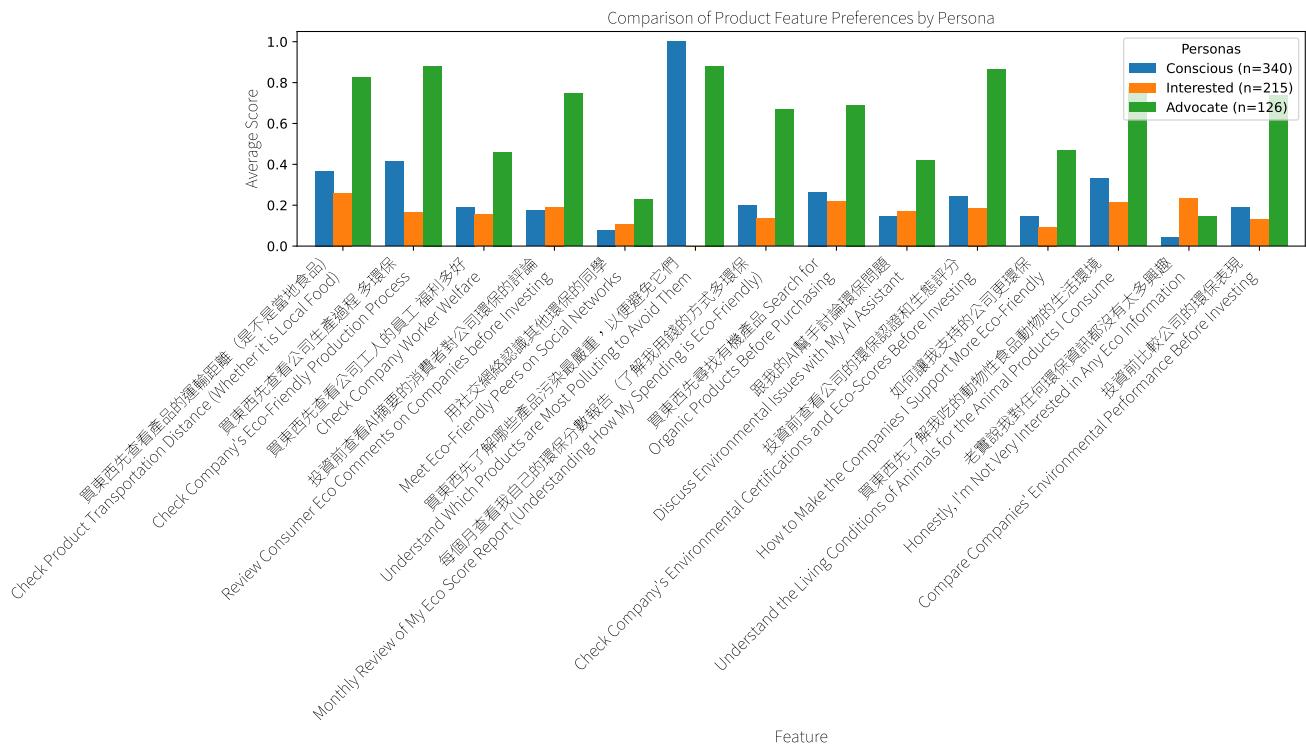
Clustering students based on AI-assistant feature choices.

Want: - Product origin - Product materials - Product packaging - Eco services

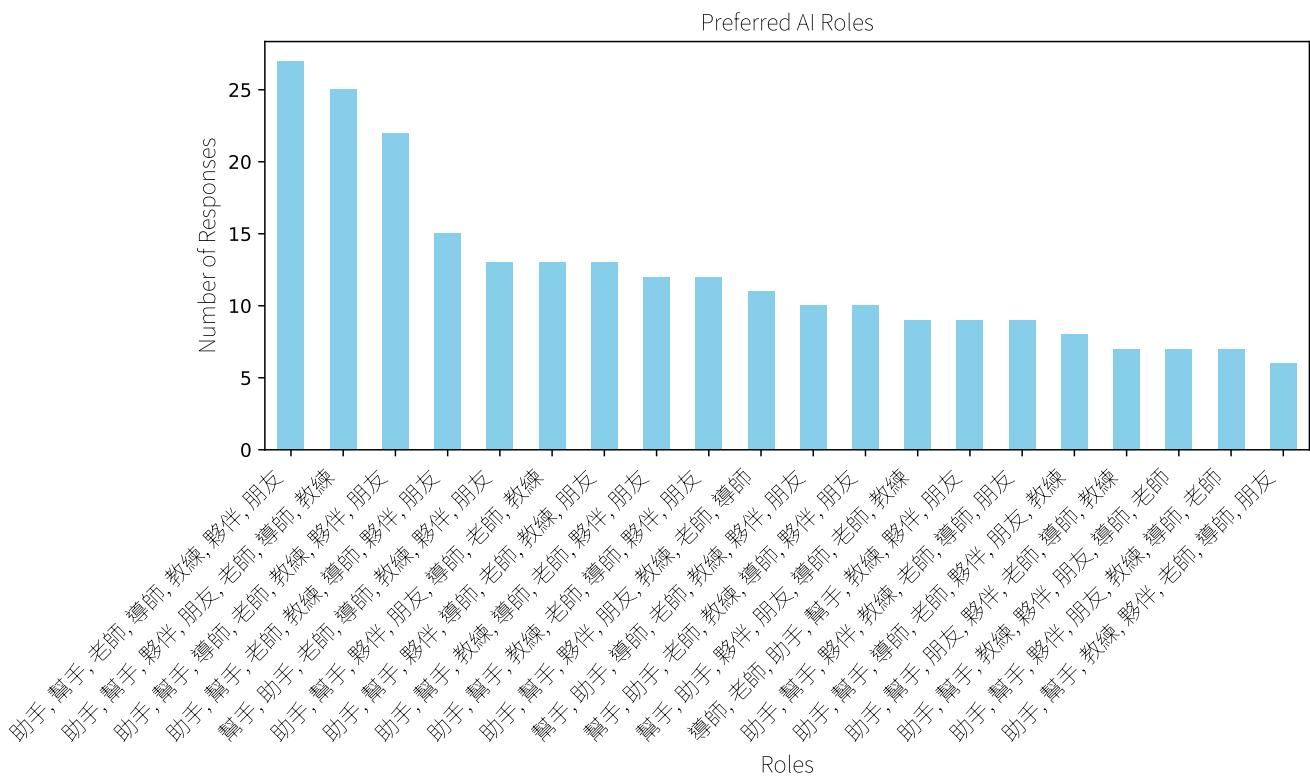
12.18.1 Feature Preferences (Overall)



12.19 Feature Preferences (By Cluster)



12.20 Preferred AI Roles (Overall)



12.21 Experts

Analysis of recorded conversation from 5 experts. Thematic content analysis using ATLAS.ti for labeling/coding the data for grounded theory. Conversations were recorded and transcribed using Google Meet and Fireflies AI. Labeling and thematic analysis was performed using Atlas.ti. Visualisations were produced using Atlas.ti and Python.

12.22 Interview 1: Designer - Cathy Wang

Date: 2023-11-10 Expert: Cathy Wang is a designer and business leader with 20 years of experience in bringing hypergrowth and hundreds of millions of EUR in revenue in digital transformation of industry.
Country: Taiwan / Canada Topics: Design, Business

Thematic Analysis.

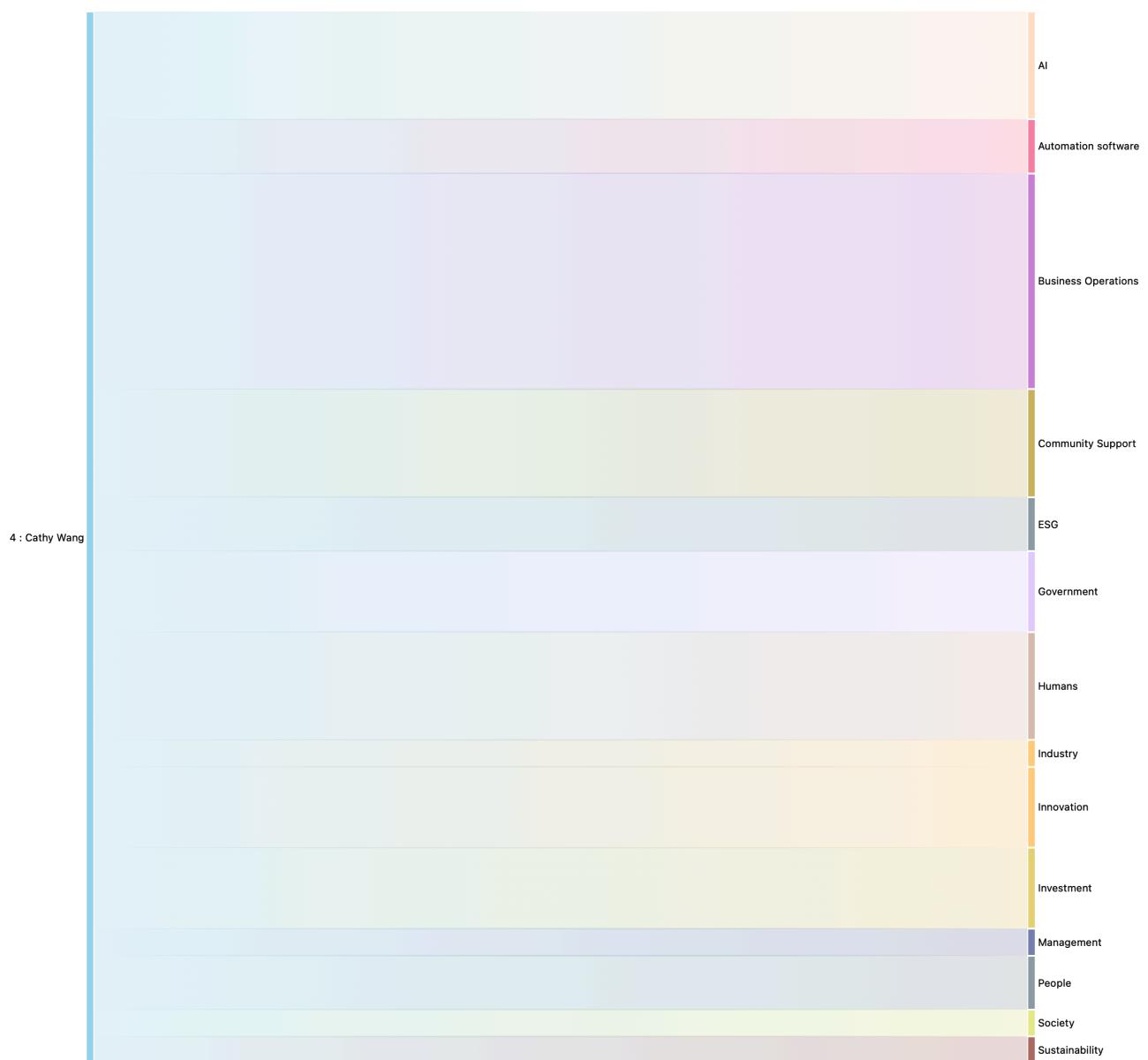


Figure 26: Cathy Wang

12.23 Interview 2: Accountant - Peijing Li

Date: 2023-11-18 Expert: Peijing Li is an accomplished financial controller and accountant with experience in varied industries from dairy to education. Country: New Zealand Topics: Economics

Thematic Analysis.

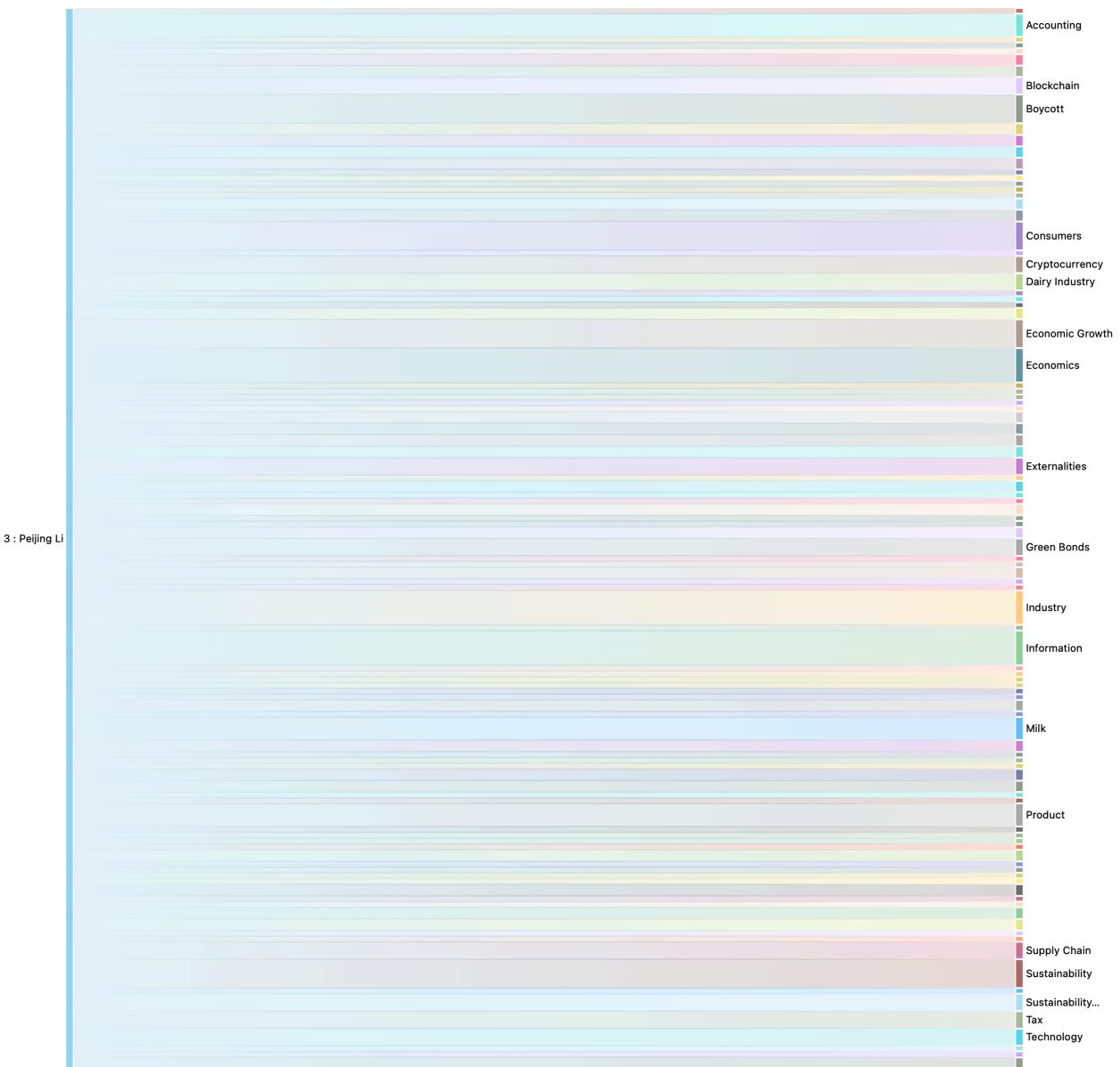


Figure 27: Peijing Li

12.24 Interview 3: Designer - Jessica Cheng

Date: 2023-12-04 Expert: Jessica Cheng is a designer with cross-industry experience from the UK and Taiwan. Country: Taiwan Topics: Design, Business

Thematic Analysis.

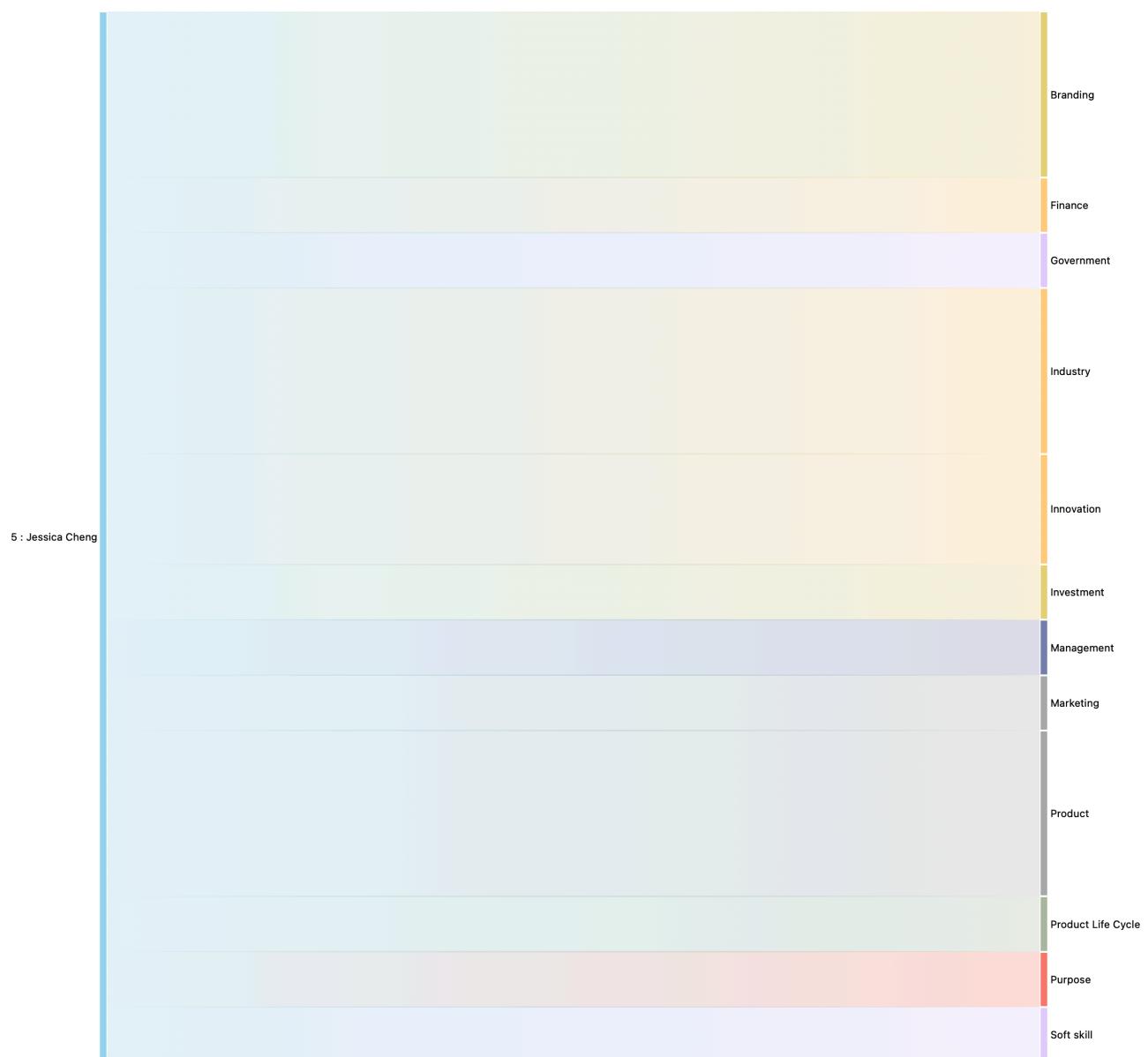


Figure 28: Jessica Cheng

12.25 Interview 4: Economist - Chen-Ying Huang

Date: 2024-05-19 Expert: Chen-Ying Huang is an economist and professor at National Taiwan University.
Country: Taiwan Topics: Economics

Thematic Analysis.

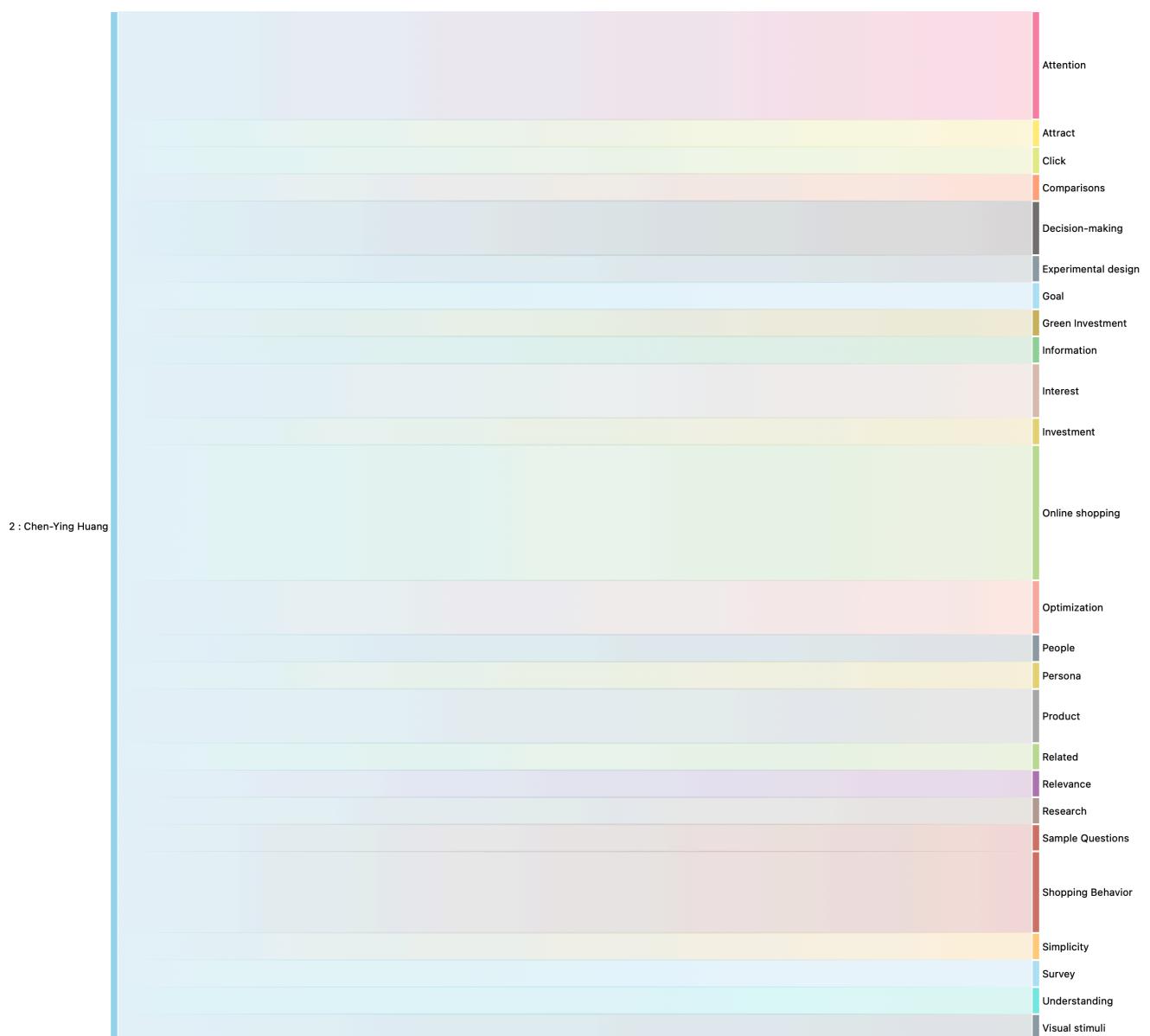


Figure 29: Chen-Ying Huang

12.26 Interview 5: Economist - Yuping Chen

Date: 2024-06-04 Expert: Yuping Chen is an economist and professor at National Taiwan University with a focus on marketing and online shopping. Country: Taiwan Topics: Economics, Online Shopping

Key learnings: “I think you are targeting experts instead of a general consumers”

Thematic Analysis.

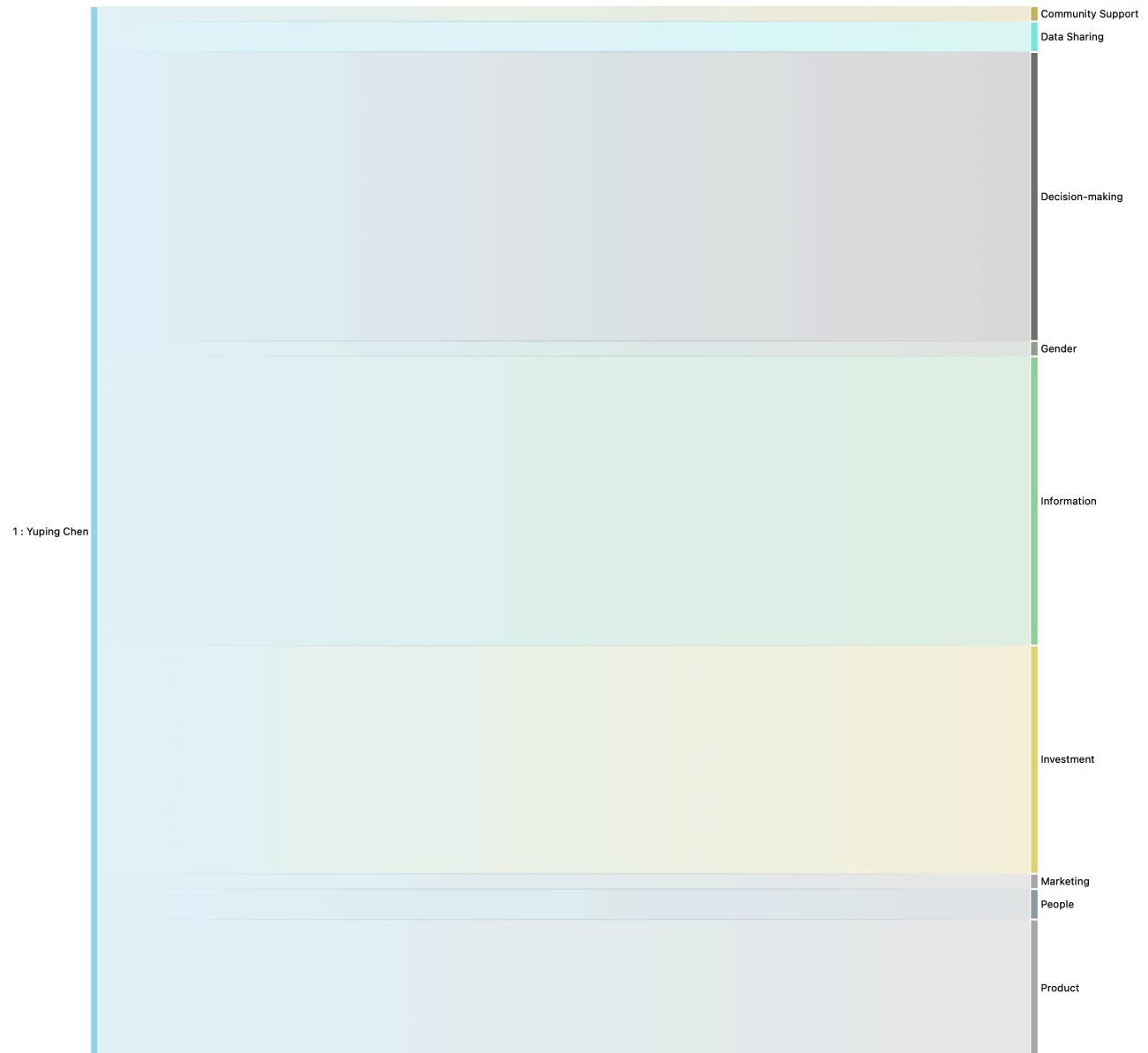


Figure 30: Yuping Chen

12.27 Overall

Common topics between all conversations become visible in the overall Sankey Diagram.

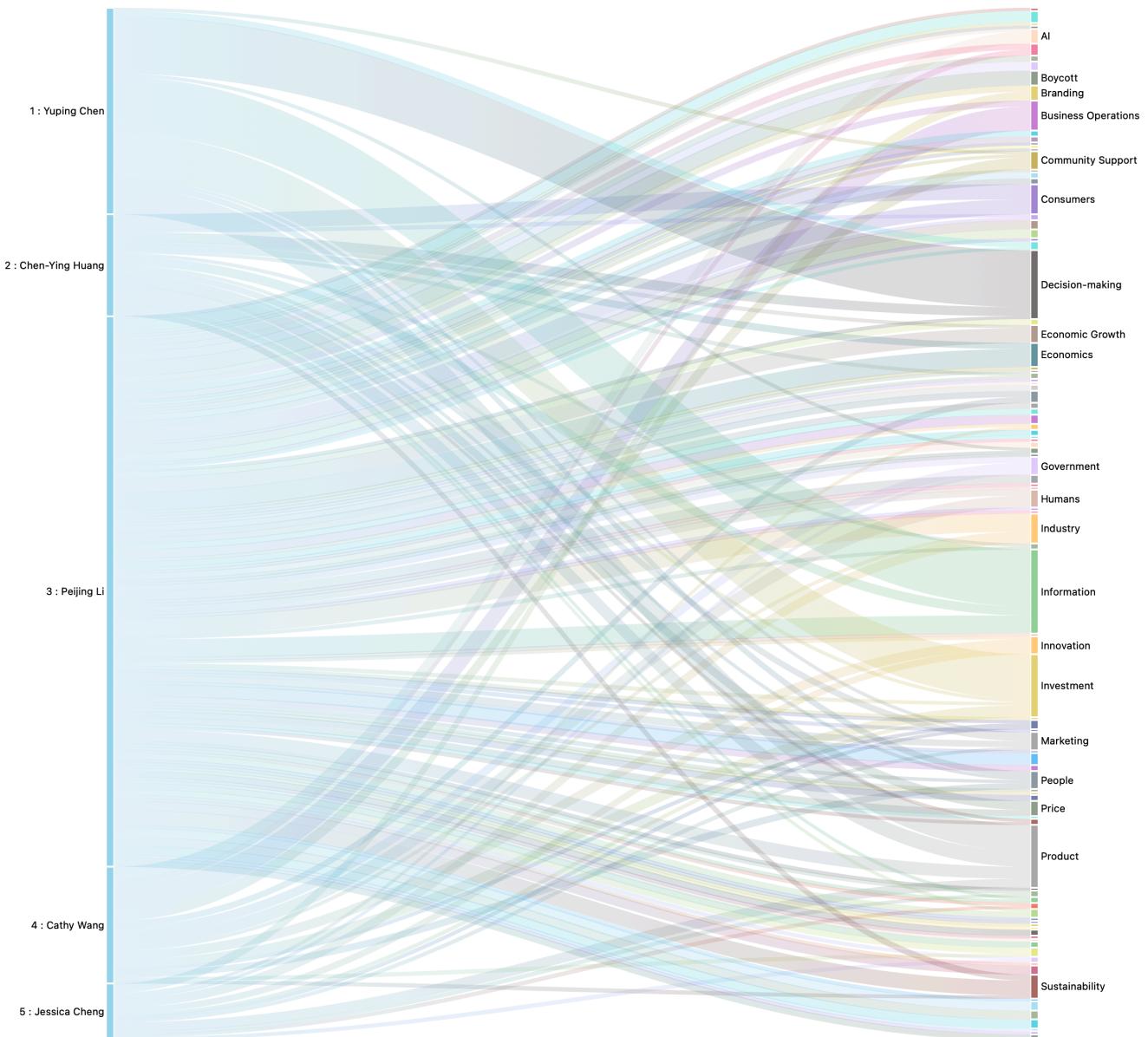


Figure 31: All

12.28 Ideas for Interfaces / Scenarios

Show all the different prototypes just like architects do. And then defend why I chose the one I did. For NW make a Loom with the interfaces and talk about them?

12.29 Prototypes of Product Features

I developed a number of early prototypes to visualize product feature ideas.

What's on the intersection of College Students, Sustainability, Investing, Data-Driven Design and Artificial Intelligence (AI)? AI-Driven Sustainable Investment Tools.

The app aims to address the market failure by providing consumers sufficient sustainability information on the goods, services and investments.

resource depletion

and adopt the doughnut economy as my overarching theoretical framework

Humans are successful because of our adaptability. The study suggests tools to adapt to our current reality.

United Nations Decade on Ecosystem Restoration

Hypothesis: extractive business practices reduce college students trust, regenerative business practices create trust among college students towards the company.

Provided there is awareness

How can sustainability-minded college students find companies that meet their expectations, standards and requirements?

- Make a public profile of my carbon consumption!!! Like on Commons.
- Shop
- Save
- Invest
- Build closer relationships with sustainability-focused companies
- Sales funnel for eco-focused products
- The eco-friendly market is fragmented
- Build trust, clarity, transparency, and honesty
- Make a 'Sustainability Flywheel' graphic, like that of Amazon's
- Sustainability is fragmented. How can billions of people build closer relationships with sustainability-focused companies based on honesty and transparency? A research project for designing a sustainable shopping, savings, and investing companion.
- Most sustainability plans rely on carbon credits to achieve their goals, making carbon credits a single point of failure. If the credits are not accurate, the whole system collapses.

- TODO: Make a table showing research results translated to design decisions
- Your Green Helper
- Make some initial prototype? make YoutTbe video... hi, you have reached? spread... through ESTBan and others?
- Currently CO₂ footprint calculators ask you a couple of questions and give a ballpark estimate. Does it make sense to track sustainability on a more nuanced level, like Apple Health, in order to encourage sustainable behavior?

Product Idea	Source		Prototype Link
Speak Truth to Power	Literature Review	Consolidate user feedback for companies	greenfilter.app/prototypes/truth-power
Shopping Divest	Literature Review	What if you could build communities based on what you buy?	greenfilter.app/prototypes/shopping-divest
True Cost	Literature Review	What if you could see the actual cost of each product including externalities?	greenfilter.app/prototypes/true-cost-
Sunday Market	Literature Review	First prototype for going to the organic Sunday Market with friends.	
XYZ	Expert Interview		
ABC	User Survey		

- *Affinity diagrams* help users organize ideas by brainstorming, sorting and labeling to cluster related information (Kara Pernice, 2018; Quignard, 2022)
- Scan a product to see the company and start investing or divesting from them Current economics is lowering the quality of life on the planet

Actionable Insights: Translate data into everyday actions the app can suggest.

- What does investing look like at the scale of billions of people? like IG
- The most effective things are Commodities? Food, transport, fashion, plant trees.
- personalized AI, meta glasses understand your context. sense and reconstruct the world around you and to understand the context in which you're using your device.sense and reconstruct the world around you and to understand the context in which you're using your device. Make suggestions and take action proactively to help you get things done — ideally, so seamlessly that you may not even notice.neuroscience co-adaptation of the interface. your future devices will learn and adapt to you as you use them.
- Scalable Climate Solutions: What really works on a large scale?
- brand colors: pink, orange, green

12.30 Shopping-as-Investing

- Introduce this concept
- The Manor (2022)
- Sustainability is hard. Green Filter helps you find companies that are making a true effort and build closer relationships through shopping, savings, and investing. Green Filter helps you find companies that are making a true effort to become sustainable and build closer relationships through shopping, savings, and investing
- Gather requirements and build a prototype for the next-generation investment app for young adults. Improving the user experience for young adults getting started with (green) investing. What would a “Tinder for (Green) Investments” look like? How can we make the logistics of investing so easy to use and take into account my values?
- My thesis core message is : everyone should change from consumer to sustainability investor (define these terms in the thesis). how to do this? can help you become from consumer to investor i believe there's space for a product like that. your green investing friend find the companies tackling certain problems and invest in them using crypto business can be a force for good
- Consumer purchases are an indicator of demand. If demand trends down, companies will stop producing this product.

12.31 ‘Investment-as-Product’

- Green Filter helps you discover how to save money and the planet with your daily shopping. By providing an easy way for people to learn about and shop with sustainable companies, we imagine a world where people invest in their future, find great deals on responsibly-made products, and get useful discounts from socially responsible brands.
- GreenFilter is a product that combines AI, design and marketing to help people manage their social impact throughout the stages of their lives, from young adult years to retirement. Its primary goal is to give people the tools they need to invest responsibly in sustainable companies, while also educating them on this topic. Our project offers a responsive website and mobile app that leverages AI and other advanced technologies. In addition, our prototype includes a reality-based virtual assistant with voice command capabilities which can provide customers with new insights into the world of green finance
- GreenFilter introduces a novel, interactive point-of-sale technology that helps people make greener shopping decisions. The platform uses artificial intelligence to suggest green alternatives for products on your shopping list, and will also help you to find other companies that can make sustainable versions of the product you are buying.
- As people become aware of the impact their shopping is having on the environment, they become interested in finding alternatives to big brands and large companies. GreenFilter provides designers an AI companion design which helps people build relationships with sustainability-focused companies by providing personalized recommendations, giving product reviews and helping them shop sustainably. This new tool will empower consumers to make greener choices throughout their lives.
- Better management of planet Earth

- How can we Shop, Save, Invest in line ecologic principles and planetary boundaries? individual action doesn't move the needle. how to group together
- App to build community
- Life within planetary boundaries
- Currently it seems there's a secret around how things are produced we want to increase transparency
- Companies that have nothing new nothing to hide should welcome this opportunity to mark themselves to keep a conscious consumers and investors.
- We want to create competition around sustainable practices enter widespread adoption
- Cigarettes and pictures of lung cancer every product should be required to have photos of production conditions switch such as Rainforest and deforestation the products that include Palm oil.
- My thesis is that a lot of people want to do good, shop eco-friendly, invest green, etc. But they don't believe the solutions work. They don't have trust. This is a user interface issue. How to build trust.

12.32 Early Feature Ideas

The following early prototypes are focused on particular feature ideas that occurred to me during the literature review process. They are naive and meant to allow thinking in terms of *what-if* a particular user experience was possible. These prototypes were not tested with users directly and formed a basis for directing the questions asked in a potential user survey.

12.33 Susan (Sustainability Conversation)

What if I could have a chat like this at the supermarket? Imagine what questions I would ask before buying a product. AI: “Kris, do you still remember Coca Cola’s packaging is a large contributor to ocean plastic? You even went to a beach cleanup!” Me: “That’s so sad but it’s tasty!” AI: “Remember your values. Would you like to start saving for investing in insect farms in Indonesia instead? Predicted return 4% per year, according to analysts A and B.” If I’m not so sure, I could continue the conversation. Me: “Tell me more” AI: “A recent UN study says, the planet needs to grow 70% more food in the next 40 years. Experts from 8 investment companies predict growth for this category of assets.” Me: “Thanks for reminding me who I am” ... Moments later. AI: “This shampoo is made by Unilever, which is implicated in deforestation in Indonesia according to reporting by World Forest Watch. Would you consider buying another brand instead? They have a higher ESG rating.”

Example Suggestions of the AI companion:

- “Don’t buy a car, use a car sharing service instead to save XYZ CO2. Service available near you: Bolt,* Uber.”
- “Use a refillable shampoo bottle to save XYZ plastic pollution”
- “Call your local politician to nudge them to improve bicycle paths and reduce cars in your neighborhood. Over the past 2 years, your city has experienced an increase of cars from 290 cars per capita to 350 cars per capita.”*

Figure 3: Speculative scenario of an interaction between a human user and a robo-advisor through the interface of chat messages in the context of retail shopping for daily products.

https://scontent.ftpe6-1.fna.fbcdn.net/v/t39.8562-6/333078981_693988129081760_4712707815225756708_n.pdf provides many examples conversations between AI and humans from Meta’s LLAMA model



Figure 32: Early prototype of my Sustainable Finance AI Companion (Nov. 2020)

12.34 Sunday Market

What if I could go to the Sunday market with other people who care about sustainability? First prototype (based on literature review) called HappyGreen's for going to the organic Sunday Market with friends. Choose industries of focus? Fashion, Food, etc?

12.35 True Cost

What if I could see the actual cost of each product including externalities?

12.36 Speak Truth to Power

What if I could affect companies with truth? Consolidate user feedback for companies.

12.37 How Far?

What if I knew how far did this product travel to reach me?

12.38 Country Profiles

What if I knew my country's top pollution sources?

12.39 Know Your Company

What if I could KYC the companies I interact with? Like the banks KYC, consumers can KYC.

12.40 CO2e Flex

What if I could show off how much CO2e I have retired?

12.41 Sustainability Watch

What if I could see all my sustainability data on a wearable device in the right context?

12.42 Narrative Layouts

What if I spent 5 minutes every day with a guide who could help me make more eco-friendly choices? How should the layout storyline be structured? Well it's like Strava (that running app) for sustainability... or if you have heard of Welltory. I believe sustainable choices that would improve my life.. be it what I consume, save, invest, etc.. so I'm trying to design an app around this idea. I'm basically building the UX of AI.. focused on sustainability. How should the layout storyline be structured? Well it's like Strava (that running app) for sustainability... or if you have heard of Welltory. I believe if I spent 5 minutes every day with a guide who could help me make more eco-friendly choices that would improve my life.. be it what I consume, save, invest, etc.. so I'm trying to design an app around this idea.

12.43 Shopping Divest

What if I could build a community based on what I buy?

12.44 Books Can Talk

What if sustainability literature could chat with me? Books can now talk to me. My bedtime story about shopping, saving, and investing. (*Sustainable Shopping*, 2023)

- (Ray Kurzweil, 2018)
- (J. Bailey, 2023)

12.45 Interactive Prototype

- <https://ai.ziran.tw/>

12.46 Prototype Development

– tools used: qr generator in Canva postman for API testing

- Google Chrome has 3.45 billion users “Google Chrome Statistics for 2024” (2023)
- Retrieval-Augmented Generation (RAG) to enhance AI content with domain-specific (close-to real-time) knowledge.
- technique first proposed by researchers at META (Lewis et al., 2020) some RAG benefits include [Y. Gao et al. (2023);]

12.47 Retrieval-Augmented Generation (RAG)

- “make contextual decisions on-the-fly, thereby opening up a more dynamic and responsive way to handle knowledge search tasks” Dewy (2024)

12.48 Testing

Prototype architecture

- Google Chrome browser extension
- API microservice
- Ziran AI
- AI backend
- Ratings API
- Redis testing ai results
- Redis Page cache / from page / separate scraping service
- documentation: GreenFilter: thesis website / github
- Ai Api got / claude
- Stock ratings API
- Community ratings api

70 questions questionnaire - use report ID to do anonymous testing - page tracking to track the usage - 7 app questions - 63 personality question

13 DISCUSSION

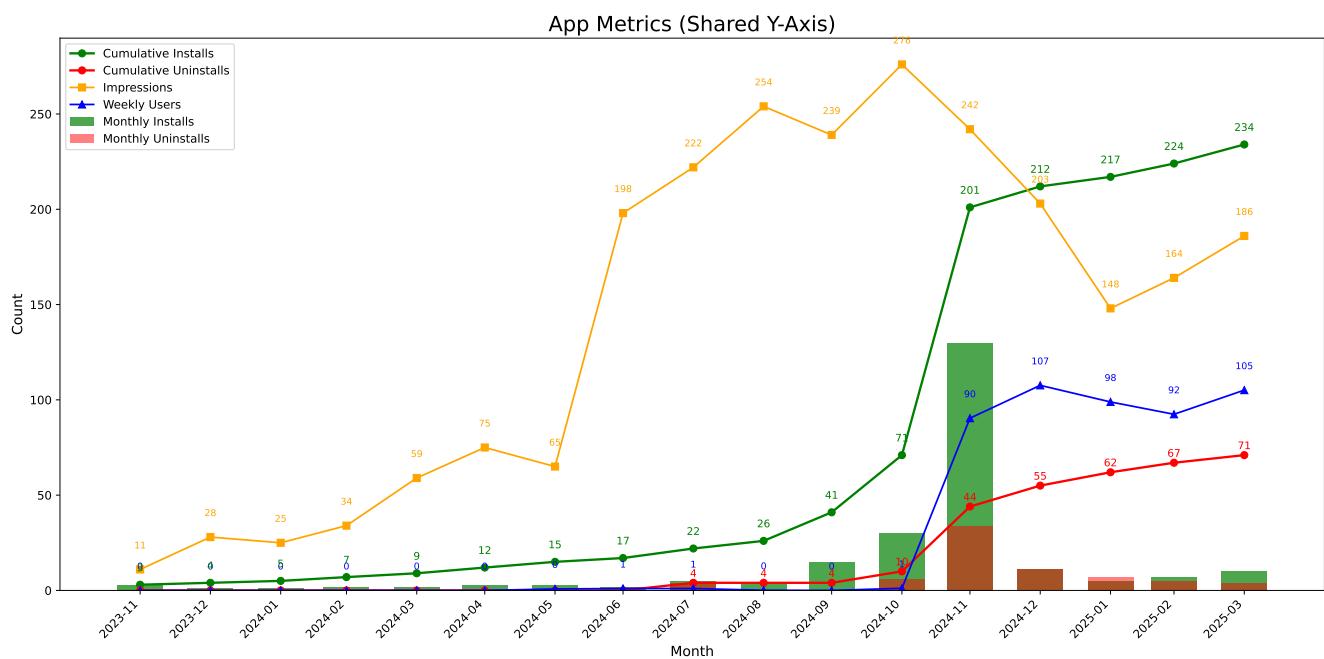
My thesis centers on embedding transparency into every stage of a product's life-cycle, from raw-material sourcing through purchase to end-of-life recycling, so that young adults can make truly informed, sustainability-driven financial decisions.

College Student Willingness to pay (WTP)

Defining the Problem Space.

- college students can get used to looking at financial charts

13.1 App Installs



Uninstalls

What percentage of people uninstalled it?

13.2 Design Implications and Feature Ideas from Literature Review

13.2.1 Finance

Design implications results from the literature review on design.

Cert

Categ	Finding	Role	Implication
Legislation	Consumer	American consumer, I can get notified by the app about highlights of poor legislation refuted by science.	
Metrics	Company	ESG alone is not a sufficient metric to prove sustainability of a company and needs to be accompanied by other metrics?	
Transparency	Investor	"10 Years of Green Bonds" (2019): "Investors want to know where their money is going", says Heike Reichelt, Head of Investor Relations at World Bank.	
Metrics	Investor	Application for design: ESG can't be trusted.	
AI	Investor/Governments	Both institutional and increasingly retail investors. Sustainable investing is possible due to consumer demand for greener products and services, and new tools such as ESG for measuring sustainable businesses and assets, as well as advancements in large-scale computational technologies to analyze large amounts of tracking data, comparing performance between different assets. Given these developments, might it be possible to create a practical sustainable investing AI advisor for consumers?	
Advisor	Consumer	Sustainability is fragmented. How can billions of people find greener alternatives and build closer relationships with sustainability-focused companies?	
Greenwashing	Consumer	Greenwashing is widespread, how can we feel trust, honesty, and transparency? A research project for designing a sustainable shopping, savings, and investing companion.	
Greenwashing	Consumer	Reading EU Commission's proposals, one might think the politicians have everything under control, we can relax and continue the same lifestyles as before. Unfortunately, this is not true. As with ESG, while the good intentions may be there, the reality is emissions keep rising, while they should be falling. It's possible to curb greenwashing!	
Greenwashing	Regulator	Regulatory against greenwashing	
Fintech	Consumer	Like a Robinhood stock symbol page for brands including live ESG metrics and ability to register divestment. Same for crypto can be automated? - People will start to discuss ESG vs price discrepancy?	
Quality	Consumer	hinnal hinnal hinna info liigub aga toidu kvaliteedi info ei liigu roheline filter finding	
Info	Consumer	good quality products stock are disconnected from the products companies make	
Accountability	Consumer	What if we gave consumers the tools to keep companies accountable?	
Education	Consumer	interaction design student who cares about the environment, I ask myself how can interaction design contribute to increase sustainability? I make the assumption that investing is inherently "good" for one's life, in the same way, that doing sports is good, or eating healthy is good. It's one of the human activities that is required for an improved quality of life as we age - and started investing sooner, rather than later, is best because of the compound interest. Nonetheless, investment also includes higher risk than sports or food. How to communicate the risk effectively while educating the users?	

Categ	Finding	Role	Implication
Engagement		Consumer	Investments platform for projects linked to your consumption habits. Can provide better products for you as well as invest in these companies. The consumer can feel closer connection to the businesses they interact with through shared values, leads to participatory design and stakeholder capitalism. Platform to understand investment products. Green crowdfunding already allows people to invest into projects to make new green products, for example from recycled materials. but what about getting involved on a deeper level. Bigger than projects, scalable solutions. Kickstarter has green projects section. Startups vs large businesses. The design of the user interface helps the adoption of a new technology. What is the suitable user interface for millennial green investors?
Fintech		Consumer	<i>Design implication: As a user, I can use the app to compare banks available in my country.</i>
Transparency		Consumer	Feature: How could people apply the same principle (Know Your Company) when buying a product or investing? Would building an ESG community help push polluting companies towards greener practices? - or starving them from cheap access to capital.
Metrics		Consumer	Feature: We need a dashboard of comparable public indicators about each company.
Community		Feature	Make a climate hedge fund with friends
Fintech		Feature	Sustainable investing product for young people everyday use Crypto, NFT provide everyday excitement trend of young people in crypto retail investors without needing to pay bank fees
Accountability		AI alert	“The company you’ve purchased from 3x in the past month is owned by Unilevel, which is under investigation for poor labor practices and deforestation”.
Education		User	Design: Help me write me investment thesis first.
Governance			Design Implications: show company board membership in the app product view.
13.2.1.1 Money anthropo	<u>anthropomorphism</u>	Consumer	<i>Design Implication:</i> make saving money look like an avatar or piggy bank or smith. mor-phism increases saving behavior; mobile money users are better at saving.
Paym	BNPL	Consumer	<i>Design Implication:</i> This suggests users are already used to having more options in the payment flow.

13.2.2 Design

This chapter has the following design implications. This chapter and design implications spurred the following feature ideas.

- Several Superapps already contain features for payments (shopping), savings, and investing - yet don't integrate Digital Product Passports to understand the products' journey, including the origin and manufacturing conditions, materials, components, CO₂ footprint and environmental impact, post-consumer repair, recycling, and end-of-life disposal guidelines.

Categorization	Implication
Green	Ranking CO ₂ 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 The key idea is making CO ₂ Visible.
Transparency	Ranking companies based on sustainability Help you to decide: what to buy, how to save, where to invest.
Decision-making	What if there was a “Green Filter” on every product everywhere?
Fantastic	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? 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

Categorization

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.

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.

General 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)

Alerts Your shopping products mostly come from Protector and Gamble (3x) and Nestle. These are large conglomerates with a massive CO₂ footprint. See the index to find some alternatives.
App shows traceability.

13.2.3 College

College Students Need Tools for Action

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

Categorization

Community: Japanese 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

"UkraineDAO Is Bidding on Ukrainian Flag | PartyBid" (n.d.) 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 Show Success Scenarios!

Trust

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

Categorization

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.

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.

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 (S. S.-H. 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 et al. (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?
-

13.2.4 Sustainability

Design Implications from the Sustainability chapter

- Start with the most polluted regions as priority?

Table 85: Implications

Category	Implication
Transparency	In unison, the reviewed technologies and practices move us closer to enabling <i>realtime ESG</i> : up-to-date transparent information about how our products 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	<i>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.”</i>
Health	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.
Tracking	
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.

13.2.5 AI

This chapter looked at AI in general since its early history and then focused on AI assistants in particular.

Design Implications: AI companions could combine sensor data from human bodies with the ability to reason about human speech, to provide increasingly relevant, in-context assistance. Because of the conversational nature of LLMs, they are very useful for affective computing.

Anthropomorphism: **Design Implications:** This suggests adding an avatar to the AI design may be worthwhile.

Table 86: Design implications arising from the AI chapter.

Category	Implication
Voice	There are many distinct ways how an algorithm can communicate with a human. From a simple search box such as Google's to chatbots, voices, avatars, videos, to full physical manifestation, there are interfaces to make it easier for the human communicate with a machine.
Sustainability	I'm supportive of the idea of using AI assistants to highlight more sustainable choices, I'm critical of the tendency of the above examples to shift full environmental responsibility to the consumer. Sustainability is a complex interaction, where the producers' conduct can be measured and businesses can bear responsibility for their processes, even if there's market demand for polluting products.
Sustainability	Personal sustainability projects haven't so far achieved widespread adoption, making the endeavor to influence human behaviors towards sustainability with just an app - like its commonplace for health and sports activity trackers such as Strava (fig. 9) -, seem unlikely. Personal notifications and chat messages are not enough unless they provide the right motivation. Could visualizing a connection to a larger system, showing the impact of the eco-friendly actions taken by the user, provide a meaningful motivation to the user, and a strong signal to the businesses?
Machine Learning	All of the interfaces mentioned above make use of machine learning (ML), a tool in the AI programming paradigm for finding patterns in large sets of data, which enables making predictions useful in various contexts, including financial decisions. These software innovations enable new user experiences, providing an interactive experience through chat (chatbots), using voice generation (voice assistants), virtual avatars (adds a visual face to the robot).
Character	A digital companion, a partner, an assistant. "I'm a Replika." said Replika, a digital companion app via Github CO Pilot, another digital assistant for writing code, is also an example of how AI can be used to help us in our daily lives.
Psychology	Humans respond better to humans?
Psychology	Humans respond better to machines that into account emotion?
Open Source	For public discussion to be possible on how content is displayed, sorted, and hidden, algorithms need to be open source.
User Experience	User experience design (AI UX) plays a crucial role in improving the consumer to investing journey. The missed opportunity to provide an even more interactive experience in line with user expectations.
LLMs	Prompt engineering findings have significance for "green filter" as it validates the idea of creating advanced prompts for improved responses. For "green filter", the input would consist of detailed user data + sustainability data for detailed analysis.
Cuteness	Lesser apps have higher retention
Transparency	Understanding algorithm transparency helps humans to regard the AI as a machine rather than a human
Anthropomorphism	

13.3 Mindmaps

Initial version of the concept map focused on the app itself.

Current concept map focusing on sustainability.

13.4 What is Research?

I, as the researcher, am similar to the blind people in the elephant story; focusing on greening shopping, saving, and investing are only the trunk of the enormous elephant that is environmental disaster unfolding in front of our eyes.

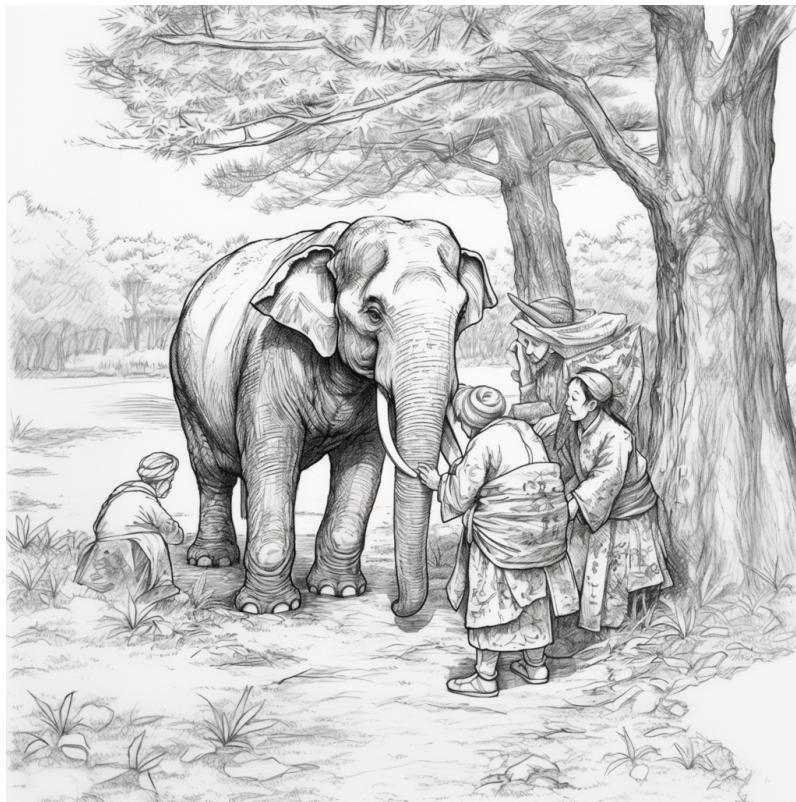


Figure 33: Illustration of the Jainist parable Anekāntavāda also known as “Blind Men and an Elephant”. Generated by Midjourney on August 17, 2023. Prompt: “A simple pencil-drawn illustration of the story ‘Blind men and an elephant. The man touching the elephant’s trunk is a research scientist. Ohara Donshu, Itcho Hanabusa, Japanese woodcut Edo style’.”

- Design research books
- Koskinen (2011)
- Ries (2011)
- Design Studies Journal

Research through design is a method for *interaction design research* in Human-Computer Interaction (HCI).

- Zimmerman et al. (2007)
- Salovaara (2020) defining a research question

- Nunnally & Farkas (2016)

interview people at google who made the green filter options

- Design artefacts
- “design’s nature as a ‘problem-solving’ science” Oulasvirta & Hornbæk (2016)
- my contribution is the design artefact, “HCI researchers also make constructive contributions by developing new technologies and design”
- Affairs (2013) Card sorting
- *How Models Work* (n.d.)

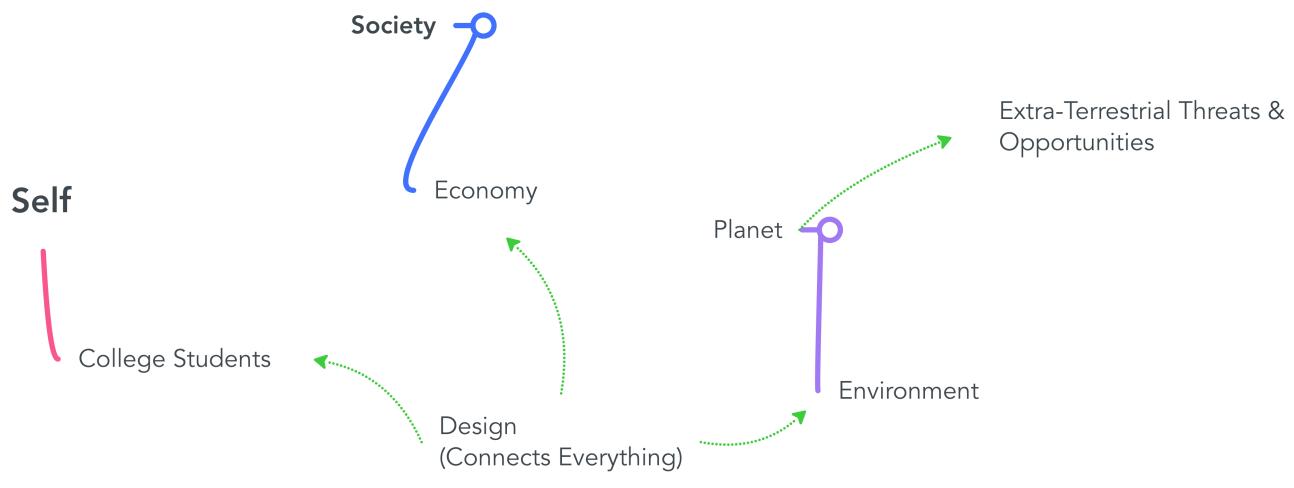


Figure 34: Everything

- Behaviour kit:

Take the metrics from the several frameworks and display them on the product and company level? People can choose their own framework and see product data through that lens and vocabularies.

Col1	Col2	Col3
Donut Economy	Unrolled Donut	
Regenerative Capitalism	8 Principles	

Col1	Col2	Col3
Blue Economy		
ESG		
B Corp		

- “research for design”. design research is about expanding opportunities and exploration
- RanYwayZ (2016)
- Mehmet Aydin Baytaş (2020)
- 047 (n.d.)
- **(KindsDesignResearch?)**
- *(5) Qualitative Vs. Quantitative UX Research - YouTube* (n.d.)
- *When to Use Which UX Research Method - YouTube* (n.d.)
- *Great UX Research for Non-Researchers / Steve Portigal / Awwwards San Francisco* (n.d.)
- Erika Hall (n.d.)
- Contact Kalle Lasn, Culture Jam
- online/offline ethnographic participant observation At this stage in the research, the central concept being studied is defined generally as user expectations for a sustainable investment app.
- What are my hypotheses?
- User experiments
- Financial statistics
- Analyzing existing apps and user pain-points
- List of topics gleaned from literature review for discussion with the experts:
- Transparency and sources of ESG and similar data
- I will test the prototype with potential users using an online choice experiment survey.
- Research Process In terms of literature review, academic inquiry in social sciences largely follows phenomena, while the issues and technologies discussed here are emergent. Not many studies exist yet (they might in a few years), which is why some of my references are to company press releases and news stories, or for public companies, their advisory for investors.
- Target potential retail investors aged in generation-z 20-29, all gender in Taiwan. In general, the Taiwanese culture is savings oriented: I'm in a good location for financial user experience research.
- Set your target goals
- Access to health care
- Access to education
- Climate action

I propose *interfaces* and *workflows* to see financial interactions through the filter of sustainability.

What kind of sustainability info do college students care about? How would college students prefer to interact with the AI? What role would college students prefer the AI to take? How can college students trust AI? What can college students do to aid sustainability efforts? How might AI assistants help college students find shopping, saving, and investing opportunities?

“Systemic change through financial actions driving policy and market changes encourage broader industry shifts towards greener practices”

Overconsumption-driven extractive business practices contribute to the degradation of Earth’s natural ecosystems, pollution of water, air, and soil, deforestation, diminishing biodiversity, climate instability, extreme weather, modern slavery, worsening human health, and other environmental and social challenges (ADD CITATION). Companies are attuned to consumer demand however widespread greenwashing makes it tiring to find sustainability-focused companies and requires extensive time for research. Even for highly motivated people, it’s difficult to know what’s sustainable.

My interest lies in understanding how AI assistants can help conscious consumers become sustainable investors. The purpose of this study is to explore how to provide the best user experience to potential sustainable financial AI companion users. In their sustainability report every company looks perfect. How can people shop, save and invest sustainably? Where does our money go and what are some greener alternatives? The companion enables people to be more transparent and responsible in their consumption behavior.

In Taiwan water is too polluted can’t swim

air is too dirty can’t breathe (show my own stats)

Start local then go global with backup data from global sources

Ask chatgpt how to organize my sections

rq: how to connect env destruction pollution to source causes

rq: how to connect everyday financial actions to environmental impact in a visual/ meaningful way

idea came riding my bike in annan can’t swim in the annan river

show local pollution map?

show factories on the map

instead of the browser plugging just make a website where you can share the link of the product (and cache the results)

on ios can use the share screen to share to the app?

ICID calls upon us to have the courage to redesign entire industries

This research takes place at the intersection of Taiwanese college students, sustainability, finance, AI, and design.

For the average person like myself, my experience with money is mostly limited to buying things at the supermarket. Food, clothes, furniture, soap, mobile phone. This leaves very few options on how to start with something new like saving and investing.

Could the Green Supermarket become the entry point to Green Savings and Green Investing?

Oboarding more people for sustainable practices is a complex interaction design issue hindered by ambiguous data (what is sustainable?) and messy human motivations (we love buying things).

What can people who want to preserve Earth's environment, exactly do? How can networks of people come together?

— LLMs enable data journalists to create stories: Big Local News (2024)

Health tracking apps paired with connected devices such as Apple Watch filled with sensors provide one model for simple interactions to dynamically track digital health data - also known as a quantified self. This data allows apps to provide tips how to improve health outcomes through small daily actions such as climbing more stairs. Small interactions allow users to align their goals with their actions.

What would be a good interface to track sustainability? What is the user interface at scale, useful for billions of people?

One way to influence societal outcomes is to decide where to put our money. While our financial decisions are a vote towards the type of businesses we want to support, is it enough?

While some people are demanding sustainability, and some governments and companies are announcing green investment opportunities, how can consumers discover the most suitable investment options for their situation?

How can retail investors access and differentiate between eco-friendly sustainability-focused investable assets?

The level of knowledge of and exposure to investing varies widely between countries and people.

Could linking green consumption patterns with sustainable investing provide another pathway to speed up achieving climate justice as well as personal financial goals?

In this simplified scenario, I'm in a physical offline store, doing some shopping. When putting a bottle of Coca Cola in my basket, my AI companion Susan will ask me a personalized question:

Does individual climate action help?

Gen-Z college students (target users) may not have the capital to make a financial dent today however they can be early adopter and they will be the decision-makers in a few years.

"Like climate change, the focus on individual actions as a solution is often misplaced, though it remains a focus of media and industry. For decades, the petrochemical industry has offloaded responsibility onto individuals through promoting concepts such as the "carbon footprint", championed in a 2004 advertising campaign by British Petroleum" Lavers et al. (2022).

Individual efforts are too small to matter unless they're inspired by Community a effort
atmospheric pollution and climate change

The latest IPCC report Calvin et al. (2023)

Dimock (2019)

- Latvian Kora app for tracking personal CO2 footprint, Earn KORA coins for reducing CO2 emissions (Kora Sustainability, 2019).

13.5 Google Chrome Extentsion

While Google is the most popular browser with 3 billion users, extensions are a relatively less known feature of the browser. Most popular extensions are Grammarly, for Taiwanese students End Note is familiar.

However it's only available for computers (extensions don't run on phones and tablets).

13.6 Results

The research helps me (and others) to

- Avoid reinventing the wheel and duplicating existing approaches.
- It aims to help app developers maximize impact by aiding complementary additionality.
- Make high-quality products. If used wisely, money can help build communities of sustainable impact.

Define every word in the title: “The Journey from Consumer to Investor: Designing a Financial AI Companion for Young Adults to Help with Sustainable Shopping, Savings, and Investing”

- Journey - behavioral change takes time
- Consumer - purchase goods without thinking about the effect
- Investor - thinking about the return
- Design - decisions
- Financial - dealing with money
- AI Companion - automated sidekick
- Young Adults - College Students
- Help - to be of assistance
- Sustainable Shopping - shopping understanding the consequences
- Sustainable Saving - in this context I mean Sustainable Savings, that is reducing one's environmental footprint
- Sustainable Investing - activity of thinking longer-term

13.6.1 Open-ended Questions

13.6.2 Close-ended Questions

13.7 Expert Surveys

13.8 Database

Compile a database on relevant apps and companies in the space

Easily access data used in this research project (please wait a bit until it loads below). The database includes sustainability-focused apps categorized by features and problems they try to solve, sustainable investing apps, and links to research papers.

13.9 Design Implications from the User Survey

13.9.1 Group-Related Features

General theory about Taiwanese society suggests that it's low-context and people need groups to do activities. But my survey about my sustainability app shows that people don't pick the features for joining groups. Joining groups was one of the least interesting choices in the survey.

Factor	Potential explanation
Survey framing effect	Survey respondents may feel the way I framed the survey question for "joining groups" made it sound like an extra commitment they didn't want to make.
Group fatigue	Survey respondents may already have too many group obligations to attend to (school, work, family, etc). Joining another new group may feel like a burden, not a benefit.
Fear of awkwardness	Survey respondents may feel joining strangers in online group is risky, uncomfortable or unnecessary.
Desire for personal achievement and changing cultural trends	Survey respondents may be more motivated by <i>individual achievement</i> to personally feel they are making a difference instead of waiting for the group. Possibly they are more individualistic than my expectations in their behavior (particularly in a digital context) and the traditional "group society" stereotype is weakening.
Are "group" and "sustainability" concepts related enough?	Survey respondents may not clearly understand the benefit for sustainability from their joining a group.

- Factorial Surveys (T. Li et al., 2022): "Factorial surveys is a research method that combines classical experiments with survey methodologies. Factorial surveys use short narratives, called vignettes, to represent various levels of independent variables that are too complex or unethical to create and manipulate in real-world or lab situations"

and a including a choice experiment between potential feature sets in consumption, savings, and investment.

Start with a simple but powerful question: — Does it matter what you buy? — Does it matter how much you save? — Does it matter where you invest? Why?

13.10 Research Limitations

First, finance is a highly regulated industry and the proposed user experience designs may be limited by legal requirements. This study does not take such limitations into account, rather focusing only on the user experience.

This work is focused on user experience design and does attempt to make a contribution to economics.

ESG data is expensive so couldn't be used in this research. ESG needs data to give us an accurate understanding of the realities inside companies and the user experience design does not address the underlying data quality problem further than by providing a link to the data source.

I don't have access to user financial data.

- Research Reason: While many people are working on AI models, there's a lack of people working on "Human-AI interaction". Sustainability is the context. How can we better team up to solve the challenges we face this century? The huge externalities.

13.11 Future Research

The literature is rich and there is ample space for future research. The following includes some suggestions for authors whose work deserves a deeper look.

- Does the specialized interface offer any advantages of a general UI such as ChatGPT, Claude, Gemini, Mistral, and others?

Some ideas for fruitful research directions

- Perception of pollution levels among Taiwanese college students.
- RQ: Does AI acceptance increase with Affective Computing?

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- 台灣設計研究院 (TDRI) on Instagram: ”北歐循環設計論壇 | 開放報名中 - 近幾年，全球的極端氣候造成各地災害頻傳，人們更加意識到要珍惜地球資源，丹麥從 10 幾年前就開始推行低碳生活，哥本哈根海洋上成排的風力發電機供應丹麥 20% 以上的能源，哥本哈根的學校建造出全世界最大的太陽能板，甚至丹麥的設計團隊進行設計皆從永續環境為本心出發，在丹麥，每一個生活環節都是循環設計！ - 但丹麥談的循環永續不只是不具經濟效益的理念，循環經濟對丹麥來說不僅具有環境層面的效益，還可提升企業的競爭力，對資源生產力、就業機會、資源供應安全和自然資源的可持續利用都有極正向的回饋。 - 本次國際論壇，我們邀請來自丹麥的設計師 Ditte Lysgaard Wind 從循環經濟策略、Rosa Nøss Bendixen 從產品設計、Helene Jensen 從時尚產業、更有台灣的團隊奇想創造、光寶科技、REnato Lab 從不同產業類別，以跨領域的思維，分享他們循環再造的創意點子！ - 北歐循環設計論壇 Nordic Circular Design Forum 活動日期 | 11 / 12 (五) 16:00 ~ 18:20 講座方式 | 線上直播與線下參與 講座費用 | 免費 報名 | 請至個人檔案點選 #TDRI # 台灣設計研究院 # 設研院 # 設計 #design”。 (2021). In *Instagram*. https://www.instagram.com/p/CWC6KG7sXBJ/.
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15 APPENDICES

15.1 Appendix 1: Research Tech Stack

For anyone who would like to repeat this research, here's a table with the software that this research project made use of.

Tool/Service	Category
Matplotlib	Data Visualization
NumPy	Scientific Computing
jupyter	Development Environment
seaborn	Data Visualization
Python	Programming Language
VSCode	Code Editor
GitHub	Version Control
fireflies.ai	AI Meeting Assistant
Google Meet	Communication
databricks	Data Platform
HuggingFace	Machine Learning
TypeScript	Programming Language
Tally	Form Builder
Zotero	Reference Manager
Quarto	Publishing/Documentation

Tool/Service	Category
Apache Parquet	Data Storage Format
Haystack	Search Framework
MongoDB	NoSQL Database
langchain	AI/ML Development
GitHub Copilot	AI Coding Assistant
Figma	Design Tool
Sketch	Design Tool
OpenAI ChatGPT	AI Assistant
Anthropic Claude	AI Assistant
Google Gemini	AI Assistant
Google Colab	Development Environment
Google Sheets	Spreadsheet
META Llama	AI Model
Mistral	AI Model
OpenAI API	API Service
Postman	API Testing Tool

Tool/Service	Category
Next.js	Web Framework
fullstory	Analytics
Polygon.io	Financial Data API
Hotjar	Behavior Analytics
Lottie	Animation Library
Docusaurus	Documentation
Google Analytics	Web Analytics
Google Maps	Maps/Location Service
vis.gl	Data Visualization Framework
Pinecone	Vector Database
Vercel	Deployment Platform
Vercel AI SDK	AI SDK
Radix UI	UI Library
highcharts	Data Visualization
React	Web Framework
Tailwind	CSS Framework
Markdown	Markup Language