

ECOLOGY OF GENERATIVE AI

experiencing the physical side of AI to gain an understanding of the ecosystem behind your screen



Master thesis Lucie Brouwer
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Master Design for Interaction
Faculty of Industrial Design Engineering
University of Technology Delft
The Netherlands

Chair Dr. Nazli Cila
Mentor Vera van der Burg

PREFACE

I feel grateful for many people and experiences throughout this final project. Half of a year has flown by, and I can not grasp what it means that this has been my last time as a student at IDE, TU Delft. The place where I met so many people who are very dear to my heart.

I would like to start by thanking Nazli Cila, for her calmness, guidings and overview. And for her sharp yet kind questions and words. Also I want to thank Vera van der Burg for seeing the potential in my premature ideas for a graduation project. And also for her inexhaustible creativity and her inspiring and critical attitude.

They have been open and supportive throughout the project, where I felt more than once lost in communicating my thoughts. Still they were there to try and understand the chaos in my head, and help me structure. Finally, I am grateful to both for seeing opportunities for growth and improvements and communicating those with me, making this project something I am very proud of.

Also, Olya Kudina deserves special thanks. I want to thank her for sharing her developing research and ideas on water in AI ecosystems with me, adding great value to the project. Also, as diving deep into a topic can feel a bit alone sometimes, I felt fresh motivation to persist working within this area after having talked with her.

The topic of this project has a whole new meaning to me. Getting to shape my own project around topics I am personally interested in and love thinking about has been a great opportunity. Besides this, The opportunity to learn a whole new approach to design, opening doors to what this field means. As I could be labelled an overthinker, I greatly enjoy conversations facilitating this overthinking. Design can be a shared language for people to build their conversation around. Design can and may facilitate communicating a position, an opinion, and invite others to share theirs. This I believe is the value of my end result. Sharing the things I've learned of which I am convinced we, me and my fellow students, all those designing for the future, and also industries involved and policy makers, should talk. And facilitating this conversation by providing something physical as a shared language.

Intentionally I saved the best for last. I want to thank my dear friends and family for supporting me throughout this process. And most of all, my boyfriend Maurice. How grateful I am to be able to be every version of myself around all of you. How grateful I am for distracting me and engaging with me in this project. Thank you <3



Fig 1: Maurice and me at the site of the exhibition testing the Chat GPT interface, picture made by Romee Postma

ABSTRACT

The workings of artificial intelligence (AI) are increasingly complex, often being described as a black box: Something of which the inner workings are a mystery. At the same time they have more and more impact on people's lives. This project focuses on the subfield of generative AI (gen AI) within AI, as there is an increasing amount of tools available on the internet, to be easily assessed by virtually anyone.

Working on tools which we can trust, XAI-GAN, a subfield of explainable AI, aims to make the working of gen AI tools insightful to both the user and developer.

It is found that XAI-GAN is detached from the physical world and only the digital world is considered relevant. The same can be found in the policies that are being developed on AI.

Utilising principles from the science of ecology a more holistic view on gen AI is proposed.

Researching gen AI from an ecological perspective exposes the physical side of this technology. This research has been structured in maps, including biotic and abiotic factors and their interactions.

Through these maps it was found that the ecosystem of gen AI is invisible to users. Furthermore, it was found that the workings of gen AI tools rely on an unhealthy ecosystem, as there is no chance for materials to naturally cycle. As a reaction the design area was formulated to make the invisible visible, with the user as the target group. With this came the design goal to engage users in a direct interaction with a material flow of AI. The chosen material stream to work with is water, as this element receives very little attention in existing literature. The maps, and specifically the map centering around water, show that water is used to cool data centres, to cool energy generation plants, in refining processes and in manufacturing processes. The sources of water differ per process. For cooling purposes usually drinking water is used. Substances like chloride, phosphorus and chemicals for treating salmonella are common additives.

Moving away from the screens on which gen AI tools are used, an attempt is made to create a physical form of XAI-GAN.

In communicating information, aesthetics play an important role. To effectively communicate to users about water and the AI industry, the aesthetic of these two (water and the AI industry) are researched. An installation consisting of pipelines is chosen as a final concept. The set of pipelines is used to show a condensed form of the water industry of AI, incorporating parts deemed essential to this industry. These parts are the source of the water used, the processes for which water is needed, the additives needed to make the water usable and the discarding of the used water.

Besides representing the industry, the pipelines include two proposed interventions. The first being the integration of an interface into the configuration of the pipelines. By doing this, the user is placed in the ecosystem and gets to experience the consequences of using gen AI tools. The second intervention is the placement of a tap in the ecosystem. Where the water used in the industry would normally be discarded into natural ecosystems, the tap offers an alternative to wasting drinking water.

An exhibition movement was organised to bring the installation to its full potential, as this is in its use. A discussion moment with the visitors provided valuable insights on the experience. These were used to form recommendations to improve the individual parts of the installation and the experience of the installation as a whole.

It was concluded that parts of the installation effectively inform the visitor about the industry behind gen AI. Also, visitors' interaction with the installation provokes thought on the ecosystem needed to use gen AI tools. However some parts of the message were lost. For this recommendations are proposed.

With the recommendations the balance between the intended message and the user's interpretation is refined. Furthermore, considering the future of the installation, the recommendations are directed at making the installation more stand alone.

More generally looking at the project the method of mapping facilitated the researching of gen AI from a more holistic perspective, looking at both factors and their relations. The installation puts individual pieces of information in relation with each other. The notion that everything is in a relation with other things and entangled, comes from ecology and is expressed in the installation. Through this I show that ecology necessarily broadens the methods of explainable AI providing a more holistic view.

The form of an installation also proves to be valuable for users' understanding of (gen) AI. With this another enrichment to the field of XAI is offered: physical XAI.

Through this project it is understood that (gen) AI should not be used lightly. This brings up new questions: what goals justify the means of using (generative)AI? Who gets the privilege of using it? These are very important questions about power and privilege, which would be an interesting subject of future research.

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GLOSSARY

Throughout the project some terms and concepts ask for extra explanation. This list came about as a record to consult myself during the project. Many of these words become meaningfull in their context, so it provided valuable to keep this list on hand, as when looked up the words can be placed in many contexts. The list found here are definitions and personal interpretations when suited, honed to the context of this project.

| | |
|--------------------------------|--|
| Artificial | made by <u>people</u> , often as a <u>copy</u> of something <u>natural</u> (Cambridge dictionary, n.d) |
| Artificial Intelligence | Intelligence exhibited by machines |
| Biogeography | “The study of why different organisms are found in certain locations, in certain numbers.” (Khan academy, Biogeography) |
| Biome | A type or category of ecosystem. Biomes are characterized by their climate, which determines the particular plants found there. The climate and the plants in a biome determine what animals live there. |
| Black box | a complex system or device whose internal workings are hidden or not readily understood (Oxford languages, n.d.) |
| Climate | refers to long-term, typical atmospheric conditions in an area, such as temperature and rainfall. "It's usually hot in Dallas during the summer" is a description of climate. |
| Condensation | Water vapor cools and turns into liquid water |
| Demography | Demography examines the size, structure, and movements of populations over space and time. It uses methods from history, economics, anthropology, sociology, and other fields. |
| Designer | A designer is understood as “anyone who has agency to make a decision, however small, that will impact a group of people or the environment (Creative reaction lab, 2018; 4) |
| Disperse | The spreading of species to new places. |

| | |
|---------------------------|---|
| Ecology | Ecology is the study of how living things interact with each other and their environment. This includes living things (biotic factors) and non-living things (abiotic factors).(Khan academy, ecology introduction, nd.) “when we try to pick out anything by itself, we find it hitched to everything else in the universe” (John Muir, 1911) “The study of interrelationsships: those unbreakable cords which tie everything to everything else. Those relationships exend to things as well as beings (James Bridle, 2022, p.12) |
| Ecosystem services | “benefits people obtain from ecosystems (MA <u>2005</u>) or the set of ecosystem functions that are useful to humans (Kremen <u>2005</u>). These include provisioning (products obtained from ecosystems), regulating (related to the regulation of ecosystem processes), and cultural (nonmaterial benefits) services that directly affect people, as well as the supporting services needed to maintain other services. Provisioning, regulating, and cultural services typically have relatively direct and short-term impacts on people, whereas the impact of supporting services is often indirect or occurs over a very long time period (MA <u>2005</u>)” (Moleón et al., 2014) |
| Epistemology | The philosophical study of the nature, origin, and limits of human knowledge. What we often don’t see are those limits. |
| Evaporation | Liquid water changes into water vapor |
| Explainable AI | “As AI systems become integral to critical decision-making processes, it becomes essential to understand and trust the reasoning behind their outcomes. This need has given rise to the field of explainable AI (XAI), which focuses on developing methods and frameworks to enhance the interpretability and transparency of AI models, bridging the gap between accuracy and explainability.” Phillips et al. (2021) propose four principles for explainable AI: explainable AI systems deliver accompanying evidence or reasons for outcomes and processes; provide explanations that are understandable to individual users; provide explanations that correctly reflect the system’s process for generating the output; and that a system only operates under conditions for which it was designed and when it reaches sufficient confidence in its output. |

Timeline of Phase I

The timeline shows, in short statements, at what point what activity was carried out. There are three categories in which these moments fit; Research, Insights and shaping a concept

Shaping project

Insights

Research

Where it started: Personal motivation and the seed - seednumber metaphor

Mapping is chosen as a means of structuring the research

Maps structuring the research on generative AI from an ecological perspective, incorporating both concepts seen as digital and physical

Developing a design direction from the conclusions of the research

Positioning myself in the field of Explainable AI, taking a holistic approach utilising an ecological perspective

Explainable AI focuses on both the developer and the user. In this field only the digital side is considered

Understanding the field of Explainable AI

Gen AI is as much physical as it is digital. It can be seen as a big complex ecosystem when thinking from an ecological perspective

Research into Generative AI and ecology to see if more metaphors can be found to explain generative AI

Collecting factors making up gen AI, moving back and forward from placing something on the map and doing more research into factors of Gen AI

Policies focus on the digital side, prioritising things like privacy, sidelining the impact of the system on the physical environment

Research into existing policies and ones in development on (gen) AI

Interviews integrating multiple perspectives into the research phase

- Drawing conclusions from the maps, current policies and interviews:
- To Users both the digital and physical side of the AI ecosystem are invisible, and you can't interact with the invisible
 - If made visible, the system would be too much to comprehend for a person
 - Materials in the GenAI ecosystem are not recycled, making for an unhealthy ecosystem in human measures.
 - Explainable AI is focussed on mathematical side, while this is not the whole picture, it should also include the physical side

INTRODUCTION

Ethics are very important to me personally. I feel a big responsibility to protect those who can not speak for themselves, which to me are animals, minorities and the earth we live on. I feel this responsibility because we are part of them, we are animals and we are our fellow humans and we are the earth. As acknowledged in ecology, everything is entangled and connected. This responsibility is a big driver in many areas, as well as in understanding AI.

A big topic of discussion is how bias became embedded in the models that make decisions for us, as well as the models that create new text or images. The latter, models used to create, are called Generative AI (GenAI). I have been using this form of AI increasingly in my work for projects at the university, as well as for exploratory purposes out of personal interest.

In the last few years I have been introduced to Generative AI through tools available online. Popular tools I have used, among others, are ChatGPT, Dall-E and Midjourney. I have been amazed by what I've seen on my screen. By how images slowly appear and become more detailed while you are watching and by sentences taking shape word for word, as if interacting with a person. This created the wish to better understand the tools, their workings and their shortcomings, like the bias I mentioned, and other I might have overlooked in my excitement to use this technology. I want to make sure I am using these tools ethically both socially and environmentally. However, using something in an ethical way is limited to my understanding of that something. We find meaning when we put things in context, as opposed to isolating things, as Anna Lowenhaupt Tsing explains in her book *The Mushroom at the End of the World* (2021). Meaning to me is an understanding allowing me to take a stance on, in this case, the utilisation of a technology. I am not alone in this wish to better understand. From a broader perspective, not only GenAI, but AI and Machine Learning is wished to be understood better, by users as well as developers.

The workings of artificial intelligence (AI) are increasingly complex, often being described as a black box: Something of which the inner workings are a mystery. At the same time they have more and more impact on people's lives. The research field with the intent of making models insightful, is called explainable AI (XAI) (Heese et al., 2023; Steinmüller, et al., 2022). A better understanding is seen as required to reach AI which is responsible, ethical and which we can trust (Robbins, 2019; Molnar, 2023; Gunning, 2017).

In the paper by Steinmüller et al. (2022) the global perspective is brought up. In this paper it refers to the model and its training and the data for training. In no way does it mean to point towards the resources needed on a global scale or to the people who are working to make those resources usable and who go through all the data to judge and label it. Explainable AI is detached from the physical world, only the digital world is considered relevant. It considers what we can do in the digital and physical world when the models do their work. The same can be found in the policies that are being developed on AI. "A more holistic approach is to view generative AI models not just as a mathematical model or piece of software, but as a very complex ecosystem" (Crul, 2024).

In an attempt to find metaphors to make GenAI explainable for myself, focussing on the digital side solely, I found a metaphor for the seednumber. The seednumber is a parameter in GenAI, which some tools allow users to set. I compared the seednumber with a natural seed: both hold information which shapes the final product, but this product is still influenced by other factors. A natural seed becomes a plant and is consumed or dies and returns its nutrients to the earth. On the right, Fig. 2 gives an overview of this comparison. Projecting the ecology of a seed onto gen AI raises the question whether a seednumber is also part of such a cycle, and if this cycle provides us with equally useful metaphors.

My drive for making the technology of GenAI tools understandable to users, and my initial use of nature as a metaphor, shaped the beginning of this project. How might the science of ecology lend insights into the GenAI technology contributing to a user's understanding of this technology?

In this report, the process of my graduation project is recorded. Throughout the report you will find timelines, summarising my activities in short statements. These are categorised into three groups: Research (blue), Insight(green) and the shaping of my project (pink). You will find the chapters to be decorated with a colour as well, as a means of providing some extra structure. This reports starts by looking at the current approaches and outcomes of explainable AI. This is followed by extensive research into AI from an ecological perspective. This research phase opened a new world to me. The physical world hidden behind our screens. With the insights gained during the research phase, the design area is formed. Where first my focus was on the digital side of AI, the models and data, this shifted to the physical side. Through research and conversations the urgency to pay attention to this side became apparent.

Motivated to contribute to an understanding of the physical side of AI, I committed to the goal of allowing users of GenAI tools to get an insight into the physical side of AI. While AI is something which is presented as a magical solution floating in the air, to be accessed whenever we desire, part of the ecosystem which is mostly hidden behind walls or below ground. Even though physical side consists of many streams of and fixed materials, one is chosen to focus on: Water. An interpretation of this material and its role in the GenAI ecosystem is presented in the form of an installation. This installation offers visitors an experience through which they get an idea of the streams of water required for the interaction with Gen AI tools. Finally with the insights gained during exposure of the installation to users, recommendations for future developments are proposed.

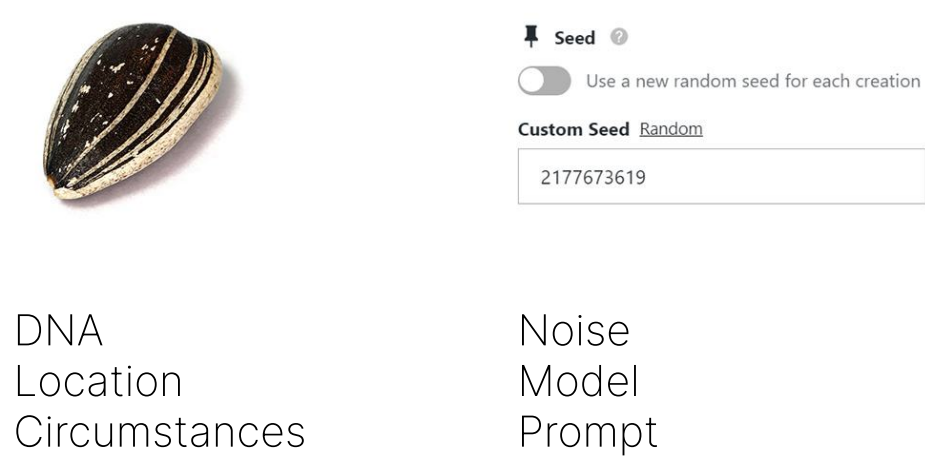


Figure 2: Seed - Seednumber methaphor

EXPLAINABLE AI (XAI)

Explainable AI today

Explainable AI (XAI) is a subfield of AI, which was developed to expose complex AI models to humans (Samek et al., 2019).

What XAI is and who it is for, will be discussed in this chapter. XAI exists as a research field and practice in general, while there are also subfields focussing on specific kinds of models, like the models used for generative AI. Both are discussed, as well as where I see an opportunity for my project in this field.

So, what is XAI today, and who is it for? To make sense of technology, users often generate folk theories based on their own experiences and social interactions. Research into users' understanding of AI, by Alizadeh et al. (2021), has shown that to users "AI is a dazzling concept that ranges from a simple automated device up to a full controlling agent and a self-learning superpower." By refining users' mental models of AI-enabled systems and resolving their misconceptions, XAI promises to be more effective use for users.

Both developers and users refer to models as a black-box. In my opinion, XAI should therefore target both of these groups. Despite the intentions to include the developer as well as the user, methods of explainable AI often present themselves as tough material to get through, demanding quite some prior knowledge and persistence of the reader (Xu et al., 2019).

Google, as a developer of tools utilising AI, state XAI is crucial for understanding output of AI tools and building trust. They describe XAI as "Explainable AI is a set of tools and frameworks to help you understand and interpret predictions made by your machine learning models, natively integrated with a number of Google's products and services. With it, you can debug and improve model performance, and help others understand your models' behaviour" (Explainable AI, n.d.).

Currently XAI efforts are directed at transparency of predictions of existing models. Within the field there are ambitions beyond achieving this level of understanding models. It is argued that AI models should be built with this reasoning centralised, without post-human processing (Xu et al., 2019; Doran et al., 2017). In line with this, Phillips et al. (2021) proposes four principles for explainable AI: explainable AI systems deliver accompanying evidence or reasons for outcomes and processes; provide explanations that are understandable to individual users; provide explanations that correctly reflect the system's process for generating the output; and that a system only operates under conditions for which it was designed and when it reaches sufficient confidence in its output.

In this project, I will be looking more specifically at Gen AI. The model typically used in generative AI is a Generative adversarial network (GAN). Such a model consists of two parts: a generator and a discriminator. The generator trains on images and then produces them. The discriminator tries to distinguish between 'real' images used for training and images generated by the model itself. The model is ready when the generated images are so close to the training images that the discriminator is fooled. The discriminator simply denies or approves. For explainable GAN models specifically the subfield of xAI-GAN is proposed. It is argued that with richer feedback from the discriminator, other than denying or approving an image, the model provides the user insight into its internal processes (Nagisetty et al., 2020). These efforts are already directed at the building of the model, as seen as an ambition in the bigger field of XAI, mentioned earlier.

Positioning

Looking at either XAI or xAI-GAN, I find the focus to be on the model and the mathematics. Many agree, users should be able to come to a point where they can trust the tools they use. But these tools are so much more than just maths. Ecology allows me to take a more holistic approach in understanding Gen AI models. Both metaphorical, as illustrated with the seed - seednumber metaphor, and methodological. Methodological because ecology looks at relations, meaning that if I have one thing, a seednumber, I can work from that point to the next, and next, etc., and equally important, learn about how these parts relate to each other and the whole.

I position this project in the field of XAI as someone who does not fully understand the workings of models. I have never built a model myself and have experience with training only through online tools. Knowledge wise, it is a bottom up approach, sympathising with other users.

The next chapter will lay a foundation for my understanding of ecology. It covers the basic concepts so I can apply them to the Gen AI system.

Ecology as a perspective

To say anything relevant about the ecology of AI, there should be an understanding of ecology itself. However, this is a whole branch of science. A course on the basics, followed at the Khan Academy, provides me with a toolkit to see GenAI from an ecological perspective. It also provides a clear scope for one of the aspects of this project. There is a limit to what I can learn on this topic in the given time. With the information from this course I will further determine the scope.

Ecology can be described as “The study of interrelationships: those unbreakable cords which tie everything to everything else. Those relationships extend to things as well as beings” (James Bridle, 2022, p.12)

Also beautifully describing these bonds, John Muir states; “when we try to pick out anything by itself, we find it hitched to everything else in the universe” (1911).

While following the course, GenAI was on my mind. I started reading the book Atlas of AI, by Kate Crawford as well as other literature on the topic. Layering one thing over the other, GenAI over ecology, gave rise to many questions. All these questions can be found at the end of this chapter.

Summary of ecology

Basics to ecology

Starting with the basics, there are 5 levels on which ecology can be studied: Organisms, populations, communities, ecosystems and the biosphere. Organisms are the individual species. The population is a group of organisms of one species living together. The boundaries of a population are to be set by the researcher. So, one can speak of the population of birds in a wood, but one can also speak of the population of birds in a province. A community is all the different populations of different species living in a given area. An ecosystem involves both the biotic living organisms and the biotic factors. It looks at the plants and the animals and their environment, like water and soil. The biosphere considers all the ecosystems on earth together. From these layers new properties emerge through interactions and relations. Ecology looks at the abundance and distribution of living things, biotic factors, in their environment made up of physical things, abiotic factors. Important measures to studying populations are demography, how a population changes over time, population size and population density. A population can be distributed in several ways. These are labelled uniform, random, and clumped, as visualised in figure YY.

Populations

To structure information on populations, such as birth rate, death rate, age and sexes, there are several commonly used tables. These are the life-table, survivorship curves and an age-sex pyramid. There also is the Life History of a species, which documents the lifecycle features which relate to reproduction, survival and death. It shows how resources are used by species to grow themselves and to grow a next generation. Reproduction can

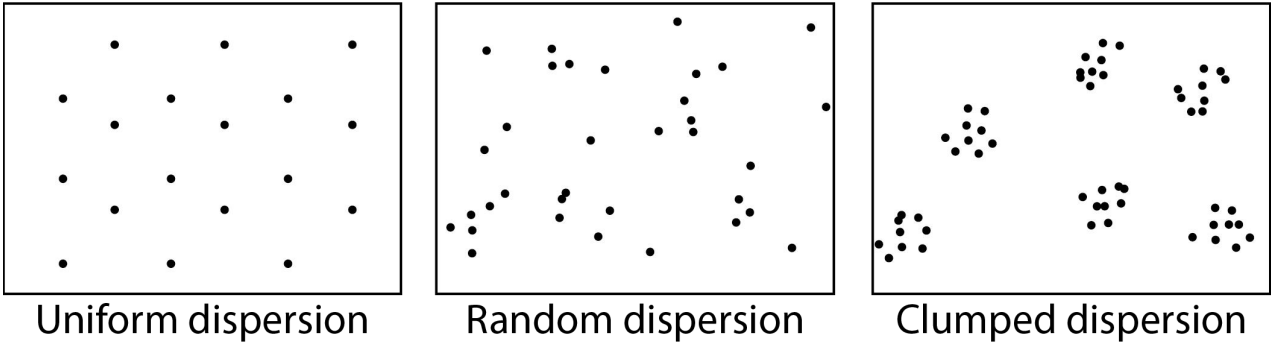


Figure 3: visualization of ways of population dispersion

be split into two categories: Semelparity, reproducing once, and Iteroparity, reproducing more than once. When looking at the growth of a population, this is always limited by the environment. This limit, imposed by the environment, is called the carrying capacity. Although a population could grow exponentially for some time, at some point it will grow logistically due to this limit. The factors limiting a population's growth can be density dependent, for example when food becomes too scarce to sustain the growth of the population. It can also be density independent, like natural disasters. In these population regulations patterns can be found, sometimes these are cyclical oscillations. This is the name for a predictable population cycle. Species of a populations can be distrubution in a few ways shown in Fig. 3.

Communities

Zooming out, the next level to study ecology on is communities. In communities different species interact with each other. This is called interspecific interaction. Interspecific interactions take many forms, categorised in how it affects both of the participants. Interaction can be positive (+), negative (-), or neutral (0). Looking at both parties involved, common types of interspecific interactions are three types of interaction which fall under the category of symbiosis: mutualism (+/+), commensalism (+/0), and parasitism (+/-). Parasitism can also be seen as predation, since one species eats part of the other species. Predation comes in more than one form. Plants are consumed by primary consumers, herbivores, these are consumed by secondary consumers, carnivores, who are one their turn consumed by tertiary consumers, etc. Plants are producers or autotrophs, which means that through photosynthesis they use carbon to grow matter. The consumer eats the producer to obtain this energy rich matter, or a consumer eats another consumer because they have stored this matter -produced by producers- in their bodies. There are the roles of predation and prey. These two influence each other and have linked cycles. The things we see mostly as dead, waste and inedible, are the food for scavengers, detritivores and decomposers. They play a crucial role in returning nutrients and minerals into the ecosystem.

Competition between species is the result of them using the same resources. A species has a niche, which is its role in an ecology. It is defined by the resources, conditions and interactions its needs and uses. Species occupying the same niche can not coexist in the same ecosystem. Either one of them will evolve to occupy a different niche, called resource partitioning. Or a species might move to another place or they do coexist but feed during a different time of the day.

Looking at a community as a whole, it can be described by its species richness, the different species in the community. Another important term is species diversity, which describes the species richness and relative abundance. Abundance is the amount of species in an ecosystem, which can be described in relation to the amounts of other species; relative abundance.

There are many factors shaping the community structure, both biotic and abiotic. Some important ones are: the climate patterns of the community's location, the geography of the community's location, the heterogeneity (patchiness) of the environment, the frequency of disturbances, or disruptive events, interactions between organisms.

In this community structure some species play a more significant role. These are the foundation species and the keystone species. A foundation species often forms, surprise surprise, the foundation of an ecosystem, usually by modifying the environment which supports other species to survive. A keystone species has a crucial role in the community, disproportionate to its abundance. Without this species the community collapses. They are different from foundation species in the sense that they act in other ways than forming the foundation by altering the environment.

Species who are introduced into a community outside their native range are called invasive species. They compete with native species for better or for worse, altering the habitat or outcompeting others.

The change of a community over time is called succession. When new formed land is inhabited by a species the process is called primary succession. The first species, in this case, is a pioneer species and they usually make the land livable for other species. Secondary succession is when a place is rehabilitated after a disturbance, like a fire in a wood. It was long thought that this succession led to a climax community, a stable unchanging community. This is questioned now because succession can follow many paths and ecosystems are disrupted all the time.

Ecosystems

The next level of ecology would be ecosystems. An ecosystem is a community of organisms in their physical environment. So, the biotic and abiotic components. In general, ecosystems with higher biodiversity are more stable. They are more resilient and resistant when it comes to disturbances.

The size of the ecosystem is to be determined by the researcher. Besides differing in size, they can be marine, aquatic, or terrestrial. The general terrestrial categories are called biomes. Within a biome, an ecosystem can still be very different. Like desert is a general category but on earth they come in many forms.

Matter is conserved through recycling, it might move through different ecosystems. Energy is conserved by flowing through an ecosystem, usually from light to heat. Neither energy or matter is created or destroyed!

Energy and nutrients are passed on in the food chain. Producers are species which make their nutrients from matter which makes up our atmosphere, using the energy of the sun. They are autotrophs. By photosynthesising or chemosynthesising they allow energy into the food chain.

They are consumed by others to obtain those nutrients, these are heterotrophs. This clear line, a food chain, is not the most realistic representation of eating and being eaten. A more realistic, and complex, image is sketched with a food web.

When energy is transferred from one species to the next, the efficiency is not 100%. This limits the length of a food chain. efficiency is usually about 10%. Solar energy which is captured as biomass in a body is called gross primary productivity. The energy which is available for the next consumer is called net primary productivity. How this energy passes through an ecosystem can be shown with ecological pyramids. An energy pyramid illustrates how energy moves through trophic levels. A biomass pyramid does the same for biomass. Lastly, there is the numbers pyramid showing how many species there are down the food chain. These pyramids show how much food is available for the next level.

Biogeochemical Cycles

The way an element moves through an ecosystem is called a biogeochemical cycle. Important cycles to living organisms are the water (hydrogen and oxygen), carbon, nitrogen, phosphorus and sulphur cycles. These maps are typical to ecology and capture a lot of information in one image.

Water

Living things rely on fresh water, which is 2.5% of the water on earth. Of this part less than 1% is available on the surface of the earth as lakes or rivers for example. Freshwater makes up a big part of our and other bodies, we could not live without!

Water can cycle very fast, when it is available on the surface of the earth. But most of the water on earth cycles slow, because it is ice, deep in the oceans or underground in reservoirs. Moving through the cycle, water changes physical state as well as physical place. The time a water molecule spends in a place is called residence time.

In Fig. 4 the water cycle is illustrated. You can see the slow and the fast cycles. Besides the importance of the water cycle on its own, the cycle is also of great importance in the cycling of many other elements

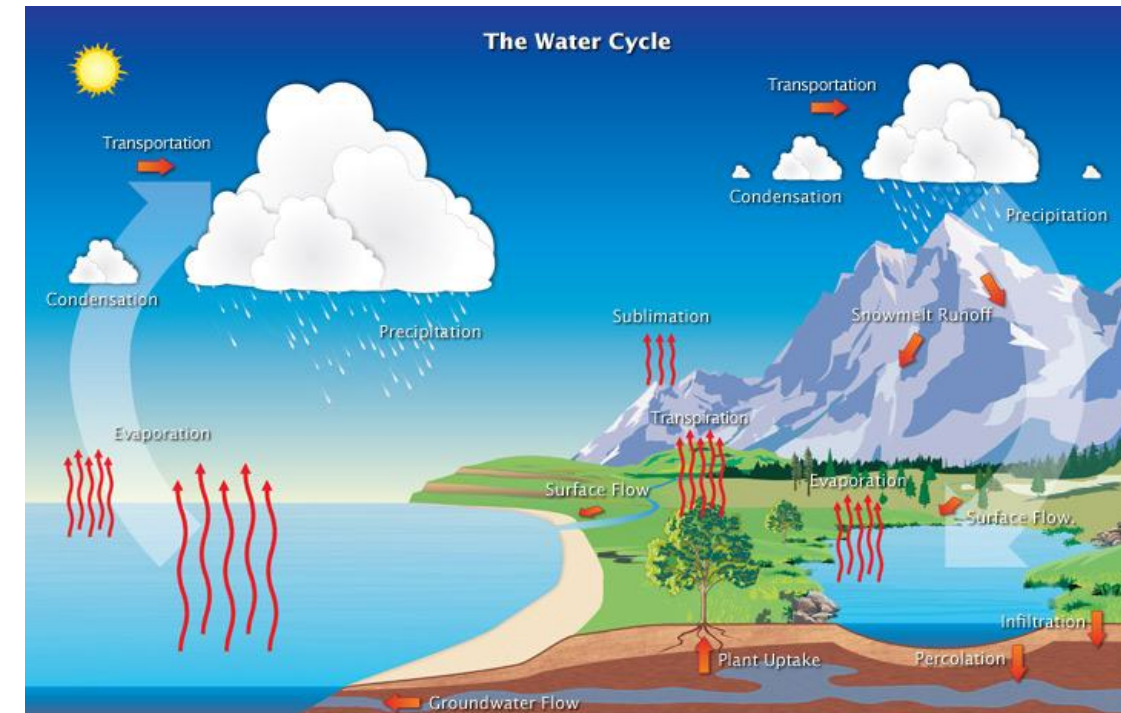


Figure 4: Water cycle by NOAA National Weather Service Jetstream,

Carbon

Just like water, carbon has a slow and a fast cycle. These can be reviewed separately but they are linked. The fast cycle is the one among living organisms, and the slow one is the cycling of carbon through geologic processes. In Fig. 5 the cycle is shown.

Carbon is present as CO_2 in the air and dissolved in water as HCO_3^- . Through photosynthesis, by autotrophs, these molecules turn into organic molecules. Heterotrophs consume the autotrophs, passing on the carbon. Both heterotrophs and autotrophs break down carbon through cellular respiration, releasing CO_2 back into the air. Also decomposers release CO_2 back into the air when processing dead organisms and waste products.

It takes about a million years for carbon to cycle through the slow path. Carbon is stored for long periods of time in bodies of liquid water—mostly oceans— ocean sediment, soil, rocks, fossil fuels, and Earth's interior. The carbon stored in water and in the atmosphere are always in a balancing act. Not only is carbon dissolved in water, below the water the ocean floor is the largest carbon reservoir on earth. On land, carbon is stored in rocks or deeper in the ground as oil, coal or natural gas.

These might enter the atmosphere when a volcano erupts or through the weathering of rocks and minerals. Or through human actions, bringing this stored CO_2 to the surface. CO_2 in the atmosphere traps heat, increasing temperature. The oceans might be able to take up more CO_2 , but this will harm the sealife.

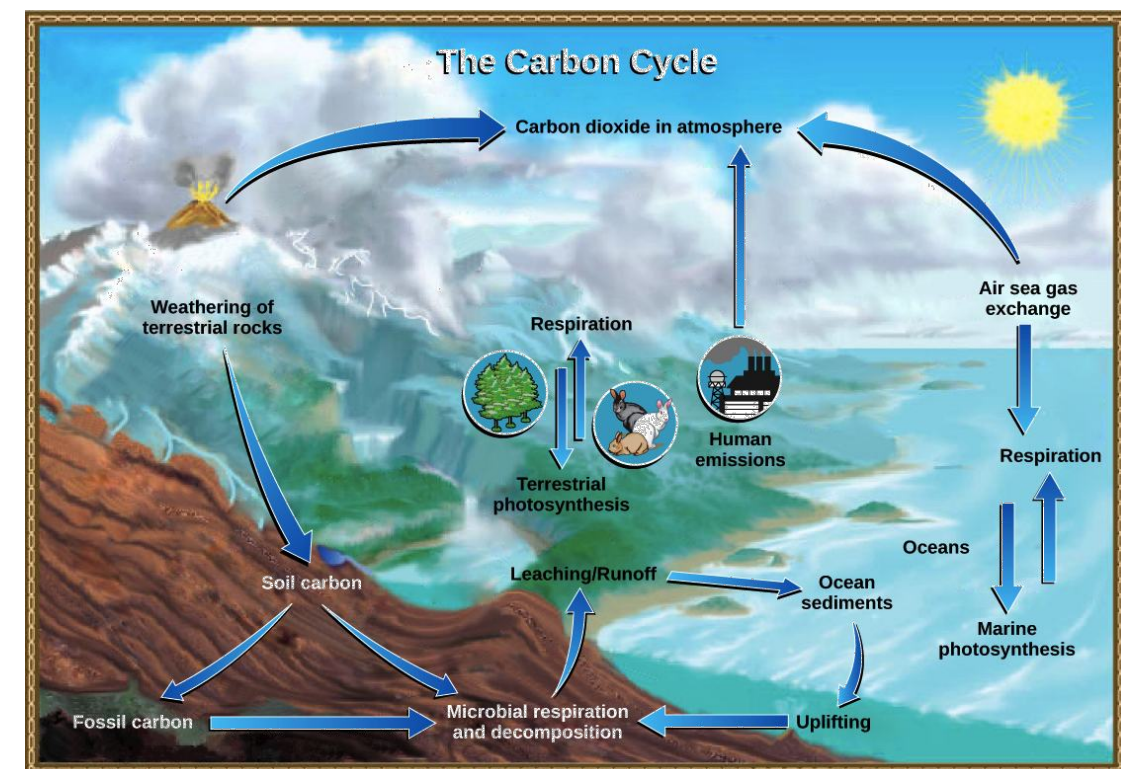


Figure 5: Carbon cycle by OpenStax College, Biology, CC BY 4.0; modification of work by John M. Evans and Howard Perlman, USGS

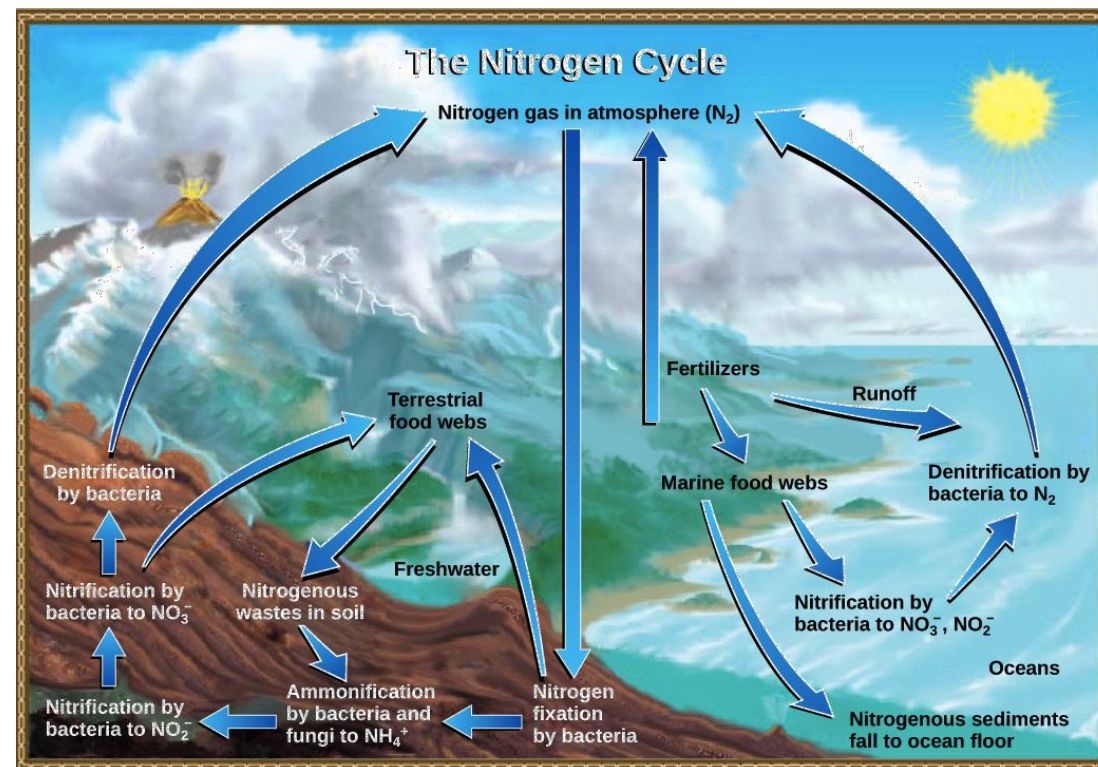


Figure 6: Nitrogen cycle by OpenStax College, Biology, CC BY 4.0. Modification of work by John M. Evans and Howard Perlman, USGS

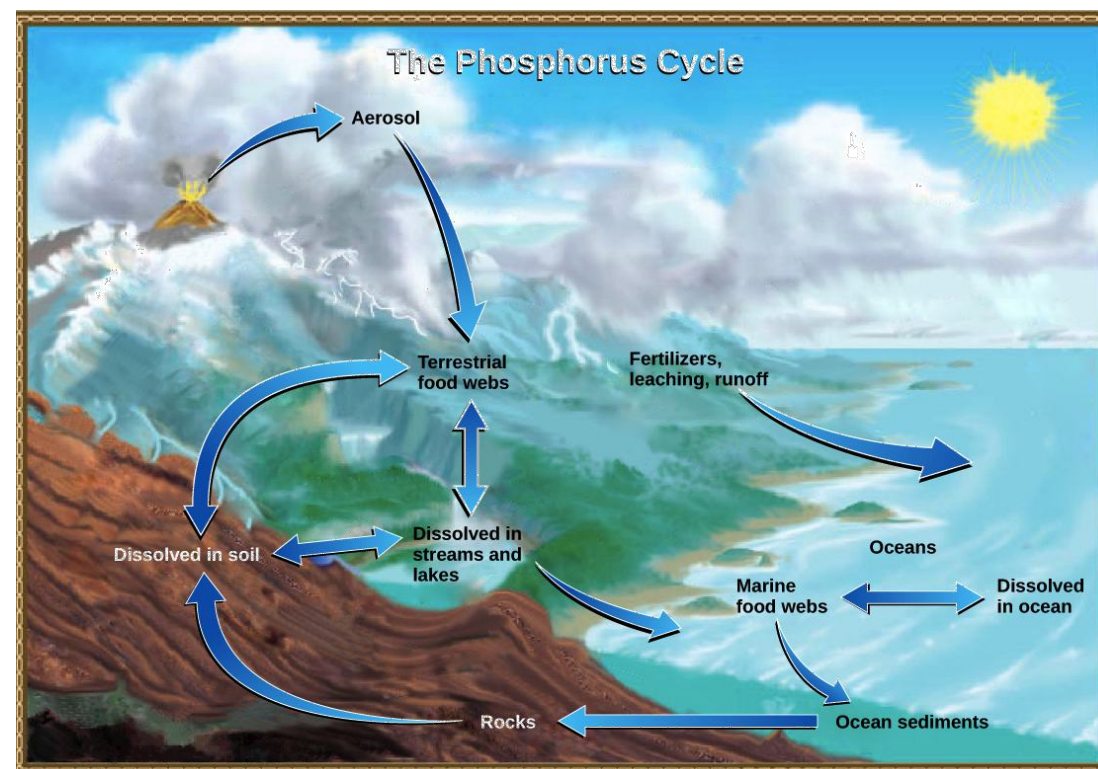


Figure 7: Phosphorus cycle by OpenStax College, Concepts of Biology, CC BY 4.0; modification of work by John M. Evans and Howard Perlman, USGS

Nitrogen

In the air nitrogen is present as a gas, as N_2 . N_2 is turned into ammonia by bacteria through nitrogen fixation. Plants and other living organisms do not have a good way to make use of the N_2 in the air! Ammonia, on the other hand, can be used by plants. Animals, on their turn, obtain nitrogen when they eat plants. Other bacteria turn ammonia back into the gas N_2 , to make a cycle. In a marine ecosystem the same happens, but then there are marine bacteria at work. On the left, the cycle is illustrated Fig. 6.

Nitrogen is what you would call a limiting nutrient, in terrestrial ecosystems. A limiting nutrient is a nutrient that is on short supply and therefore limits the growth of plants. This is why you will commonly find nitrogen in fertilisers. When a fertiliser is used, usually they have run off and end up in lakes for example. This can result in eutrophication, the blooming of algae and. When an exceptional amount of algae bloom at the same time, they will die around the same time too. In this dying process they use a lot of oxygen which leads to the dying of other organisms, who are in need of that oxygen. It drastically lowers the biodiversity in that lake.

High levels of nitrogen, in other forms than N_2 , lead to acid rain and increased greenhouse gases.

Phosphorus

Phosphorus, in contrast to the previously described cycles, only has a slow cycle, shown in Fig. 7. In nature it is mostly found as $P(O_4)_3^-$, phosphate. It is found in rocks and is released by slow weathering, and then enters surface water and soil. Volcanic ash, aerosols, and mineral dust can also be important phosphate sources. Phosphate can be taken from the soil by plants. The phosphate is obtained by animals when they eat plants. When plants die, or when animals die or poop, phosphate returns to the soil. Or it will move to oceans in runoff water where it is used by aquatic organisms.

Phosphorus is a limiting nutrient in aquatic ecosystems. Again, also this nutrient can cause eutrophication, resulting in dead zones. Dead zones are zones which are depleted of oxygen. Fertilisers, phosphorus-containing detergents, and improperly disposed of sewage can all be sources of nitrogen and phosphorus that drive eutrophication.

Species Range

Life is not distributed evenly across the earth. All species have different needs, biotic and abiotic ones. Examples of abiotic needs are temperature, humidity, soil chemistry, pH, salinity and oxygen levels. A species has a tolerance for a condition, or a range of that condition in which it can survive. All organisms have these ranges, microbes, fungi, plants, and animals.

When you draw a graph of the individuals of a species which can survive in the range of a factor, you get a bell curve. The curve shows the preference for specific factors. Their preferences influence the distribution of that species around the globe. Another factor influencing the dispersal of a species are the geographical barriers and historical chance. The ranges of species and the distribution of biomes (types of ecosystems) are shaped by climate and are called biogeography. Climate is long term, typical, weather conditions. On the right, in Fig. 8, the types of biomes found on earth can be seen. Moving away from the equator, usually the temperature drops. This is because sunlight is less isolated. There is less sun per area, and more sun is deflected in the atmosphere. This sunlight difference creates airflows and rainfall. The airflows are commonly seen as six flows moving around the earth.

Besides sun and latitude, also altitude determines temperature. At higher altitudes you will mostly find colder climates.

Also, bodies of water are of great importance to the climate. They serve as reservoirs for water, which can evaporate from the surface to fall later as rain or snow. A body of water also minimises the change in temperature of nearby land. Lastly, water also influences climate through its currents. A current carrying warm water will bring this warmth along to the land it passes.

The global climate change that is happening now, is proven to be the result of human activities. We are very good at adapting to climates with all kinds of technologies. Other species, on the other hand, might not be able to adapt. For species sensitive to small differences in temperature, this could be a devastating change.

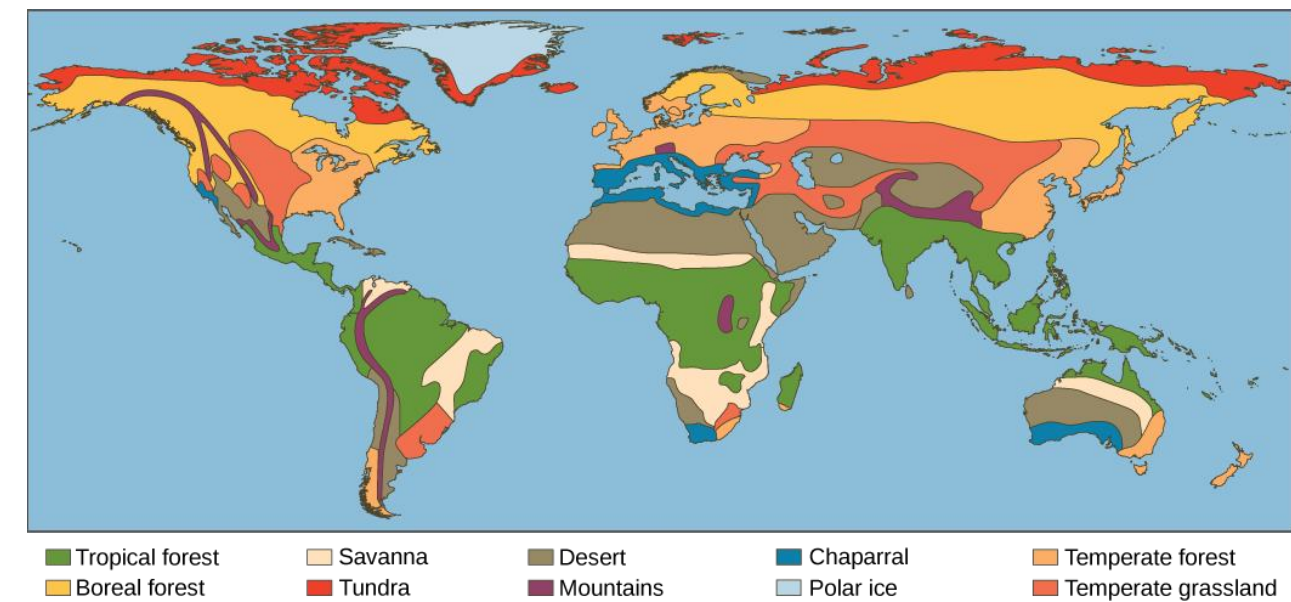


Figure 8: Biomes on earth by OpenStax College, Biology, CC BY 4.0

Conclusions

Questions on ecology of Gen AI

As noted at the start of this chapter on ecology, the scope for researching Gen AI, are the basic rules and understandings of ecology. The concepts used in ecology are an interesting vocabulary for exploring generative AI. Ecology provides a language to describe the sometimes intangible things making up the GenAI system. Where some concepts of AI are ungraspable for me, this refreshing language of ecology supports structuring these parts of the system. I can make sense of them in an insightful and manageable way.

On the next page you see the questions which arose as a result from applying ecological principles and words on findings of AI, in Fig 9. The concepts of ecology helped me to look further than I would have been able with just AI concepts, as these contain a lot of jargon. The questions have been categorised in 8 groups, as found in the legend. One question was followed by the other, illustrating my investigation of GenAI.

A conclusion from this first research is that Generative AI cannot be seen as one species. It is not one thing on its own, it is made up of so many elements. I consider it to be an ecosystem. This contrasts the ways in which currently XAI tries to make AI insightful. Refering back to the chapter on XAI I want to highlight a few parts of the explanations provided: *Provide explanations that correctly reflect the system's process for generating the output; provides the user insight into its internal processes & help others understand your models' behaviour.*

Understanding AI from an ecological perspective, Bridle (2022) offers an valuable interpretation:

“Computer ... are made from stone, and the compressed relics of animals and plants. Over aeons of geological processes, bodies, trunks and stems have been rendered into oil, and in a fraction of that time rendered into plastic compounds to support the silicon hearts of our machines. Computers themselves are one of the words spoken by stone” (p.171)
He goes on that the language in which we communicate with computers is native to neither party.

Mapping as a method

Opening ourselves up to this view on computers might provide a valuable layer for our interactions with computers. This idea I want to explore further by mapping this ecosystem. Mapping is done often to look at ecosystems within ecology, see the biogeochemical cycle maps. Yet there is no fixed method, as it can be used as a tool for many sorts of maps. Mapping will be a subjective exercise with the goal of structuring information on the Gen AI system, as this is something I miss in currently available literature. As mentioned in the chapter on explainable AI, a holistic view is missing. This offers a great opportunity to bring separate pieces of information in relation to each other, where they are now presented as unrelated parts.

In the first part of research, I quickly learned that GenAI is not only a complex digital technology, I learned for the first time about the physicality of AI as well. Because this side receives little attention in recent research, and because I feel it is of great importance to understand what the consequences are of consumption choices, physicality should be part of my research too. Maps will both include physical and digital parts of Gen AI.

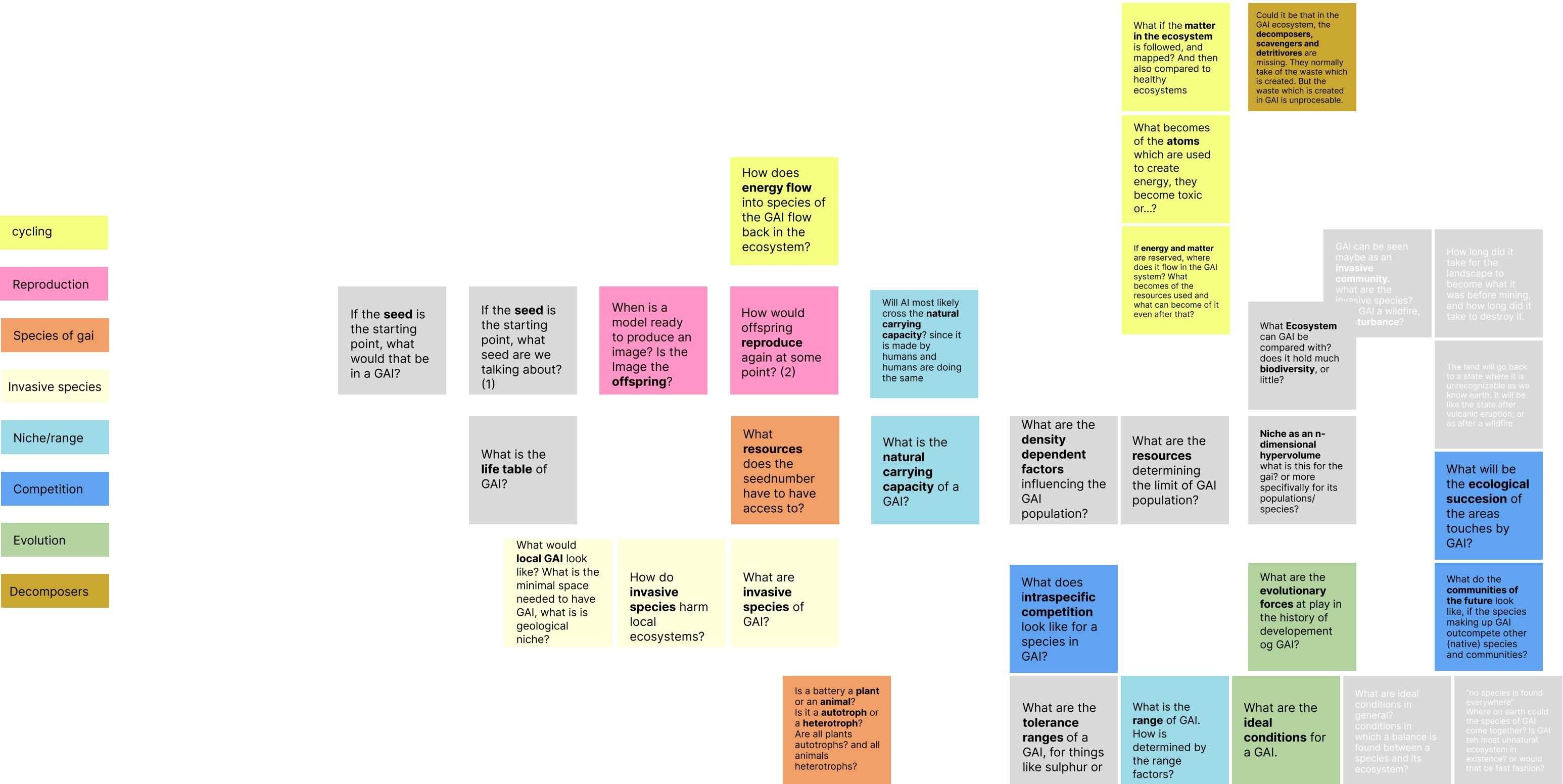


Figure 9: Question arising in the first research, illustrating my investigation into Gen AI.

Mapping the ecosystem of Gen AI

Gen AI Ecosystem Maps

GenAI is not one thing, but many things which in 'collaboration' form a system. In other words, it can be seen as an ecosystem. Mapping this ecosystem will allow me to structure the information found through the research conducted in the previous chapter which resulted in the questions on Page 17. These questions are the result of layering two sources of information; the ecology course and the Atlas of AI by Kate Crawford (2021).

The questions fall under the umbrella of two bigger questions:

- What factors make up the GenAI ecosystem?
- What are interactions with a big impact on natural ecosystems inherent to the GenAI ecosystem?

In this chapter I aim to answer those questions by elaborating research through literature and interviews, and structuring this in maps. Mapping is a subjective exercise, which is the visual result from identifying species and understanding them in relation to each other.

The questions are driven by the desire to understand, not yet to explain. This is the goal of mapping the ecosystem; making sense of terms such as *Generative AI*. I want to give these words body and meaning.

From that point I can work towards explaining my final goal.

Understanding something can be on many levels of detail and from many perspectives. which is very well illustrated in the Atlas of AI (Crawford, 2021). She covers the physical parts and the digital ones, moving through different levels of detail. In the maps I want to find how all parts connect, and what new findings in recent research connects too.

Setting the Boundaries

If GenAI can be seen as an ecosystem, its boundaries should be defined. Where does the ecosystem stop? This question is a difficult one and, as often repeated in ecology, this is up to the researcher. As with any other ecosystem, you could go on and on, finding more connections, expanding the ecosystem. Again, I think of John Muir who said "when we try to pick out anything by itself, we find it hitched to everything else in the universe" (1911). The map made by Ali Fard, in Fig. 10, shows one group of objects needed in the genAI ecosystem. It shows pipes encompassing the entire surface of the earth. There are no clear physical, geographical boundaries. Even more so, the AI system only works as it does today because of the connections on global scale.

Besides this "each object in the extended network of an AI system, from network routers to batteries to microphones, is built using elements that required billions of years to be produced" (Crawford & Joler, 2019). This makes the tentacles of AI not only vast in space but also time.

Setting the boundaries of an ecosystem is up to the researcher. It is a decision which is, inevitably, the result of a personal view on that ecosystem. In more classic ecology research a geographical boundary would be fitting. A line which could be drawn on a map, excluding factors outside of that area. For the maps created in this project the choice of boundary is different than usually in ecology. This is because the AI system only works as it does today because of the connections on a global scale. For these GenAI maps, the boundary will be the end of the GenAI system. I will look at the tentacles of GAI systems

and will stop when linking species does not serve the purpose of mapping anymore. This means I will centre the maps around a few crucial 'species' and determine their direct links. After these direct links is where I define the boundary to be, I will avoid secondary factors. This will exclude a lot of valuable information from being mapped, but is necessary to come to insights about the physicality of GenAI as a whole. Secondary factors would engage me in more detailed explorations, which might be nice for another project.

In ecology ecosystem maps are used to simplify a scene, to gain insight into patterns, health of ecosystems, or with the goal of conserving an ecosystem. The maps in this chapter will show all species contributing to keeping the system alive. In these maps scale and distance are ignored to obtain overview and readability.

But to account for the distances between factors, another map will be developed as well. This will be a map showing where on earth the factors are located. With these two maps one can see the geographical place of factors, and the interaction between factors, because in this case those two functions do not fit in one map.

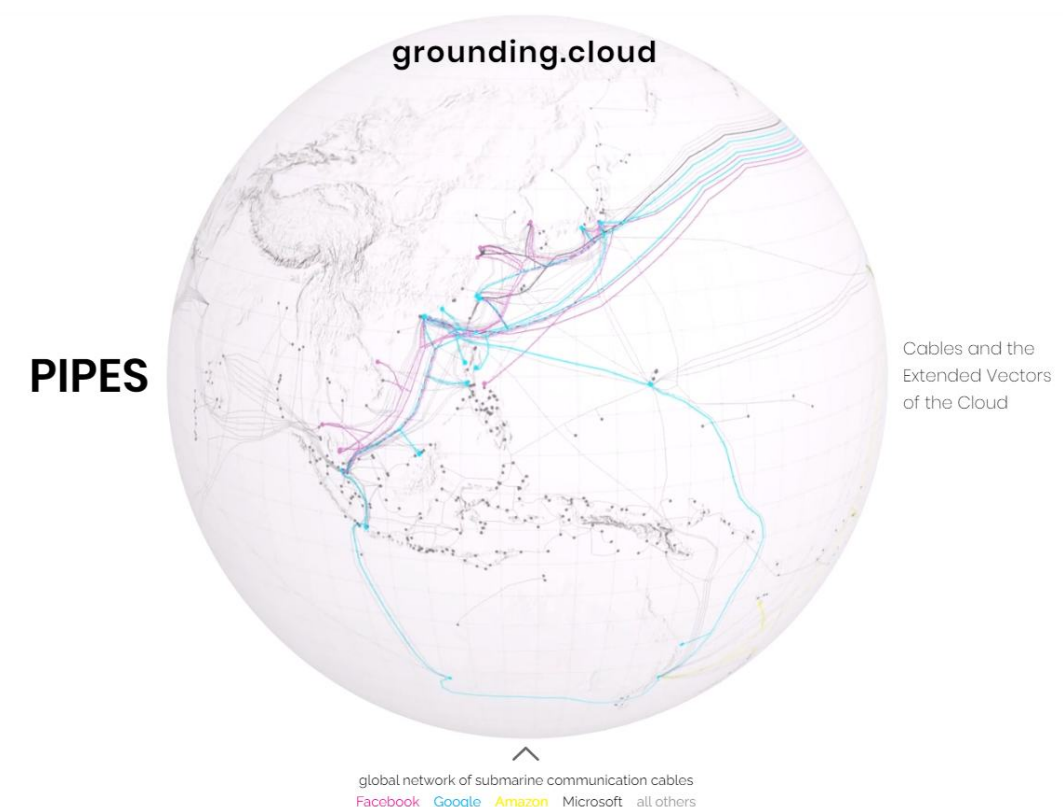


Fig 10: Grounding the cloud, global network of submarine communication cables, by Ali Fard

Contextualized definitions

In the maps, both biotic and abiotic factors are shown together. An ecosystem is made up of both of those factors. Biotic factors, in ecology, are living things and abiotic factors are the non-living things. More about this on page E2. These definitions are not directly usable in this context. I see Generative AI as an ecosystem, while this ecosystem consists of things that might technically not fall in the category of living things, but which have started to live their own life. To differentiate between biotic and abiotic factors in this context, I want to detail the definition.

Biotic means being alive, but what parts of being alive can support me in classifying things as biotic in this AI system? To classify I focus the definition of biotic to Living beings that consume. They consume energy from different sources in different forms, like sunshine or nutrients, which can be both biotic and abiotic.

Abiotic means non-living. In this case I want to add that these factors do not need to consume to exist. Furthermore, abiotic factors determine whether a species can or can not survive in a specific location. These definitions become more clear when looking at the maps. An in-context example can found on page 26, annotated with a *.

Interactions

The maps show the factors and the relations between the factors. The lines indicate a direct interaction and the arrows indicate a flow of nutrients, a flow of nutrients which includes a consumer and a consumed. If you would like to know more about these nutrient flows, there is a short elaboration on page E1.

In the maps you will find groups of factors that belong together. Not every image of such a factor in a group is linked to another factor. That is because the maps record several mental processes: Understanding the factors that make up concepts of generative AI, like the group showing elements of a datacenter; and the linking of concepts of AI, like the link between a data centre and internet cables, both groups of which the internal factors are not linked when shown as a group.

An important principle in ecology is that in an ecosystem all materials are recycled and energy flows through. This provides me with a measure to judge the health of the GenAI ecosystem.

Knowing that GenAI is physical, this has become an interesting and relevant measure. This can be measured with the use of a map.

Themes of the maps

The maps contextualize concepts which are hard to grasp, in an attempt to make them more understandable. Done for people like me, without the knowledge to even start to try to make sense of something like ‘the cloud’ from a developers perspective.

That is not to say that the maps will make everything transparent and solve the AI mystery. The maps visualise my research into the workings of AI.

Learning about the physicality of AI, I felt the need to make that insightful. The cloud being an important factor to gen AI, it is a good place to start. A word many people know and use, yet completely detached from its physical materials. Therefor map 1 is a map centering around the cloud.

After the map of the cloud comes a map closely connected to the cloud; map 2 is the map centering around data centres. Data centre is an interesting word to me, because the image associated with it is something physical, yet this is an image which came about by images. Never have I seen a data centre up close, at least not consciously. So actually, this is still not something physical. Besides that, in the name is the word data, a concept very foggy to me and most certainly not physical.

This invites us to make a map on data itself as well. Map 3 is a map centering around data. This is where things get quite challenging, because things get less tangible here.

Looking at the geochemical cycles important to gen AI, there are a few that present themselves in the first maps. An important in the GenAI ecosystem, but easily taken for granted, is the flow of water. A flow so important in our everyday lives as well. Map 4 is a map centering the cycle of water. The last map, map 5, focuses on Lithium. Lithium is a material which can not be ignored and which is naturally integrated into the first maps. What if a map is focussed on this material solely, what new insights will be gained?

The maps structure different phases of the research. The first map foremost facilitated the discovery of factors. The accompanying text with this a map elaborates on these findings. Having found the relevant factors in by making the first map, I moved on to coming to a deeper understanding of the ecosystem in the second and third map. Therefore, the accompanying text in the second and third map report more insights, coming to conclusions about the factors and their interactions.

The two final maps focus on the processes in the human made cycles of water and lithium. The accompanying text covers the new findings on processes, as well as conclusions on those processes.

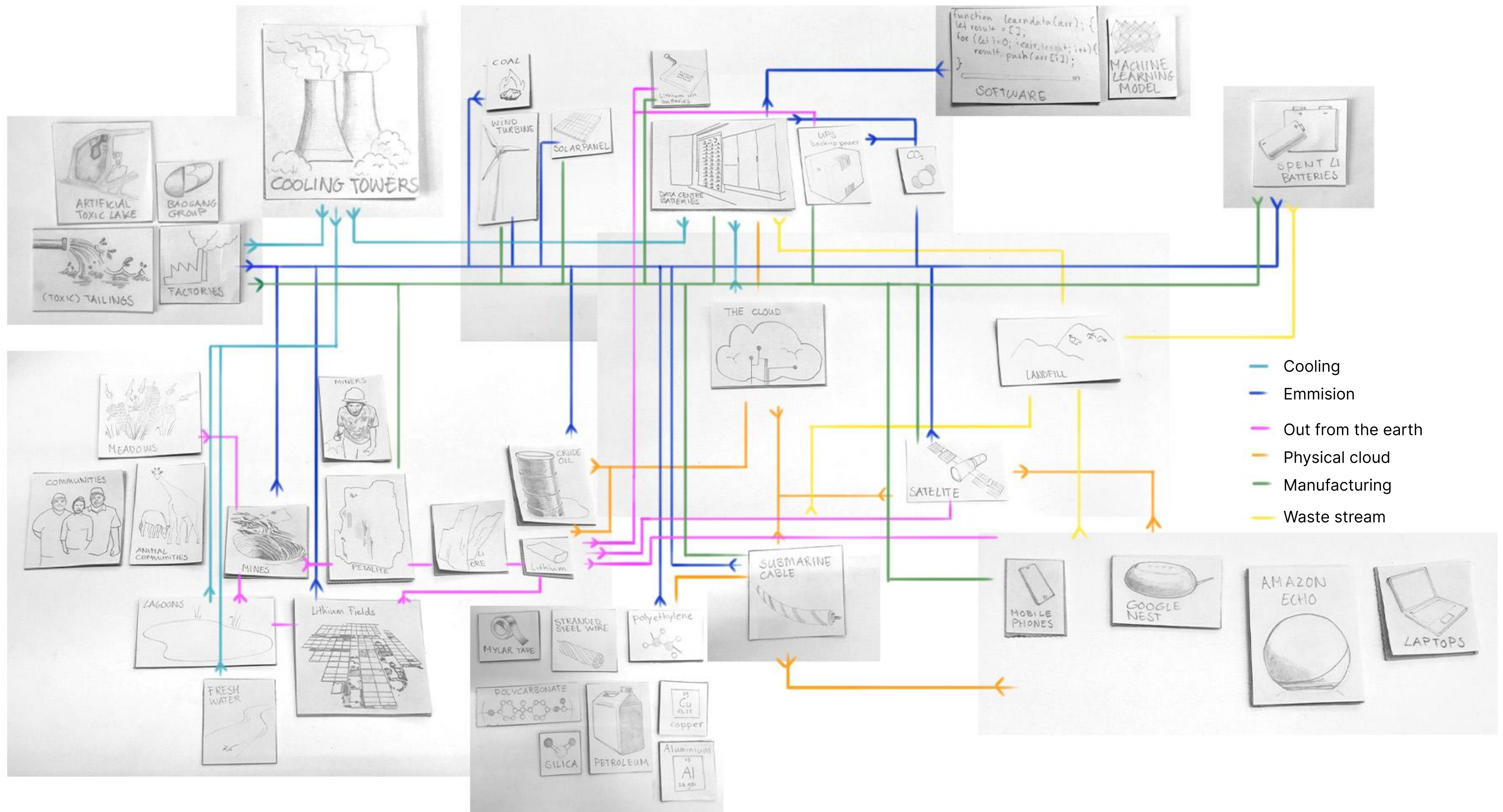


Fig 11: Map 1, centering the cloud

Maps

Per map explanatory text will be provided. These texts represent my research process. They develop from reporting the discovery from factors to insights and conclusions. This part will move through this process by showing a map, giving the accompanying text after which the next map will be provided and discussed.

Map 1: centering around the cloud

This first map is quite simple, in the sense that it shows mostly material things in the world. Material things can easily be drawn because we can see them. What we cannot see are the interactions. These have to be indicated with a line. As mentioned earlier, the line also involves a flow of nutrients. A flow of nutrients can be explained by many things. This means all lines have an extra meaning, like a need, wish, goal/ambition, belief, ect. On one end of the line there is a consumer and on the other end there is a consumed (provider), so to say.

Despite this map being relatively simple, it embodies many discoveries made while learning about the physicality of the GenAI system. That is why this first map is so strongly focussed on these physical aspects. Learning about one physical factor, I felt the urgency to uncover what more there was to be found. This is done first without the distraction of other urgent topics like bias in data or politics, to name some examples. The finding of factors, resulting in this first map, paves the way for the other maps. From here I choose what to look deeper into, considering its relevance in the ecosystem. In that sense, the process of making the maps that follow this one, will be different. Now I have collected factors to work with, the next map can explore different relations between the factors. However, more factors will most likely have to be added in that process.

But first, let's have a look at this map centering around the cloud; the species (biotic factors) in it and the material streams. The legend provides a grip onto this maze of images and lines. The first one in the legend is 'cooling'. A data centre, the crucial part of the clouds' infrastructure, generates heat when AI models are trained and when they are used by end users. Also refining and manufacturing needs water in their processes. And everything in the cloud is a manufactured product, using refined materials. Next comes 'emissions'. Emissions are the result of the manufacturing of all the materials needed as well as the result of energy generation, needed to run the processes. 'Out from the earth' shows the materials from their origins in the earth, to their form after manufacturing, and their final destination as waste. 'Physical cloud' shows all the 'species' which together form the cloud. 'Manufacturing' connects all the things in the system requiring manufacturing before they can play their part in the whole. Finally, waste streams show from what point onwards something becomes waste.

The map centres around the cloud. The word cloud suggests something floating in the air, flexible and light. The idea of this being something physical is not completely new, to me, but never would I have guessed the immenseness of the ecosystem supporting this cloud. The word cloud seems to me completely inappropriate, as it misleads the user of the cloud on this physicality. On the other hand, the history of the word in this context explains why it was used to describe a technical, physical thing. The image of a cloud was used in a diagram by developers, to describe something they did not completely understand.

It was a foggy concept and referred to accordingly, suiting its technical role in the diagram (Bridle, 2022). The appropriateness of the word depends on the perspective you take, that of an engineer or that of an end user. Nevertheless, in both cases the word doesn't aid the understanding of its physical existence. Fig 12 is found when opening the wikipedia page on cloud computing. Not the most academic source, yet very accessible. In my opinion it does a good job in sketching a first impression of what you access when you access the cloud. However, what is lacking is the materials behind the representative images and the chain behind those materials. Nevertheless, it focuses very much on the physicality of the cloud.

The lower image, Fig 13, represents the other category of images found when searching "cloud computing". Less insightful, I would say, but closer to what I used to what came to mind when I thought of 'the cloud'.

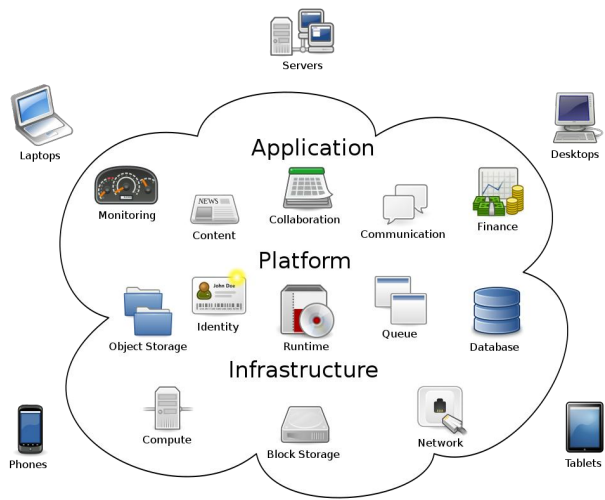


Fig 12: Diagram showing overview of cloud computing, with typical types of applications supported by that computing model, by Sam Johnston



Fig 13: Cloud solutions by Anser

Here you will find some more indepth information on a few crucial parts in the ecosystem. Cobalt is not mentioned in the map, as it is a limiting nutrient in natural ecosystems, but not in the AI ecosystem.

Batteries

Batteries can be found in many devices which we use almost everyday, and usually contain lithium. In map 1 you see, for example, a phone contains a battery with usually less than eight grams of this material. The devices seen next to that phone in the map all contain batteries as well. Another big device containing lithium is a data centre. The lifespan of all these batteries is limited, and usually disposed of as waste at the end. This is a pity considering lithium is a natural resource which needs to be mined, refined and processed (crawford, 2020).

17 rare earth elements

Rare earth elements possess unique electronic, optical and magnetic characteristics unmatched by synthetic or other natural materials. Extracting them out off the earth is costly and polluting, as only a very low percentage of the mined material contains the desired material. The energy for such a process still often relies on crude oil as a resource. The usable amount of extracted material can be as low as 0.2%, for dysprosium for example. Leaving the rest to be discarded, considering earth as waste. This processed waste is dumped creating harmful substances like ammonium. Mining and refining requires large quantities of water and releases large amounts of CO2 (Crawford, 2021).

Cobalt

Cobalt is a metal finding its main application in lithium batteries. It is a material involved in photosynthesis and nitrogen fixation, detected in most ocean basins. It is a limiting micronutrient for phytoplankton and cyanobacteria, as mentioned in the ecology chapter, rendering it extremely important in natural ecosystems. U.S. National Renewable Energy Laboratory estimates that 65% of the U.S. domestic cobalt demand in 2040 could be supplied by end-of-life lithium-ion batteries, provided a robust take-back and recycling infrastructure is in place (Sovacool et al., 2020).

Submarine cables

Submarine are a global network providing us with internet. Internet which is also used to accessgen AI tools. The materials are as seen in the image on the right, fig 14.

Data

As data and data centres are directly connected, the question prompts up: What are the physical manifestations of data? This will be explored in another map, map 3.

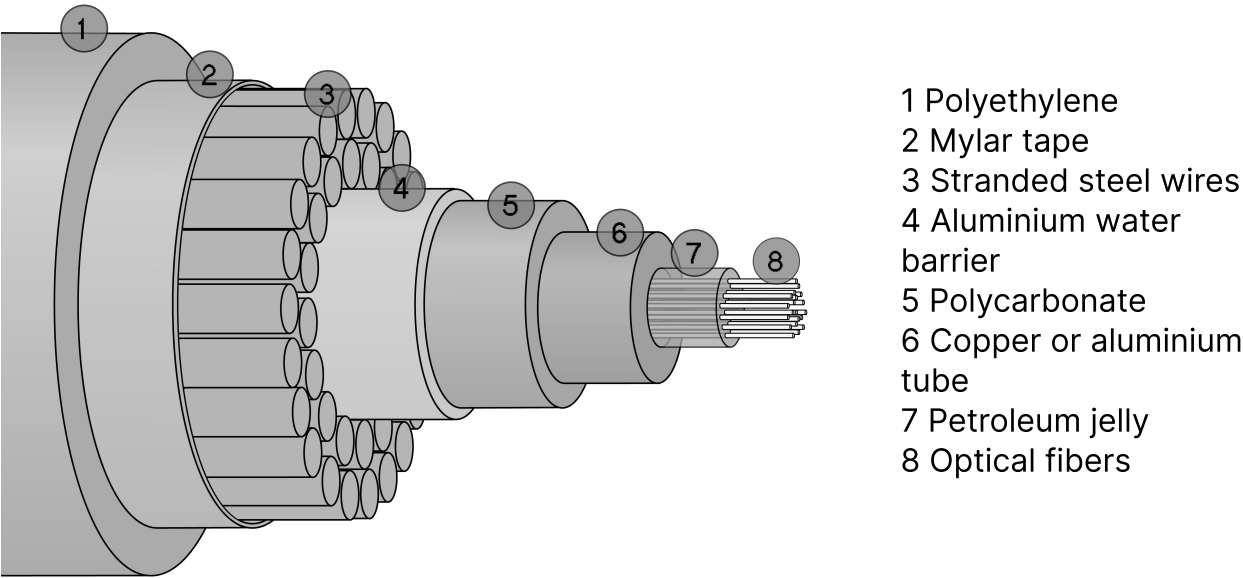


Fig 14: cross section of an internet cable

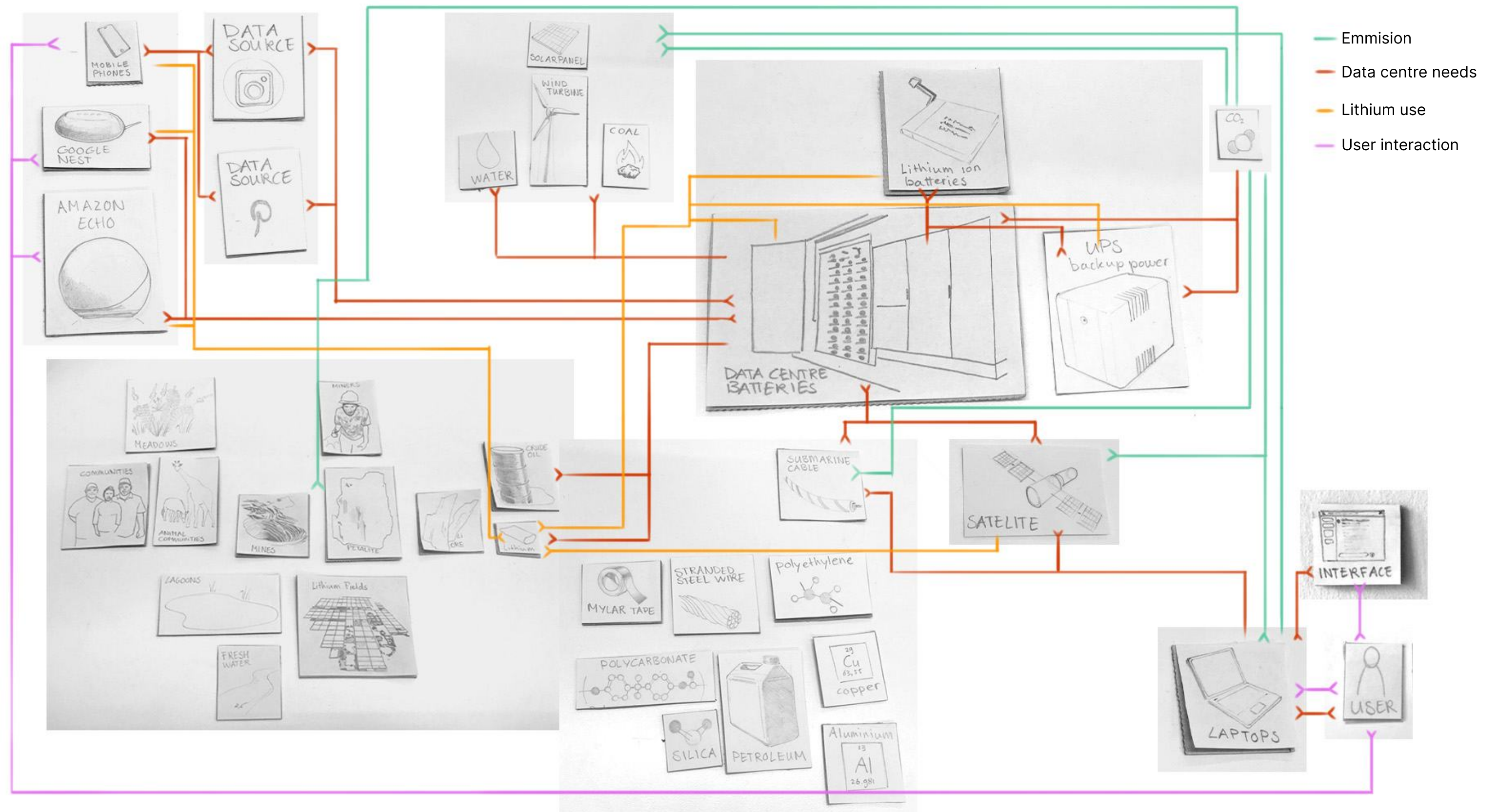


Fig 15: Map 2, centering a data centre

Map 2 centering around data centres

Data centres are the place where we access Gen AI tools, through our interface. Data centres play a crucial role, and many things in the ecosystem come together in these physical places.

By focussing on one physical part that makes the cloud, the data centres, I tried to simplify it compared to the previous map. Therefore it is repetitive in some ways, yet it also introduces new things.

Looking at the legend, here again the emissions are covered. Next I looked at a data centre as if a consumer and asked myself the question; What are its needs? Here I left out what it generates. So the generation of heat, which requires cooling, which can be seen as consuming, which has been left out in map 2. This map does, however, make an first attempt to fit data into the picture, as a consumable to a data centre. It is the very stuff kept in the building, giving them a purpose. Finally, user interaction is integrated in the map. They find their place in the map as a provider of data as well as using the products driven by that data.

The interesting thing about this map, to me, is that it starts from almost the same point as the previous one on the cloud. Making the first map revealed physical points of the cloud, the data centre playing a prominent role.

In a way the map has some characteristics of an exploded view. As the maps record the picking apart of a physical thing. The data centre is placed in the middle and moving away from there, parts needed to build a data centre are shown. These are then linked to new concepts or physical things.

The map on the cloud, map 1, focussed on physical things in the world. This map, on the other hand, is a first step in trying to understand the user's role in the ecosystem and their connection to a data centre as a user and supplier of data. This view shows the entanglement of the digital and physical parts of the ecosystem. It challenges me, as it proves complex to record the crossing from the physical world to the digital world. Bringing this into focus, on the one hand, results in new elements that ask to be explored. The map on data centres, map 2, shows the interface as the end of a line. This placement can be questioned. What is the role of the interface when viewed from a different perspective? On the other hand, the focus also results in leaving many physical things out of the map, as it has a smaller scope.

As the first maps, map 1 & 2, focus on this physical side, the next one will explore the digital side of the AI ecosystem. In doing so I will look closer at the role of users, as they mainly experience the interaction with the digital side. In this next map, map 3, the starting point will be data, a bridge between the user and the digital side of gen AI. This way I try to get a grasp on the entanglement of the two worlds that have been found to together make up the ecosystem.

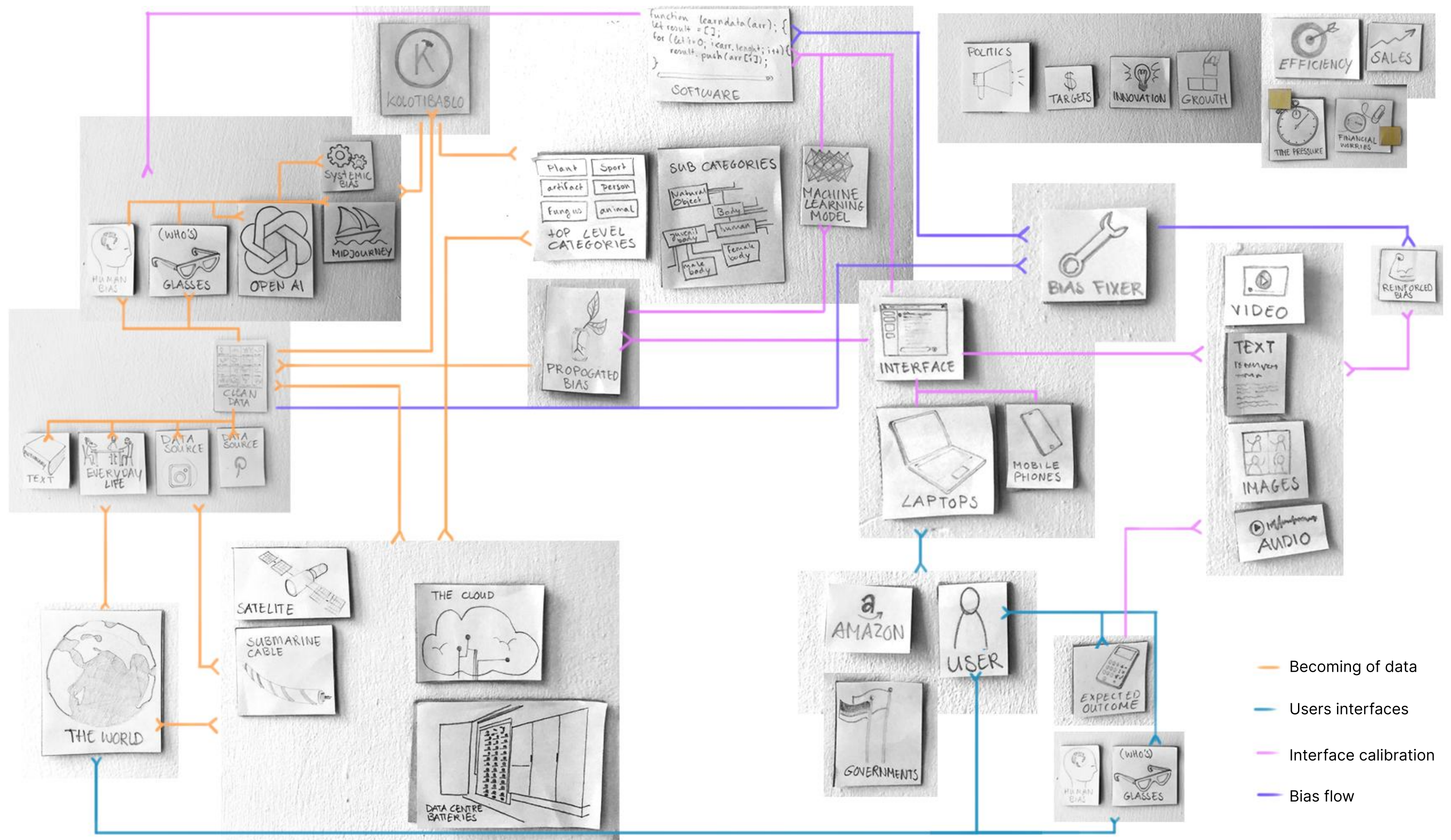


Fig 16: Map 3, centering data

Map centering around data

This map, map 3, looks at what factors data consists of and how its factors relate to each other. As you will find, the legend is more abstract than those of the previous 2 maps, map 1 & 2. This reflects the abstractness of the concepts with which I try to work.

The first on the list of the legend, is the becoming of data. This shows the origin of data and the processing of that data to become usable for training a model. Following this is the user interface, illustrating the interfaces with which a user has an interaction. The next, interface calibration, shows the interaction between user, data and interface can be interpreted as a feedback loop. Finally, the bias is shown, trying to relate it back to its origins.

*

In the map you see images of both biotic factors and the abiotic factors. The top right factors fall in the category of abiotic factors. They are the factors making up the space in which species live, much like temperature is a natural abiotic factor. Some species will flourish within the circumstances in a specific climate while others would not survive. Abiotic factors are present in many shapes and forms throughout the ecosystem, as for example something like temperature is, and therefore don't have lines connected to them. Sometimes they are present in a pure form, where choices or directions are clearly the result of such an abiotic factor. Sometimes they are less present, and just floating in the air, influencing things without anybody noticing.

Because we live in a capitalistic world, and because AI is a product of capitalism, things like growth and efficiency will be explicitly mentioned as goals in relation to this technology (Crawford, 2021). But even when we think we have other motives, these capitalistic motives shine through, because we have learned to see these as factors of success. Whether it is about yourself, for example personal growth, or about a company, success is measured in capitalistic ways. We seem to be trapped in this way of thinking (Ursula K. Le Guin, n.d.).

The biotic factors in map 3 are shown in groups, and the lines resemble relations between the groups. Some groups have relations within themselves worth showing.

On the left side the world is shown. As mentioned by Seowoo (Nam, S, personal communication, 15 Jan 2024), a designer working with data, anything in the world can be data. The full interview with her can be found on page 35. She points out, data sources for images can be online platforms like instagram and pinterest, but as said anything that can be captured can become data. The same goes for language, anything written or which can be written, can be data. Nevertheless, Seowoo also points out that the capturing of data is subject to time and financial limitations. This will influence what can be captured, and researchers might cherry pick what is easily available to them. This means that existing datasets might be used again and again to train different models, simply because they are available. The same goes for how this data is classified (Crawford, 2021).

Besides ease, other strong influences are personal values, beliefs and experiences. The data is cleaned and classified by humans. And also the software is written by humans. All of this together shapes what users see on their screen. A Generative AI tool is not something neutral that appeared out of thin air, maybe drifting next to a cloud. It is far from perfect, because humans are not perfect.

Considering data, in the centre you see propagated bias. This map shows that AI could be the perfect blank slate. It could be the perfect 'human'. It would not be racist and reinforce equity. It would be not only intelligent but also wise.

If only there was the data to train a model to be like this... Does that data even exist? We are releasing more and more that the data and model is biased, because we are. And because our systems are.

What if feminist theories and indigenous wisdom could be data. What might models bring us then?

This leaves me wondering. Does a perfect AI exist? Many efforts are directed at creating artificial general intelligence (AGI). According to Amazon AGI are "AI systems that possess autonomous self-control, a reasonable degree of self-understanding, and the ability to learn new skills. It can solve complex problems in settings and contexts that were not taught to it at the time of its creation" (What Is AGI? - Artificial General Intelligence Explained - AWS, n.d.). OpenAI describes AGI as being generally more intelligent than humans and as something that will outperform humans at most economically valuable work. They cheer at the prospect of "increasing abundance, turbocharging the global economy, and aiding in the discovery of new scientific knowledge that changes the limits of possibility".

Also, they mention their focus on avoiding concentration of power.

The map shows the users' direct relation with data goes as far as their interface. This is where they experience data and where they create data. This despite the fact that anything they do, just living their lives, can become data sourced by others.

So the users direct interaction with the cycling of data and how it captures bias, is limited to their interfaces. This is an obvious and big opportunity for intervention. What is interesting to note is the diversity of users. There are companies, organisations, governments, individuals, who are all using AI and who have their own perceptions of what AI is.

This is yet another opportunity: how might the output of an AI tool contribute to the expected outcome of a user. And should it inform about the current capabilities and limits of a tool, which are directly of concern to a user? Or about the physical limitations concerning the earth?

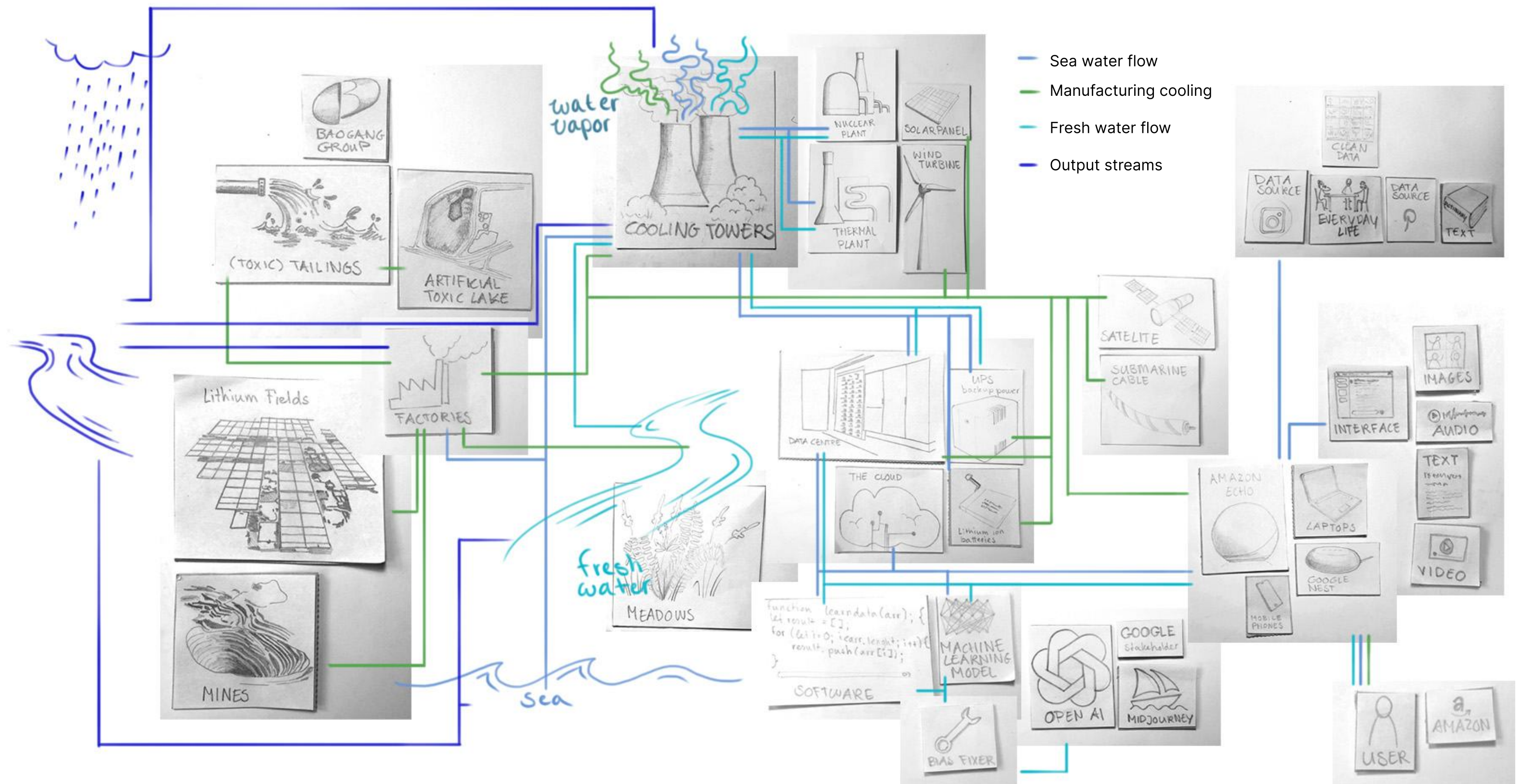


Fig 17: Map 4, the water cycle

Map centering around water

This map has a slightly different setup. It is inspired by the maps of biochemical cycles, on E3 and E4. Mapping the cycles of elements is not a new thing and will not show the elements in a new way. The classic images, well known from school books, visualize an important concept in ecology: matter is recycled. As explained in the chapter in ecology, naturally elements move within one ecosystem or between ecosystems. They same elements, the same molecules are utilised by species over and over again.

However, what makes it worth to give mapping the cycles another shot, is that at the rate with which we use elements currently, the natural cycling goes to slow. The elements are renewable, but this natural cycle takes to long for how we currently consume. We either use elements in a linear fashion, or we try recycling it ourselves. This goes for water, which is the first map focussing on, as well as for lithium, which is the focus of the next map, map 5.

This map illustrates the ways water moves through the gen AI ecosystem. It shows two main water sources: Seas or oceans; and rivers and other fresh water sources. Water is mostly used for cooling. This is the most important reason for water usage in AI (Zhang, M., 2024). As seen in the map, many lines moving away from the water sources go up to the cooling towers.

When a model is trained, a lot of energy is needed. The heat that is created from this, requires the centres to be cooled. This is a peak moment, but data centres have to be cooled when in operation all the time. When a user has an interaction with a tool such as Chat GPT, this also requires water (Li et al., 2023)

Besides the cooling of data centres, a big water consumer are refineries. The process of acquiring lithium from earth which has been mined, uses water. In the case of the factory of the Baogang Group, the tailings (the byproduct of a refining process) they end up with are pumped out, creating an artificial toxic lake (Crawford, 2021).

Furthermore, the manufacturing of many products requires water. Either in the process of manufacturing the materials needed or in the process of putting products together.

The water used for cooling in these processes partly evaporates. This contributes to displacement of water around the globe, enlarging uneven distribution of global water resources (Ren, 2023).

What is most disturbing about this map, or actually about the water cycle in the gen AI ecosystem, is that according to some sources most water used is potable water (Ren, 2023). The water is taken from resources which are also the sources we need for ourselves directly. As mentioned in the ecology course, only 2.5% of the water on each is so-called fresh water. And of this again only 1% is readily available, in the form of rivers and lakes. With increasing interest and investment in AI, more and more water will be needed for this cycle. However, no single data centre ever mentions the use of potable water. What kind of water, as well as the additives needed is a topic not spoken of.

In terms of ecology, cooling facilities are what would be called an invasive species. It is a species which competes with native species for resources. It outcompetes others in the sense that the environment is altered making it unlivable for other species. Cooling facilities produce hot water which the native species are not accustomed to. They have no time to adapt to the invasion of the ecosystem by this outsider (Kudina, personal communication, 2024).

In general there is some information on water in the Gen AI system to be found, yet the pieces of information don not align. This material stream is only just becoming a research topic and from the industry itself little information is provided, almost as if non-existent.

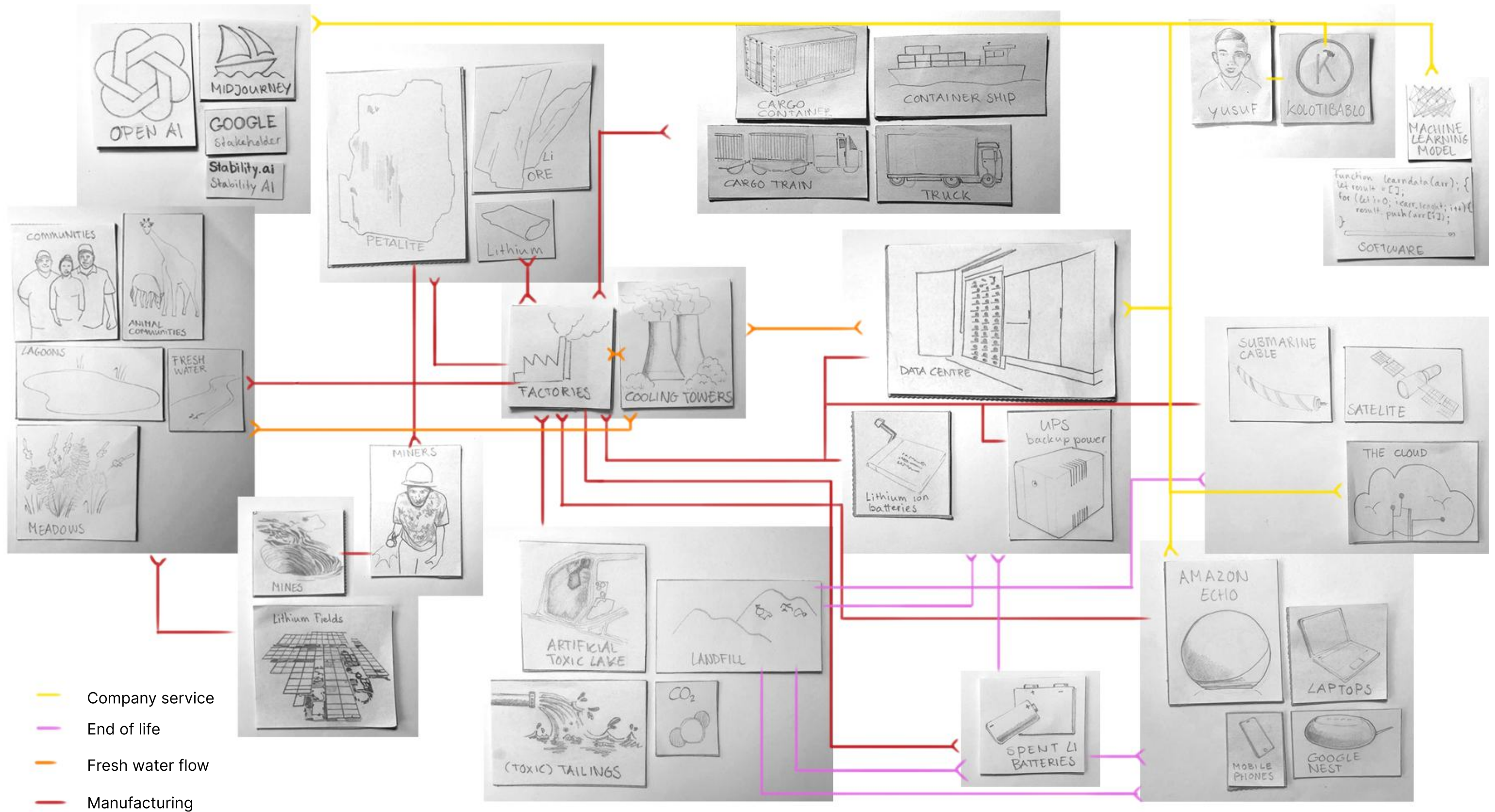


Fig 18: Map 5, the lithium cycle

Map centering around lithium

This final map looks at the cycle of lithium in the AI ecosystem. Just like the map on page 13 & 14, in the chapter on ecology, there is a map of the natural cycle of lithium, seen in Fig. 19. The map made shows a cycle anything but natural.

The legend distinguishes between 4 groups of interactions. The first is company service. These lines connect what we see very obviously as provided by these companies and the first factors behind that. However, through the other interactions they are connected to factors further down the line.

Next comes the end of life. This shows the things which are in their final form and are destined for the landfill when not usable to us anymore.

Following up, fresh water flow connects the water cycle to the lithium cycle. Lastly, manufacturing shows the role of manufacturing in this map on lithium.

Lithium is needed for many things we use in our everyday lives. The main application is in modern batteries (Schlesinger et al., 2021). These batteries can be found in our phones, laptops, electric vehicles such as cars, etc. At the current rate of extraction, lithium reserves will be depleted in 200 years. Existing lithium mines will be out of operation in the years between 2030 and 2060 ("The World's Ten Largest Lithium Mines," 2024). After this new grounds will be explored to extract lithium from the earth.

Most likely, lithium will not be extracted at the current rate, but much faster, due to growing demand. This demand is turning meadows and lagoons into salt flats, extremely lowering biodiversity and destroying ecosystems. On the next page fig 20 shows such salt flats.

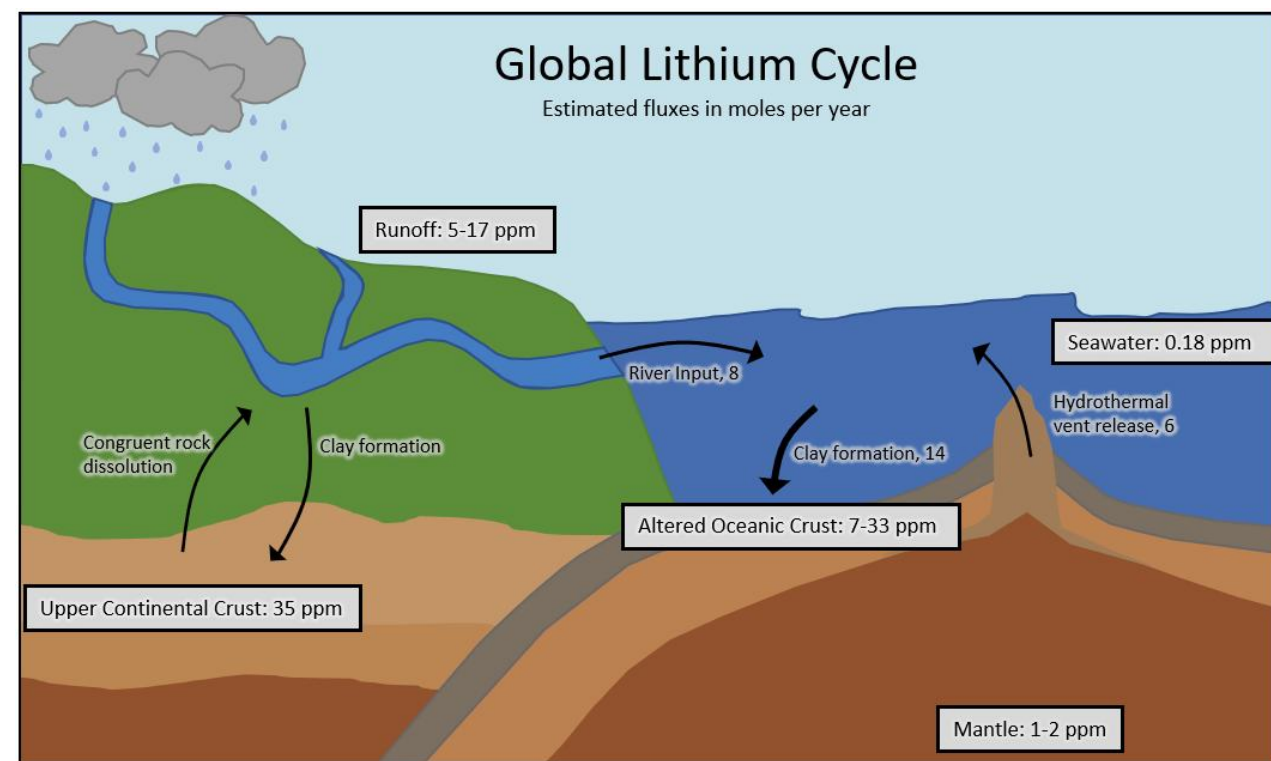


Figure 19: Biogeochemical cycle of lithium

Finally when they are depleted, the mines leave a dried out open pit in the earth, abandoned without its use for people.

The mining itself is energy intensive, often still depending on crude oil, but needed to extract the lithium. In the process of mining, unfortunately, not only lithium is released from the earth, but also other toxic metals which harm local life (Sovacool et al., 2020; Zheng, 2024).

When mining for lithium, the material taken from the earth needs to be refined before it is of an usable grade. The images on the next pages, Fig 20 to 27, show the sequence from a mine to a product.

The mining being energy intensive, ideally lithium is recycled. It is predicted that even if a 100% off all batteries are recycled, demand is higher what can be delivered (Wanger, 2011).

Besides being energy intensive, the industry is very polluting. The art group Unknown Fields Division, tracked the most commonly used earth minerals to their source. They found a mine with a refinery in place in Inner Mongolia, China. Here an artificial toxic lake is the byproduct of the lithium mining and refining industry (Smith, 2022). Images taken at that site during their visit can be found on pages 31 & 32, Fig. 21 & 23 and Fig. 26 & 27. It exposes what is needed for us to use our luxury goods, far away from where we use them. Acid free refining is being developed, as a more sustainable solution than the current processing. This new process has limestone as a waste product. Currently, Tesla is developing its own inhouse acid free lithium refinery. They claim this a useful material for construction (The Tesla Team, 2023). Besides potentially being a useful construction material, it is also a limiting nutrient. This means that increasing the amount of available limestone will lead to the flourishing of some species. This in its turn will lead to the death of many other species who can not compete with the suddenly flourishing species.

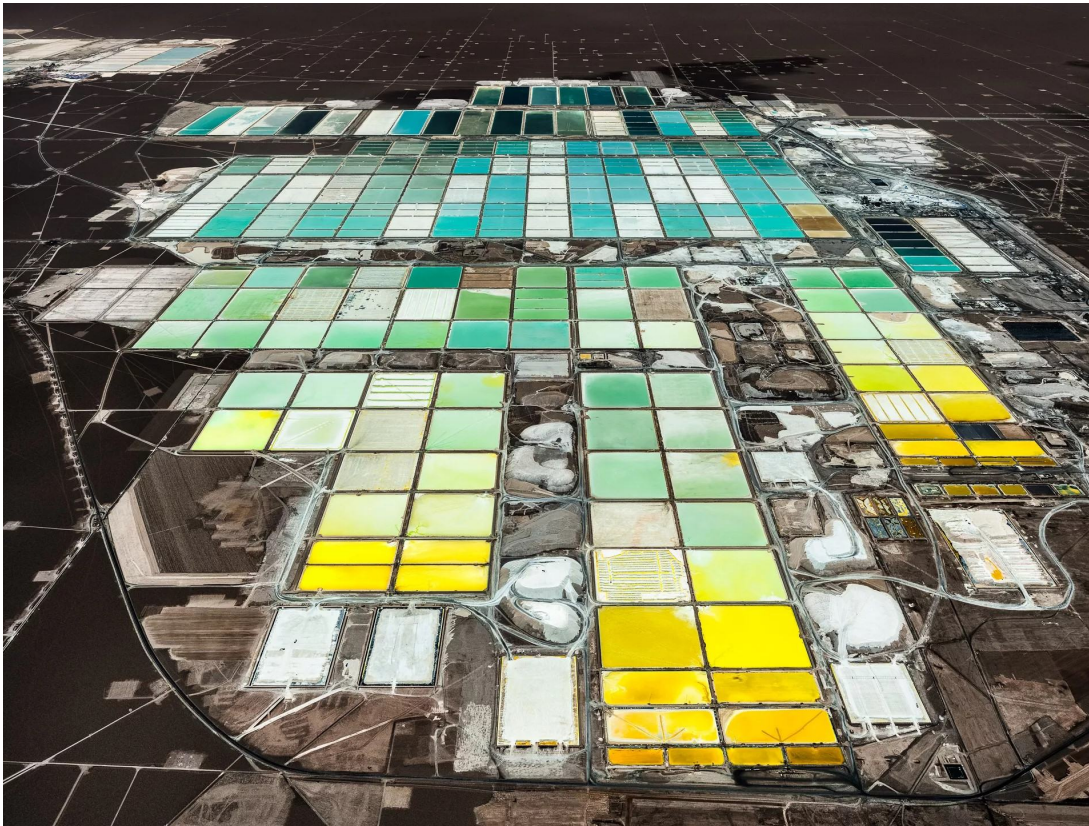


Fig 20: First in the sequence. A liquid mine.
'Lithium Fields' in the Salar de Atacama salt flats in northern Chile by [Tom Hegen](#)



Fig 22: Second in the sequence, pegmatite extracted from a *more classic* mine. Pegmatite textures, department of geology and planetary science, university of pittsberg



Fig 21: Also first in sequence, a more classic mine.
Toby Smith/Unknown Fields: Cross-section of coal, earth and top-soil on the edge on one of China's largest coal mines, that supplies fuel to run the nearby rare earth plants



Fig 23: Third in sequence, a lithium refinery.
Toby Smith/Unknown Fields: Workers monitor a volatile mixture of lime with molten iron at one of the blast furnaces within the Baogang Steel Company.



Fig 24: Fourth in the sequence, refined lithium.
Spodumene, department of geology and planetary science, university of pittsberg



Fig 25: Fifth in the sequence, the final product.
Lithium battery



Fig 26: Also fifth in line, a toxic sludge forming an artificial lake.
Toby Smith/Unknown Fields: The highly toxic and radioactive tailings of a rare earth refinery.



Fig 27: Also fifth in line, the toxic lake.
Toby Smith/Unknown Fields: Harvesting toxic clay on the lake side

Policies on (gen) AI

The ecological perspective shows that everything is connected. This means we carry a responsibility not only towards our own species but to others species and non living materials around us as well. When it concerns such big responsibilities, we often look at governments. In this part I consider the role of governments, and their role in the face of ethical and responsible development of new technologies.

What do governments see in the past, present and future which are required for development of new policies?

To understand this in context, I will look close to my home. I will consider lawmakers, at different levels: the European Union and the Dutch government. These are the institutions who should protect against harm of new technologies and enable use them safely. What is, in their eyes, needed when it comes to the risks and opportunities considering AI? And in project, especially Generative AI.

In general, governments focus on the harm which can be done to the users of Gen AI. The european parliament (EU AI Act: First Regulation on Artificial Intelligence, 2023) formulated that Generative AI tools should meet the following requirements:

- “Disclosing that the content was generated by AI”
- “Designing the model to prevent it from generating illegal content”
- “Publishing summaries of copyrighted data used for training”

Risks presented by the European parliament are underuse and overuse of AI; missing opportunities to put AI to use resulting in competitive disadvantage, poor implementation of important programmes or applying in scenarios where it has no added value, leading to waste of investments. Also identified as a risk is liability; who is responsible for a car accident involving a self driving car? Furthermore, AI is seen as a threat for fundamental rights and democracy. The design and data of AI can both be unintentionally biased. Democracy too is threatened by AI, due to extremely realistic fake content or manipulating what is shown to end users. What's more, AI is seen as a danger to the number of jobs available.

These are some examples from a long list of threats identified by the European Parliament, potentially harmful to the end users, so to speak.(Artificial Intelligence: Threats and Opportunities, 2023).

And, ofcourse, generative AI is also praised for what it can bring.

What seems to miss, however, is the other damage done in the process before a user can access a tool on their laptop.

Maybe this is not considered a concern to policy makers, because improving everyday life of humans is their priority. Having access to AI tools for more efficiency and for creative expression are surely improvements to foster. As long as privacy and bias are not a problem (Artificial Intelligence Act, 2023). But if indeed general wellbeing of humans (and humans only) is their priority, they should be concerned nonetheless, regardless of privacy or bias. As we are destroying our own home, depleting natural resources and harming ecosystems, in this search for ethical and scalable technology. Wait, for this we can use AI tools too maybe?

A google search on sustainability of AI brings up hits mostly praising the role of AI in the search for sustainable solutions in almost any field you can come up with (Artificial Intelligence Act, 2023). I don not mean to argue that this is all wrong, but I do question it. How does using AI to save the planet, applying it to find sustainability solutions, weigh up to the cost of AI itself? Will the resources and other elements we are trying to save, to keep this planet inhabitable, be depleted by using them to fuel this solution finding?

Explainable AI, hitherto, ignores the physical embodiment of AI and its appetite for resources. As seen in this chapter, the same ignorance can be found in governments. Looking at their role in the Netherlands, in their own words they are responsible for creating and maintaining an environment that is safe and healthy for humans (Government of the Netherlands, 2013). It seems that the space AI takes in, in the environment they are meant to make habitable, is considered to be solely digital. If ignorance is indeed the reason for this, then who can blame these institutions when there is so little public knowledge on this topic? However, there might be a conflict of interest, as governments are also responsible for economic growth. Again looking close to home, in the Netherlands there has been an increase in the amount of data centres, which is an important player in the AI ecosystem (Dutch Data Center Association, 2024b). This is good for economic growth as AI is a growing market and big companies are interested in Dutch land (Eemshaven, Netherlands – Data Centers – Google, n.d.).

No risks of harming planet earth, the environment of every human, are considered or identified in recent policy developments. This underlines the urgency of attention for physical (Gen)AI. Be it the true cost consisting of fossil fuels, non renewable resources for computation, water streams, data acquired from dark places, labelled at dark places by people with no name (Crawford, 2021).

Other perspectives

The conducted interviews explore different perspectives on the topic. Breaking out of my thinking offers a necessary refreshment, providing me with insights on relevance within the researched area.

4 interviews were conducted, with the goal of learning about other views on the topic, enriching my research. The interviewed were; 2 foragers Jochem and Dennis, DFI alumni Seowoo, Ethics & Philosophy of Technology researcher Olya and finally data centre engineer Remko.

Municipality Rotterdam

11 januari

Jochem and Dennis are two forest rangers in the municipality of Rotterdam. To me this is very interesting as Rotterdam is known to be a very grey city. I was curious what their view on nature is and whether they saw nature and the city as things working together or maybe even as one. Besides this, I wanted to learn how they felt about the development of AI. Both for the opportunities it offered as well as the threats it brings in different ways.

We discussed some ecological concepts in relation to their work environment. An interesting topic was the setting of boundaries on ecosystems. In Rotterdam there are green areas. These are labelled as separate ecosystems, but in doing so the interactions between them are ignored as the focus lies on the interactions within that ecosystem. Furthermore, setting these boundaries makes the ecosystem seem somewhat static. The line that is drawn tells the viewer 'this is it', while actually it is ever changing. We touched upon the role of decomposers in the city ecosystems. In the city there are species we see as dirty or annoying, like rats or seagulls. While actually these are of importance to the bigger system, as they consume what we leave as waste. In doing so they are shapers of the cities as well. We speculated on whether AI is an invasive ecosystem, as it destroys the existing ecosystem by taking everything it needs. Especially the rate at which it does so leaves other species without a chance to adapt.

Finally, they rightly pointed out they did not really feel they had a choice on whether to use AI or not. Both because they felt the need to keep up with today's technologies and because it is embedded in systems without users knowing it.

Library The Hague

18 jan

In her master's thesis Seowoo Nam explored how forest data can be gathered with respect for and inclusive towards the interdependencies among trees, humans, and other species. She looked for more-than-human data to collect from the forest, with the goal of approaching governance of the forest in an inclusive way.

We talked about data, what it is, where it is and how it is used. Seowoo now works for a design company specialised in working with data. She sees data as "just data". Data can be anything and anywhere, but it has to be gathered. When gathering data there are more factors than just the goal of insight at play. Time and money influence what data can be collected. After having gathered the data, the person who processes it is the one to decide what is relevant and what is not. And how the insights are presented in the end is also a personal choice. The usage of data is the representation of someone's worldview.

We wondered about the concept of managing nature. Seowoo found that today we see nature as something we can deploy to help us reach our goals. It is something that captures CO2 and releases O2 and it holds water in its soil. We rarely consider the needs of the trees, plants, animals and other organisms. When plans are made it is hard to see all of these as stakeholders, because they experience the world in their own way. A way that is very different from ours. They have different life spans, needs and threats. The term managing itself has the connotation of a power imbalance. Whereas, we thought, teaming up would imply a more equal process.

Talking about AI, and how she sees it being deployed at her work, she feels there is a lot unknown

“decomposers are actually rebuilders”
-Jochem Hagoort

Fig 28: Watery bodies, Sarah Fokke, 2022



Ethics of technology TU delft

1 Feb

Through Nazli I was introduced to Olya Kudina. She is an ethicist of technology, and currently works at the TPM faculty as an assistant professor. She does research into the interaction between norms and values and the development and adaptation of technology.

With Olya I discussed the research that I have been doing up to the first of February. Together we looked at the maps that were created to structure the information found. Olya appreciated how the maps provided an overview of the systems' separate factors as well as their entanglement. She saw great value in the ecosystem mapping approach, because it highlights Generative AI as a sociotechnical system.

We talked about how AI is utilised in fighting climate change, while the impact of AI itself is not accounted for.

What the maps show, which she formulated so accurately, is that one can not engage with the invisible. This is concluded by looking at where the user or interface of the user is located on the map. This is somewhere at the edge. Nevertheless, we do have a very real relation with water. We use it everyday. We ourselves are part of a water cycle, too. This is beautifully visualised by Sarah Fokke, a Dutch artist. Her installation 'Watery Bodies', seen in Fig. 28, explores the physical relation we have with our surroundings. She sees water as the element that allows us to connect with our surroundings and all the other beings in there as well. Since All need water, they consist of water and have water flow through their bodies. Where then does your body begin and end, she asked herself. This is an interesting question which can be projected on many beings and elements.

You can connect with the things around you through water, but by using Gen AI systems, we connect through water with places all over the world.

We brainstormed on ideas on how to engage computer science students into the physicality of AI systems. There was this idea of asking 'what is it' over and over again. This would force the students to break things down into their physical components. A follow up question could be 'where does it come from'. These questions will lead to places all over the world.

Olya, in line with Nazli and Vera, advised me to choose an interaction, location or material to focus on. And then find the intersections between digital and physical.

On the topic of using AI in this project she said "Don't be a saint". AI is a great tool to work efficiently and a graduation project is big. If AI is used, make it a point of discussion. This is more interesting than straight out choosing to not use it at all. This does require some courage on my side, and some open mindedness from the public.



a



b

Fig 29: Images of the outside, a, of Smart DC Rotterdam, and the inside, b, of that same data centre.

Smart DC Data centre

19 March

Smart DC is a data centre built in the Van Nelle factory in Rotterdam. The outside and inside are shown in Fig. 29. When I contacted them they were very quick to reply and happy to give a tour. This was a stark contrast with many other contacted data centres. Either I did not get a response at all, an automatic response stating I would be contacted as soon as possible (which was never), or I was not able to visit for a tour. Smart DC matched me with Remko, one of the inhouse engineers, and we scheduled the tour for a week after the first contact.

He was very open about their sources of water and energy, although he would not name quantities consumed as this is secret information. This did not demonstrate transparency, yet he was happy to answer and elaborate on many other questions.

Remko has worked in data centres for over 20 years now, all in the Netherlands. One thing that became clear is that every data centre is different. All have their own preference for cooling and energy sources and backups. These depend on size, customers, location and many other factors as well as constant development in data centre technology. As a base, every data centre needs backups for everything. Backup for power supply, backup for power infrastructure, backup for cooling systems, backup for fire detection systems...

Next, a data centre is a highly optimised building. This is achieved best if systems can keep up to date with new innovations in cooling and energy efficiency.

The location in Rotterdam uses an air cooling system. Nevertheless, Remko told us water cooling is a very common way to cool, and that he had worked at places where they did that as well. He confirmed cooling systems use drinking water for cooling. To this water softeners were added, but initially no other chemicals. Cooling with water uses water towers. In these systems the water has to be checked very often for legionella, because this develops easily. Legionella is a bacteria always present in water, developing fast when the water stands still (Legionella expert TU Delft, personal communication, March 28, 2024) If this is found the water does have to be treated with chemicals. The water from the system is discharged into open waters or into the sewer system.

When touching upon the criticism data centres receive increasingly in the last few years, Remco explained how it is unrealistic, and to him unfair, to judge a data centre as just that specific building on its own. In his view, a data centre is at the bottom of a triangle. There are so many elements, companies, groups and individuals, reliant on data centres.

Companies which are in need of data storage or offering users cloud services, others building their product on this connectivity, like online gaming. Or our connectedness with others in this digital age, through many online platforms.

Remco strongly emphasised how they are at the bottom, with many others relying on them. Still they depend on others as well. They do so, quite directly and on a daily basis, on companies generating energy, others specialising in water accumulation and treatment solutions, companies taking care of the infrastructure they need. Besides this they build on companies developing batteries, servers, as well as all other components making up the data centre. Ofcourse, I could go on and on, because that is the point of my research:

Tracing these lines to their resources

Besides this they rely on their environment

Research conclusions

From the research done in this first phase of the project, conclusions will be drawn. I will go over the parts, the maps, the part on policies, and the interviews and connect them to each other. With these conclusions final statements are formed summing up the insights gained, to help me in formulating design directions. The design directions are discussed and one is chosen to continue with. Finally the limitations of the method mapping will be discussed.

Overall conclusions

All maps are considered, discussing insights gained through the process of mapping as well as from looking at the maps individually. In the subchapter on policies I explored what is now seen as acting responsible in the face of the development of these technologies. Furthermore, I integrate different perspectives, enriching the research. These all together present promising design areas. Finally design directions are discussed to continue with in the next phase.

The 5 maps on interactions between factors show different levels of the Gen AI system. They do not present information in the same way. Some are tangible, appealing more to imagination; a mine is something you can envision through images you have seen in your life and stories on the news or other platforms. The more abstract maps, on the other hand, leave a lot to fill in for the reader. A concept like politics is broad and subject to experience and interpretation. I don't see this as a problem, it represents reality. Just like a mine is a word subject to interpretation through mental pictures, so is politics. However politics is more opinionated. Still, the level of description is an objective way of describing the factors. However, what factors are included in the maps is not completely objective. What is included is a result of both research in this area and what I deemed relevant in the gen AI ecosystem. Relevance is decided on level of detail, aiming to provide a more holistic view on the system, yet focussing more on exposing the physical side than the digital side. Exposing this side is important after learning the lack of attention to the physicality of AI within the research field of explainable AI. The urgency of focussing on this side is underlined when looking at policies which are being developed, completely ignoring this physical side as well. Finally, through the interviews I learned people are curious to know more about this side. The maps show that the user has no access to the whole system. Curiosity can only arise from having something to question. In the chapter on Explainable AI I explain my positioning and focus in the research phase. The interviews show the desirability of the expansion of the research done and methods developed for explainable AI to cover this physical area as well. This opens an interesting design area for me to work with in the design phase. What if this physical industry of AI was not invisible to the user. It would create the opportunity for users to make informed decisions concerning AI.

The maps become more interesting when looking at them together. Making the maps brought to my attention that there is a crossing between the digital and physical world, so to say, that is needed in understanding the ecosystem. By putting the maps together they complement each other by showing different views on the ecosystem that are all relevant. And also by allowing this navigation from the one world, the digital, to the other, the physical.

Where one map ends with water, this thread is picked up in another map. Things we experience as separate things are entangled, and relevant to each other's existence. The process of mapping and the maps show how much there is to Generative AI. It can not be put in one map, and it can also not be put in five maps. These maps are far from showing everything there is to generative AI.

The maps that have been made first are the cloud and data centre map. These clearly show that even when a person (me) can dedicate all its time to mapping Gen AI for a few months, the level of detailing that is reached is far from complete.

The final maps you find on the previous pages are the result of many iterations. More and more factors were added, as pieces of a puzzle that were found and layed. Still, these puzzles are not complete yet.

All this information is too much for a human to take in and understand. As Seowoo understood it, there is a capacity of the mind, there is only so much it can see at once (Personal communication, 2024). And Generative AI is too much to see in one piece. This is a known concept in epistemology, the theory of knowledge, especially on its limits.

Concluding statements

GenAI operates in two different worlds, digital and physical.

Both digital and physical worlds are hidden from the user, and you can't interact with the invisible.

In all maps, the user is somewhere at the outside of the map, if placed on the map at all. This is because the only direct and deliberate interaction of the user with the system is through an interface of a device. The user does have more interactions in the ecosystem, but less direct. To name an example, a data centre and a user compete for the same resources, which is potable water. Just like the data centre competes with fish for freshwater. In this case the fish does not stand a chance, and research shows if developments keep at the same rate, we also do not stand a chance, we are like the fish. Another less obvious interaction is between a user and bias in a model. This is a mutualistic interaction, both enforce each other.

If such interactions would be visible, it would be too much for the human mind to comprehend.

This very real relation is there but not interacted with very consciously. AI is seen as a sociotechnical phenomenon, in the way that data is something digital yet something from the real world. We are data, but we are also inhabitants of the world from which we take physical resources to build AI.

It is not feasible for humans, and other species, to interact very consciously with all other factors. It is simply beyond our capacity. This is something which was confirmed in the interviews. Everything is entangled but we have to simplify to get a grip on things.

Materials in the GenAI ecosystem are not recycled, making for an unhealthy ecosystem in human measures.

The nutrients in the system are not being recycled. If a natural cycle was to be followed, returning the nutrients to the earth, we would still not be able to call this recycling, because nutrients are being extracted at a rate which is so much faster than the rate at which materials are formed in the earth. Following an artificial cycle might be possible if the grade of material can be recovered so new products can be made again. Even then this would cost a lot of energy and water.

Explainable AI is focussed on mathematical side, while this is not the whole picture, it should also include the physical side

Where I was first focussed on the mathematical and digital side, the new insights show the need for explainable AI to include the physical side.

Design Direction

With the insights from the maps there are three promising design directions that fit my goal of contributing to explainable AI. They fall in the area of making the invisible visible. To do so, one point of (non)interaction will be chosen for an intervention to make the vastness and entanglement of gen AI systems visible.

The three design directions:

1. Linking the interactions on a screen to physical materials in the world.
2. Engaging users in a direct interaction with a material flow of AI.
3. Recording information and communicating it in a way that is accessible to users.

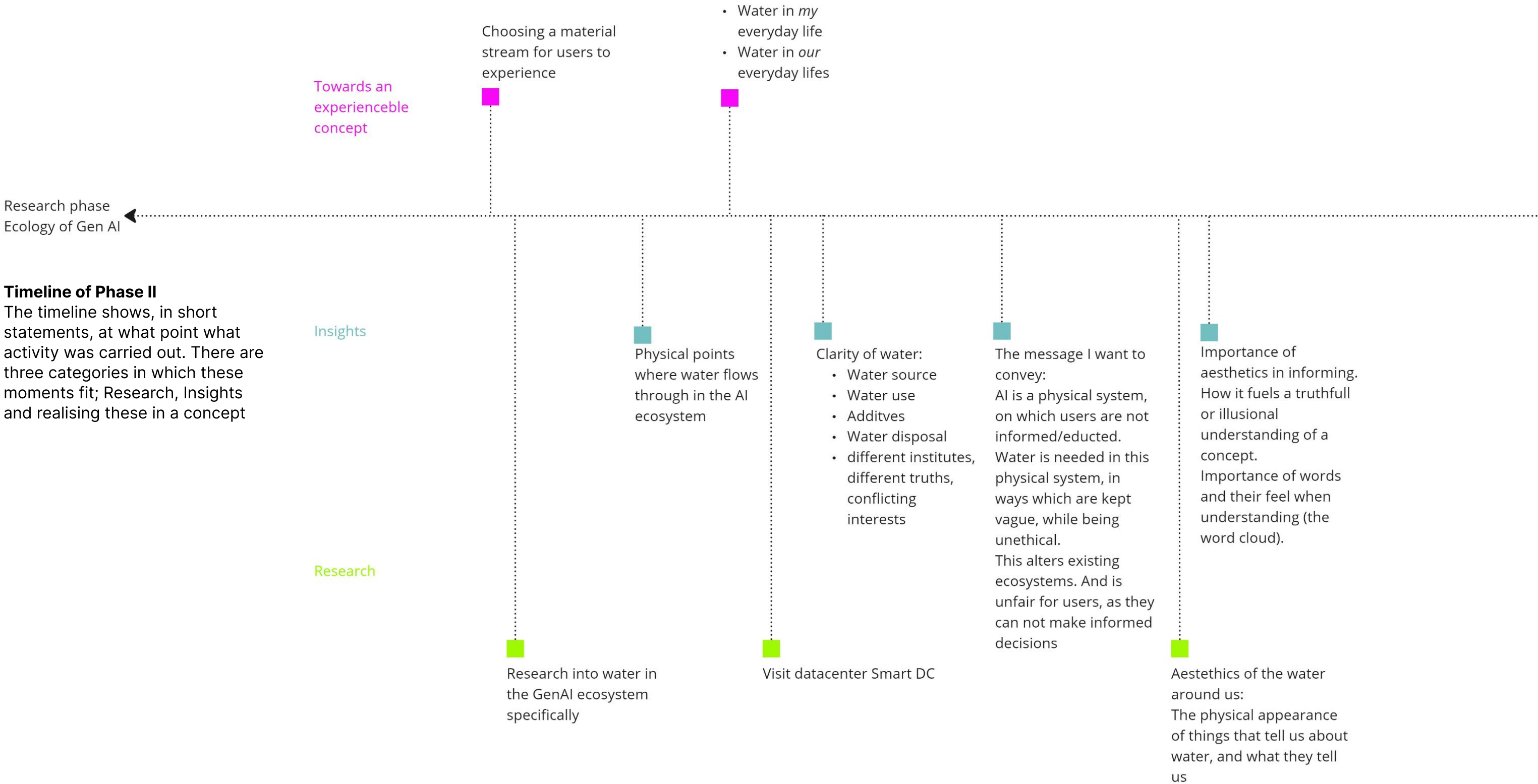
With Olya I discussed what is relevant to focus my project on. The interview with her can be found on page 35. We agreed that Generative and other forms of AI form a threat to existing ecosystems at this very moment. Exposing users to the current situation, and how using AI tools contributes to this situation is important and relevant at this very moment. Making the invisible visible, or making the intangible tangible will therefore be my goal in the next phase. An insightful interaction that is accessible to users creates an opportunity for increased awareness on this topic. Besides this, personally I would love the challenge of creating something in the world as opposed to something on screen. That is why I will be continuing with the second concept direction.

Limitation of mapping

It is worth noting that the cycles and ecosystem overviews do not go into every little detail. My goal was to cover several physical things, and things seen as digital (like data), that make AI. The maps help to get a sense of what I actually is, but getting a sense does not mean full understanding of the physical chain making up AI. This is also because of the boundaries set to the ecosystem.

Take the water cycle for example; The water cycle shows how water moves through the GAI ecosystem. Nevertheless, it leaves out when water is moving through which place and how much of it. Choosing to train a model during peak sun hours will allow for using solar energy, but because of the heat more water for cooling is needed (Li et al., 2023). The map shows the usage of water and where it is coming from and going to, which is interesting information, but only part of all there is to know about the GAI system.

To develop a meaningful interaction, more research will have to be done. In the next phase, first a material stream for users to engage with will be chosen. After that, what research has to be conducted to come to a more contextual understanding of the industry, will be discussed.



Narrowing down

Material stream

As discussed in Concept development on page 40, the format of the final output of the project will be an experience for users of the currently available GenAI tools. The experience will give an insight into the physical infrastructure of GenAI. The infrastructure can embody many materials and places. In this experience I want to highlight the vastness of the infrastructure in an accessible way. Therefore I will focus on one material stream. Choosing one material will keep the amount of information manageable for visitors. And, by choosing a material instead of a building/place, I can incorporate more steps of the infrastructure. Because the material moves through these places.

The physical material streams that came forward in the maps are:

The physical material streams that came forward in the maps are:

- Lithium
- Rare earth minerals (in general)
- Water
- CO2

Despite all these streams being interesting for showing parts of the GenAI infrastructure, water is chosen to work with. Of all these materials, water is the one receiving least attention. Only recently, focus in research has been shifting to water use in the AI ecosystem. One of the main conclusions of research into this area is that there is very little transparency, and even things being kept a secret on purpose (Li et al., 2023). This makes for a very interesting topic to work with in the final phase of the project. To me this physical material flowing through the infrastructure represents the same lack of transparency as is the problem with the digital side of AI. For both one could say they are a black box.

To build a meaningful experience, I will research this topic specifically; Water use in the GenAI ecosystem.

The Flow of Water through the Gen AI ecosystem

Research in 2023 showed regional shortage of potable water in the Netherlands. The demand for potable water will only grow in the future. It is expected that this will lead to a shortage for all 10 water companies in the Netherlands in 2030, if no action is undertaken.

The government is held responsible to take such action. However, producing or sourcing water at new locations is difficult because of conflicting interests. There are several industries using water in their processes (Quick Action Needed to Prevent Drinking Water Shortage in 2030 | RIVM, n.d.) One of them is the Generative AI industry, which makes use of data centres in the Dutch landscape. These centres rely on local water sources. There is very little information available on data centre water use in the Netherlands nor other places in the world. Most of the time it is not reported if recorded by the owning company at all. (Vegelian, 2021; Mytton, 2021)

Besides the cooling of water there is also the discarding of it. When the water leaves the cooling system it is discarded into open waters and becomes available to be used again, according to CBS(2021). After 2021 the Dutch statistics company did not report on water used for cooling purposes anymore.

The disposing of cooling water into open waters might be problematic considering the addition of substances to the water. Many data centres themselves state that no additives are needed to use water for cooling. However, other sources state something different.

Lubron is a water treatment company referred to by the dutch data centre association. They “focus on cooling water treatment and humidification in order to deliver optimal heat transfer and operational reliability” (Dutch Data Center Association, 2024). This means water needs treatment before it is ready to be used for cooling.

Rijkswaterstaat looked into additives found in blowdown from water used for cooling facilities. They found much of the additives are discarded unfiltered, in large quantities, into Rijkswater. Microsoft is allowed to dump water with a chloride concentration between 250 and 750 mg/l, and Nimble is allowed to dump water with a chloride concentration between 250 and 1500 mg/l. This is because the specific body of water Nimble disposes into already has a higher salt concentration. Because part of the used water evaporates in the cooling process, the salt content of the left over, to be dumped, water rises. Because of this new water has to be added and there is a blowdown to maintain the desired salt content . In 2022, the yearly emitted active substance of all industries was estimated at 720 tons. This includes data centres as well as other industries like the metal industry and the chemical industry.

As there were many different sources stating different things, it is hard to know what to believe. A tour and interview with Marko, an engineer at the Smart DC data centre in Rotterdam, brought clarity. He has been working in the data centre industry for over 20 years and worked in data centres that all operated differently. He could tell me that indeed drinking water is used for cooling and that additives were needed. Chloride is always used, and other additives differ per data centre. One thing that goes for all data centres cooling with water, is that salmonella always poses a problem. This is treated with chemicals although he could not say which ones.

Water is also used in the manufacturing industry, on which data centres and other points in the Gen AI ecosystem rely. Furthermore water is also used in the energy generation industry, on which both manufacturing and data centres rely. A final important big stream of water to mention, is one geographically a lot further away. In the refinement industry a lot of water is used. In the maps chapter attention is paid to this interesting and dirty stream.

On additives research showed that phosphorus compounds (phosphates and phosphonates), corrosion inhibitors with nitrogen, polymers, oxidative biocides like chlorine bleach, and non-oxidative biocides are the additives most frequently used. Biocides are added to cooling water in order to stop biological growth fouling the systems. Other agents are used to prevent the accumulation of lime scale, disperse infiltrated dirt, and inhibit corrosion (Berbee and Rutten, 2022).

Water is seen as a resource we can put to our use. In the case of cooling it is a carrier of heat and cold. To a cooling facility, a local water source provides coolness. This is the ecosystem service. The water provides this service only if it is taken out of the ecosystem. Ofcourse the water can be returned to the ecosystem, although slightly altered. As mentioned before, part evaporates, displacing the water molecules, as seen in Fig. 30. The water returning contains additives, barely filtered, and is warm, as it carries out the unwanted heat from the factory or data centre. Can this water provide the same ecosystem service again, and if so for how long? Other species also rely on that water, it provides ecosystem services to them too. Can the altered water, in temperature and composition, still meet their needs?



Fig 30: Steam rises above the cooling towers in The Dalles data center in Oregon. These plumes of water vapor create a mist at dusk. Google photo

Water to us

What is the role of water in our lives? How do we relate to it on a daily basis? These question help to identify objects which can be used to communicate the water flowing in the GenAI system to the public.The pictures in Fig. 31 show snippets from my everyday life interactions with water



Fig 31: A collection of images of water around me

Water infrastructures

We have many ways of handling water inside and outside. As it is a liquid, it flows through pipes to where we want to have it. Pipelines are the infrastructure in which we recognize water. That is, in some specific pipes we recognize water.

Pipes of curiosity

Below, in Fig 32, you see pipes photographed while I was walking around in Rotterdam. They left me questioning what is connected on the other side, where they run to, and why they are so stubbornly positioned on the sidewalk. What is coming out of them and do passers by breath that in while walking there? Or is something going in? This questioning attraction would be an interesting quality to use.



Fig 32: Two pipes sticking out of the ground on the sidewalk

Fig 33: A collage of water in many of its shapes and in relation to each other



This, Fig. 33, is an outlook into the world from the magazines in my living room. Interesting patterns which emerged where the groups of colour: Lush and green for areas where there is a lot of water and warmth; Oranges for areas where water is withdrawing or always on the low side; black, dusty and more hard greys for water in urban areas and industrial uses; icy blues for colder areas; warm sandy colours combined with saturated blues for coastal places.

Message of the concept

Negar Sanaan Bensi and Paul Cournet (2023), two architects, asked themselves the question; “What is the cloud?”

This led them on a journey resulting in the book Datapolis. The book exposes what data is through multiple lenses, focussing on the physicality of it.

In their book, they elaborate on the architecture of data centres. They explain how they are built from the inside out. As machines with a casing around them. Which is done to be secretive towards the outside world and efficient. An example of the outside of a data centre can be seen here in Fig. 34a. Which is in stark contrast with the inside of that very same data centre, as seen in Fig. 34b.

My goal is to create the opposite. I want the AI infrastructure to be out in the open instead of closed or behind doors. However, in the installation I want visitors to also get a feel for the lack of transparency of the current system. The installation shows a contrast between being out in the open, but still disguising some things, evoking questions with the visitors. This means they will have learnt new things, but end up with more questions as well.

I realise more and more how important aesthetics as well as the words we use for things are in informing. If a word or aesthetic does not represent what it actually is, users will easily be misled. This is often done and not always a bad thing per se. Nevertheless, losing sight completely of why users can use something, like a genAI tool, fosters naïvity, which I believe is not a good thing. It is so easy to take something for granted, especially if you don't know what something really is.

Another view on the aesthetics of technology was formulated by scientist & science fiction writer Arthur C. Clarke. He formulated three famous laws of which the third was most known. It goes as follows:

“Any sufficiently advanced technology is indistinguishable from magic”(1973).

I see truth in this law as well as a problem. As stated here, magic is an inspiration for developing technology. The goal is for the user to not understand what is happening, but to just be amazed. In the installation I want the opposite to be true, because I believe the opposite to be true. Technology is not an invisible wonder, it is visible materials connected by people's ideas and labour. Nor is it solely our computers or other smart devices, it is everywhere in the landscapes around us. Right outside our doors, running through our cities, taking the shape of blocks in meadows. This is what I would like to offer to users: something that is undeniably technology, connected to how we actually use that technology. In the case of this installation that use is the use of generative AI tools.

Thijs Biersteker, an ecological artist, brings together science and art. His work is to “extract emotion from data”. His pieces convey the work done by scientists.

The installation of the GenAI infrastructure is the output of connecting facts with my emotions. It takes the research, the maps and knowledge gathered on water, and allows for other people to connect to it.

The challenge is to keep it accessible, and not alienate people. How can I integrate the information gathered while not presenting visitors with dry reading material?



a



b

Fig 34: Images of the outside, a, of Smart DC Rotterdam, and the inside, b, of that same data centre.

Ideating concepts to convey the message and create an aesthetic that represents the actual industry

Selecting promising concepts for carrying the message: A pool, pipelines, water tap

Selecting promising concepts: A pool, Vending machine, Pipelines

- (No) transparency:
- rainpipes communicate water, but you can not see what is inside of them
 - sound gives a hint, but does not tell everything
 - Tap hints drinking water, but other parts of the installation tell another story about water

First material tests: cardboard and plastic

First tests with rainpipes

Integration of Gen AI interface, through Ipad. Users can use a Gen AI tool and will directly experience water flowing as a consequence

What a pool would facilitate for: A pool has slides carrying water as well as many typical things telling a user about water. What rainpipes would facilitate for: Rainpipes are obvious carriers of water and found all around us. The idea of a pipeline infrastructure can be realized because of their aesthetics and their managability.

Character of the installation: Out in the open (as oposed to behind doors or below ground) Industrial (as opposed to digital and fluffy).

Conceptual:

- Discovery and questioning by user
- Provocation of user
- Waste of water
- Physicallity of AI infrastructure is in our backyards

Physical:

- (No) transparency
- Confusing visitors, mixed messages trthroughout installation
- source does not match use
- Landscapes around us where we unexpectedly find industry.

People need a strong action reaction connection to understand consequences of certain happenings. Like a direct link between sending a prompt and waterflow

How can visitors interact with the installation to experience physical AI?

What is possible with existing rainpipe parts and mobile watertaps? How can an interface be integrated into these existing parts?

Gen AI infrastructure

Pool

As the water coming out of data centres or factories is warm, since it carries out the heat created by servers or other machines, this could be used for a pool or a spa. Or even an artificial hot spring. The idea of a pool, however, is inclusive towards a bigger group looking at entrance prices. This is suited with the accessibility of GenAI tools, and makes it a more interesting concept than a spa.

The pool has many very typical interaction moments, which anyone who learned to swim would recognize. Frequent swimmers mentioned the reception, the smell of fries and chlorine, lockers, the benches which fold down to close the changing cabin, the sheet material used for these cabins as well as other things in the building, the showers before swimming. When it comes to the actual pools there will be the shallow pool, the deep pool, and sometimes the fun playing part with slides or streams. In the pool there are the floaters separating the 'lanes', the springboards and diving boards, the nozzles allowing new water into the pool and the racks on the sides of the pool for water overflow. The whole space usually has a very high ceiling and hard materials causing noises to echo very much, acoustically not ideal. In this space there is a lot of daylight, big windows, as well as a window from the cafeteria to the pool. The building in which the swimming pool is, usually also has other functions. These functions are mostly other sports (personal conversations, feb 2024).

Drinkwater Vending Machine

A vending machine could be a very interesting concept as it has a way of conveying information which we are accustomed to. The bottles on the inside show us what the options are. An interface for choosing one of them tells us the price. By interacting with this interface we get what we want, although sometimes not, everyone has an experience with something getting stuck in a vending machine. If such a machine would be combined with pipes at the back which could supply the bottles, an infrastructure could be represented.

This concept puts a very strong focus on the interaction with the machine, in this representing an gen AI tool, and the cost of this interaction being water use. But instead of the water being wasted, you get the water.

Pipelines

The pipelines represent the AI system. It is something that is all around us, living on the same resources; fresh water.

They appear to be tentacles of a widespread network. The pipes show up in many places, connecting the network from your location to the other side of the world, in the case of an AI system.

Using pipes to represent the water infrastructure would make the invisible visible. There is currently no accessible knowledge to act upon. This makes sense on the one hand, because the invisibility simplifies the world of the user. Making every cable, every material stream, every connection visible, would be extremely overwhelming. It would probably be so much information that you would ignore it all together.

However, presented in a manageable and insightful way, this could be a very clear message.

Although we usually would not have a direct interaction with such an infrastructure. In the installation I want it to be clear how this interaction is actually there. When we use a GenAI tool we use water. It is needed for cooling the data centre, for generating energy which is needed to run the data centre, for manufacturing all machines and devices in all parts of the ecosystem. And the water needed is not just any water, it is potable water. These are two points I want to make clear through interactions with the installation.

This concept is the one I will be working with as I see potential in how it informs the user. It lends itself very well to be industrial, and not fluffy. Also, I can play with the pipes feeling out in the open, yet still hiding some parts, like the pipes of curiosity recorded on page 42. One of my critiques is how hard it is to learn what is added to potable water used in the system. And that this is then discarded with these additives in open waters. A pool requires chloride for usage, making it a controversial concept. It would represent the wrong thing, making this concept unsuited for my purpose.

I do want to provoke the user, but by making them feel uneasy by showing them what is really happening. Not by adding to the problem.

The same goes for the vending machine idea. This concept would work with bottled used cooling water. The bottles would be an extra material stream consisting of single use items. A wasteful concept which isn't in line with my ideals. However, the idea of presenting users with the option to drink the water used for cooling, can be a very useful provocation. As this water was potable water to begin with. In the installation users can learn about the additives and then decide whether they would want to drink this potable water.

This can be implemented in another way in the pipelines concept. A tap can be placed at the end of the pipeline, at the place where the water would normally be discarded. It is a naïf intervention, trying to lower waste of potable water, provoking the user.

Developing through prototyping



Fig 35: Exploring with pipes made from cardboard

Tests with cardboard and test setup

What if the pipelines are placed in a stream and there is a difference in ecosystems around the two pipes. Around one the temperature is normal, where water is taken out of the stream. Around the other the temperature is higher than normal, because here the water used for cooling is discarded. This idea speculates on the consequences the water has on its environment. The temperature of the water is a topic hardly ever discussed, by data centres or other organisations. This makes it a topic too vague to make a statement about and include in the installation.

Cardboard was used to make a first test setup, seen in Fig. 35, it would be very unsuitable to use for the actual installation.



Fig 36: Exploring with pipes and setups made from plastic in my garden

Test with plastic and test setup

These small pipelines, seen in Fig. 36, allowed some testing closer to a more realistic aesthetic. What stands out is how recognizable they are in carrying water. Also people commented on how the pipes seemed to be moving in and out of the ground, as one long connected piece of pipe. This is a quality useful in the installation, as I want the pipes to represent a bigger connected infrastructure.

The open ended pipes are points for tapping water. This was less obvious to people. Here other options can be explored.

Gen AI in the installation

The link the pipes create with water is quite clear, through material choice. Drain pipes are recognized as carriers of water.

The link with gen AI is not there yet. The pipes can show the way water travels from a source to a factory, refinery or data centre and then the way it travels from these points to open waters. Somewhere in between an interaction with a gen AI tool activates the flow of water. If I implement an interface where users can use such a tool and by doing so, activate the flow of water, a strong action reaction can be created.

Several positions of an interface in the pipelines could be argued to be logical. An interface is made of materials that needed refining and manufacturing after which the device itself also needed manufacturing and it runs on electricity. All of this involves water. Close to the devices on which we use GenAI tools, is a data centre. By pressing enter to send a prompt a user starts the flow of water at that very moment. The other flows of water don't necessarily take place at that very moment or are activated by such an interaction. This makes the pipeline running from source to data centre to outlet the most suitable placement for a GenAI tool interface.

Interface integration

In the installation it will be possible to use a GenAI tool. The chosen tool is ChatGPT, as this is the most well known language tool. I wanted the tool to be a language tool because it allows me to integrate a sassy answer, when asked a question, which is seemingly given by the tool. This to provoke and evoke critical thinking about water and AI. Besides this, using a language model interface is an opportunity to provide some necessary background knowledge to make sense of the installation. The final interface can be found in appendix A.

The sending of a prompt starts the flowing of water, which can be realised in multiple ways.

First the flowing of water can be real or simulated by sound or light or other suggestions of water movement. As discussed below the pipe will be untransparent. This means using actual water is not necessary, the suggestion of it is enough. For this sound is sufficient, which can be played on a speaker in the pipe. One way or another a signal has to be sent to this speaker. I consider a few options to reach this goal. Either a sensor can be built using arduino, using a script to send a message to the bluetooth device.

Another method was brought to my attention which would limit the need for extra buttons and sensor and therefore limiting alterations of the physical device. This method is javascript injection. This allows you to alter the code used for the interface of the actual site. I have very little software skills and despite others helping me, sending this signal when hitting enter seemed very hard.

Another feasible option is building a mockup version of the interface in Figma. This would allow me to keep the same interface and use the same buttons for sending this signal. A final option is that I would press play from a distance without people noticing. This will be used as a backup option.

The practical integration of the interface in relation to the whole installation will be discussed on page 52.

Testing with drain pipes

Both on the conceptual and practical side, the suitability of drain pipes was tested. On the left, in Fig. 37, you see the first pieces, a tap point and a part indicating the rest of the pipeline behind it. It was put in two contexts to see the effect of the underground. The underground can contribute to visibility, but apart from that the underground also has to make sense. What is a context in which the pipes can be placed that contributes to the message I want to convey?

On page 54, this topic will be elaborated on. On page 51, what pipes are included and their configuration are discussed.

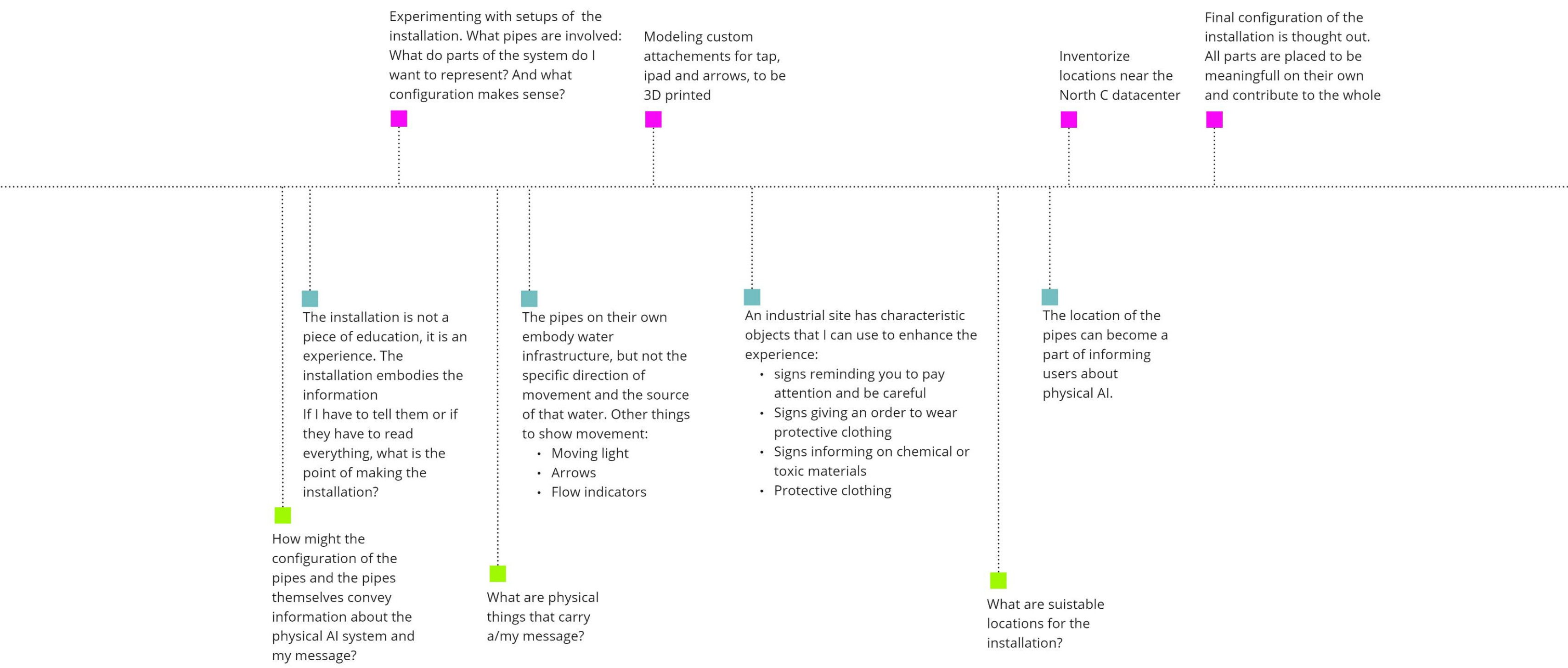
The aesthetic is recognizable for a big group of people. They carry a liquid and usually this liquid is water. On the other hand the mat physique hides what is actually flowing inside. This aesthetic suits the desired aesthetic as discussed in Message of the concept, on page 44.

The pipes can be used to build reasonably big structures. The size should facilitate user interaction with a water point and an interface, while covering a distance to represent the travelling of water.

Here the pipes in the back are half a metre high, which is too low for

Fig 37: Tests with drain pipes





Conveying information

The research on water in the AI industry will be condensed into pipes and a few interactions. The pipes are the infrastructure for water to flow through, from source to point of use and on to a point of dumping. These three points will be indicated using the pipes, for three streams of water: The stream of water in refining, in energy generation and in data centres. These are two big streams flowing in 'our backyard', illustrating how close to us this industry is. And one stream flowing far away from me, in the Netherlands, showing the extensiveness of the ecosystem.

The point of interaction with the iPad is where the streams come together. Because to interact with a gen AI tool, all streams are required. Putting the iPad in the installation, changes the positions of the user. In all maps the users now move away from the edge closer to the inside. Depending on which map is taken as reference they can now be positioned somewhere in between cooling facilities and dumping points, or right next to a data centre. This intervention lowers the barrier for experiencing the ecosystem and exposes the tricks behind what Arthur C. Clarke would call magic.

The second intervention is one that offers a questionable solution to lower waste of potable water. It gives the user an opportunity to tap the water, where it would otherwise be disposed of. In the installation, people can find that substances are added to the water, creating the question whether you would actually want to drink this so-called drinking water. The addition of the pipes through which additives flow can be found on the next page, page 51. Iterations on the composition of the pipes and communication of information are found here in Fig. 38 & 39.

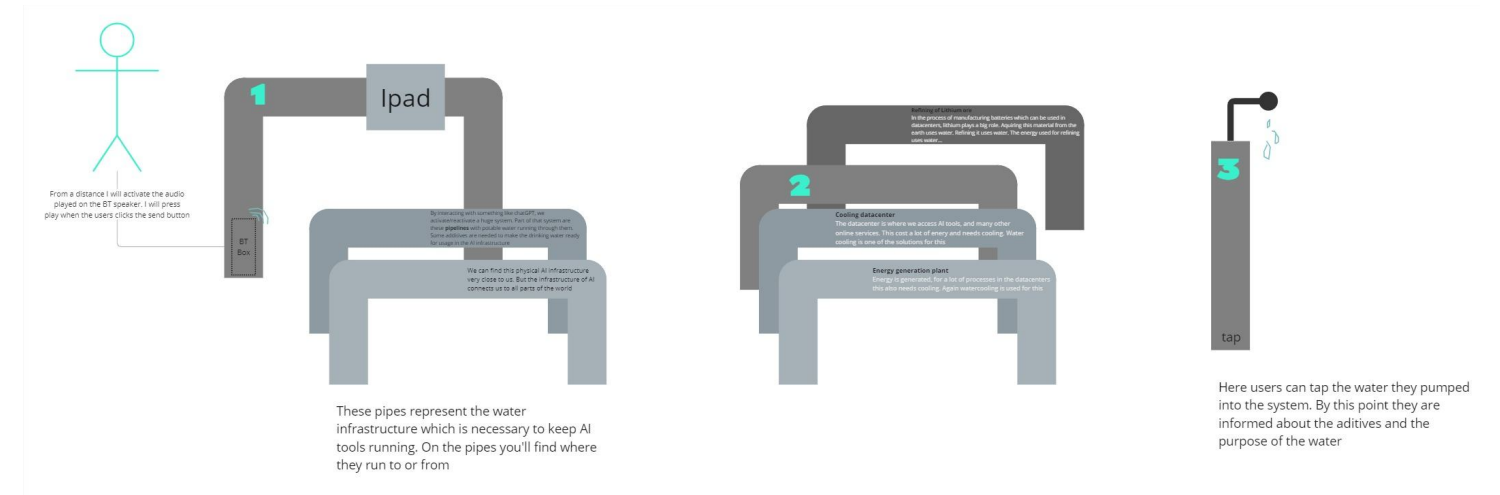


Fig 38: First visualisation of pipe setup

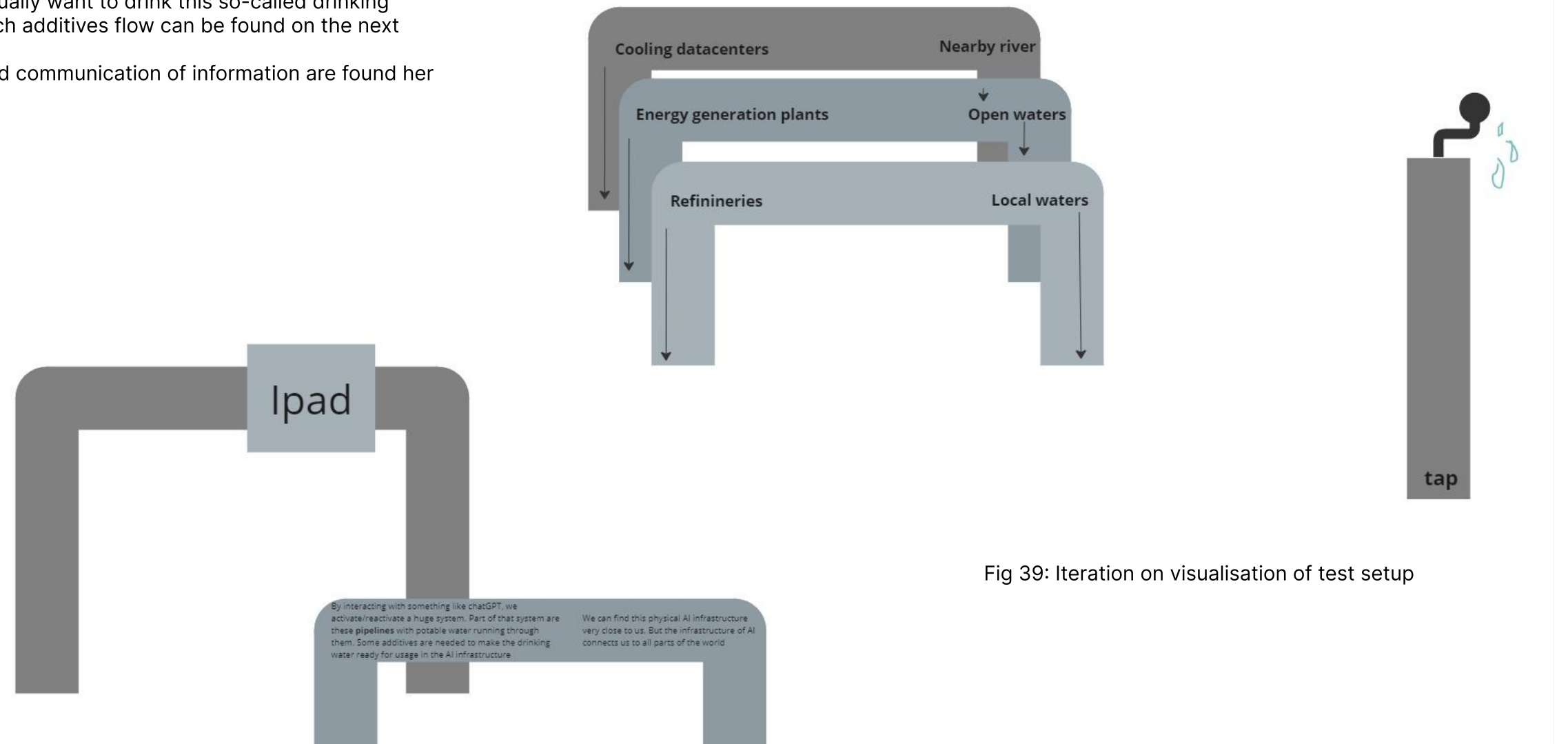


Fig 39: Iteration on visualisation of test setup

Setup of installation

The setup is important to how visitors walk through the installation, and with that how they experience and learn. Either the setup can be in a way that it makes sense from all entry points, or a path is created that needs to be followed. In the message I want to convey there are layers of information, you need one part of information before you can understand the next. That is why I experimented with a sequenced setup to start with. In this setup I imagined all information I want to give users, to be written on the pipes, as seen in Fig. 38, on the previous page. However, the point is to make all the information I have gathered experienceable. Moving away from text, the installation will embody the research done and message formed from this research.

The layering of information, or the experiencing of it, does not need to happen in a specific sequence, as long as you have all the layers in the end. Considering the feeling I want to evoke, discovery and confusement, it makes sense to have a setup that is free to be explored. Nevertheless, one piece of information is quite crucial to have in understanding all other parts of the installation; the knowledge that AI is something physical. Having a logical starting point where this can be brought across is needed. Fig 39, shows an installation with less text, and the exploration on how to convey the message in another way. From here I worked on the installation setup seen on the right here in Fig 40 and 41

The top figure on the right is quite elaborate, more elaborate then needed to include all points as discussed on page 50. I do see value in expanding the amount of pipes as it could work well in showing the vastness of the industry and the complex entanglements in it. However, I leave this for future improvements as I will first test the interventions.

The setup is chosen as seen on the right bottom, to show the coming together of streams from different sources, and these flowing to the tap through the IPad. In appendix A an overview of set up explorations can be found, including 2d and 3d studies.

In the top view of the installation in the lower image there are 5 pipes. Number 1, 2 and three are half a metre high and 1 metre long. Attached to them are the tubes which allow additives to flow in. Pipe number 4 is the one to which the ipad is attached. This pipe is higher so the interface can be used. The pipe is 1 metre high and long. The final pipe, number 5, is the pipe with the tap attached on top.

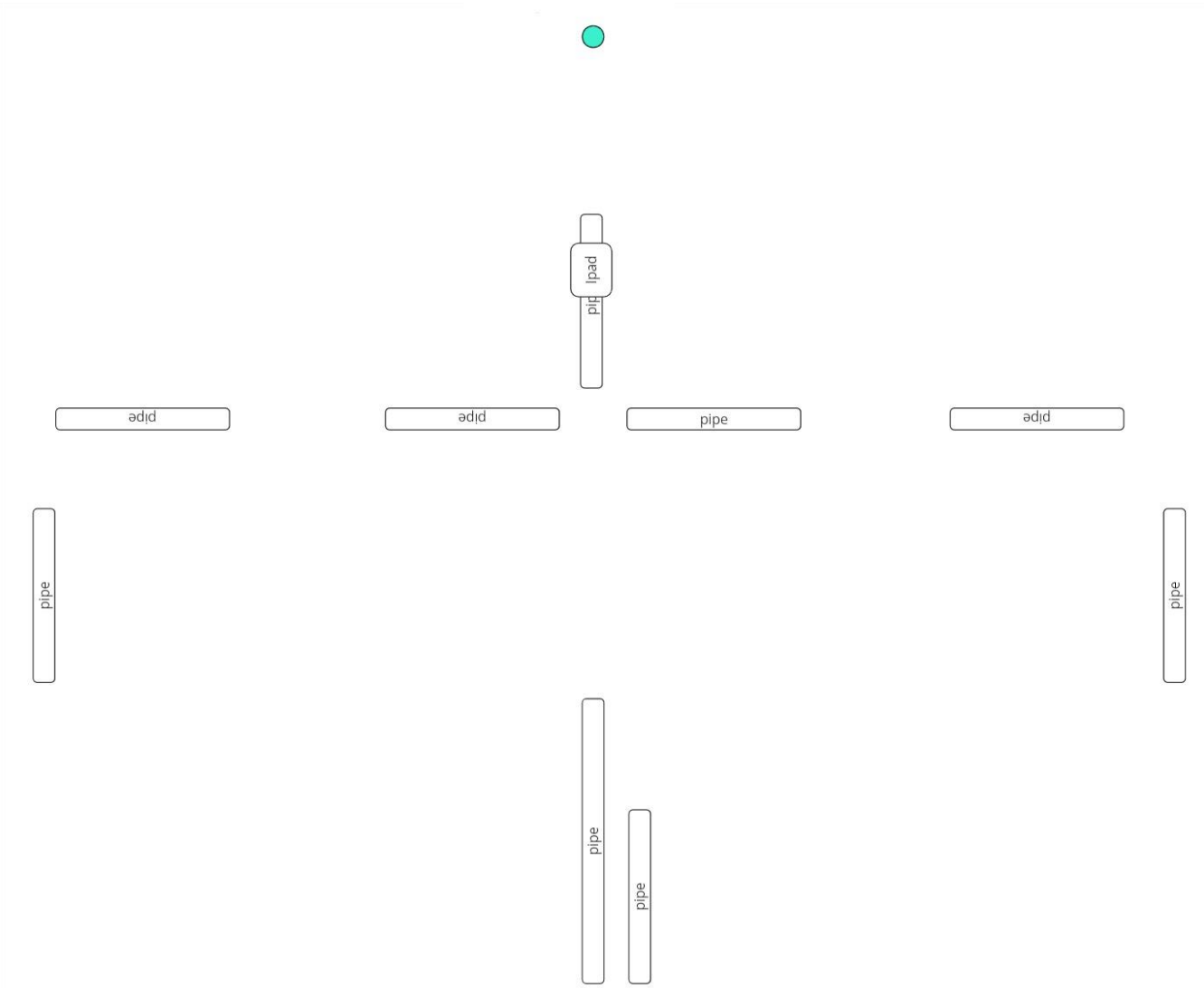


Fig 40: Iteration on visualisation of test setup 2

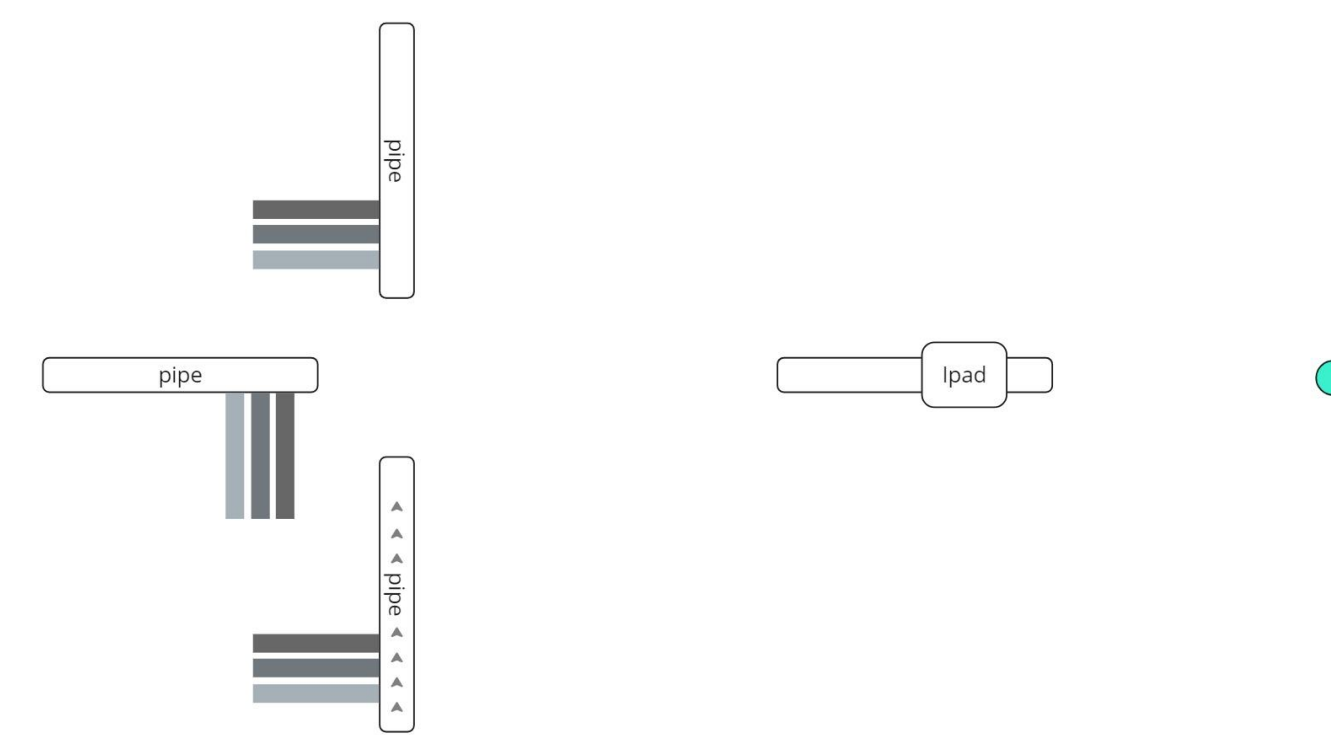


Fig 41: Iteration on visualisation of test setup 3

Installation parts

Flow of water

The water flowing through the pipes can be enhanced, to make it stand out more to the visitor. So the pipes go from static to indicating movement. As mentioned in PE2, sound will also be integrated to indicate movement. Spreading my time, the solutions for indicating moveement on the pipes will be low tech. Arrows are used along the pipe to show a direction. as seen in fig 42

Fig 42: Printed arrows



Water tap

The water tap is finally chosen as seen below because it signals the visitor that you can tap something here. At first I kept the pipe aesthetic as seen in fig 48. This is too cryptic and would need more explanation. This tap, in Fig 43, explains itself.

Fig 43: The three parts to make the tap



Ipad attachment

The way the ipad is integrated should communicate that it is part of the infrastructure, as opposed to an attached external part. That is why the integration was changed from as seen in Fig. 44a to as seen in Fig.44 b . The 3d print makes the ipad part of the pipeline.



Fig 44: a & b Integrating the ipad

Ipad Interface

The interface of the ipad is limited to my development skills and the help I can get with this challenge. The final choice for making the interface is figma. Here a few prompt options are given to the user, as seen in Fig. 45. By clicking them the integrated water audio file will be activated. On clicking the interface will also move to the next page, where Chat GPT answers the chosen question. The full interface can be found in Appendix A.

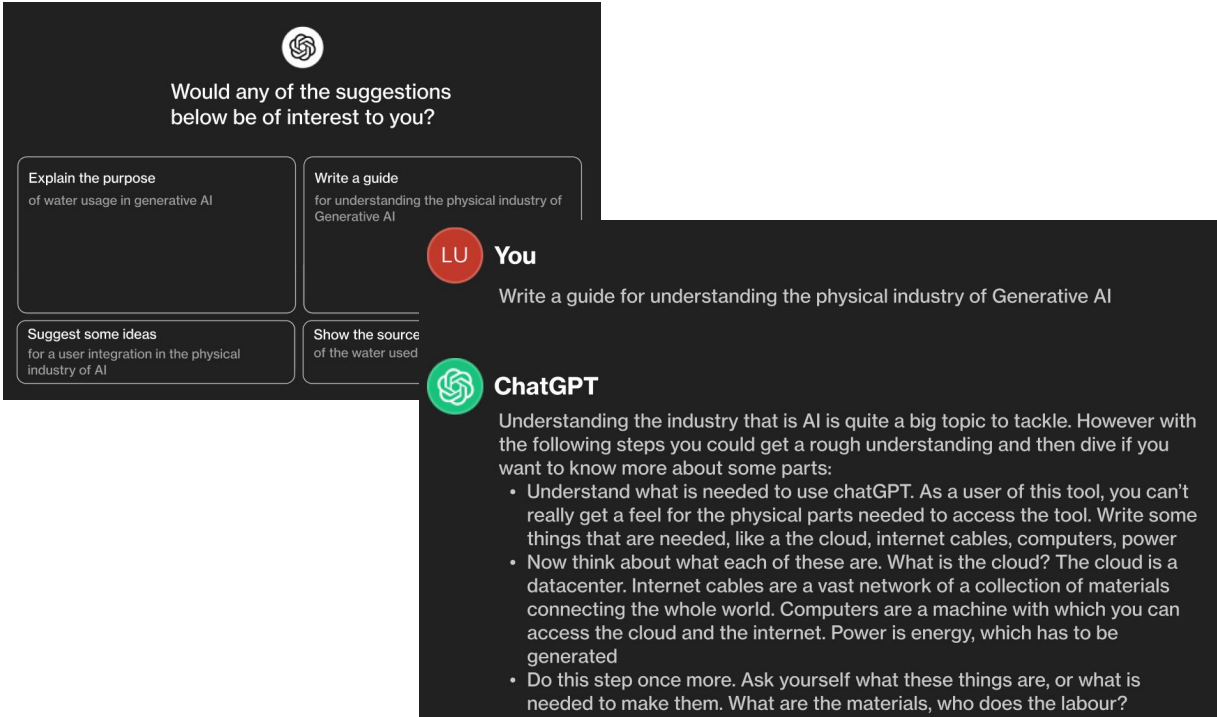


Fig 45: Integrating the ipad

Signage

A typical thing communicating that you are entering an industrial zone are signs. These signs can show many things. For this setting it is relevant to show that there are materials that are harmful for the environment. This is indicated with the yellow sign. The message around the drinking water point is stronger with the drinking water sign. This sign stands for the message coming from data centres. Despite reports from the government, they state they do not have to add anything to the water. Lastly there will be a point where users have to put on glasses, which is also indicated with a sign. They will have to wear glasses to enhance the feeling of being in an industrial zone as well as to protect them from harmful additives coming in their eyes. All these signs are pictures in Fig. 46.



Fig 46: Signs

Location

The location of the installation is determined by a few things. First, the installation is extra interesting when placed next to or close to a data centre. Data centres are a part of the infrastructure very close to us yet often overlooked. They are in the cities we live in, disguised as office-like buildings, in existing buildings taking the place of something that has become obsolete, or in our landscapes interrupting grassy landscapes. Close to the IDE faculty, at the south end of the TU Delft area, there is a data centre. This data centre by North C stands between recently built offices, patches of grass and construction sites, as seen in Fig. 47. The grassy areas lend themselves very well for building the installation. Placing the installation here, imitates the interruption of ‘natural’ landscapes, I mentioned before.

Data center North C

Areas available and suitable to build the installation

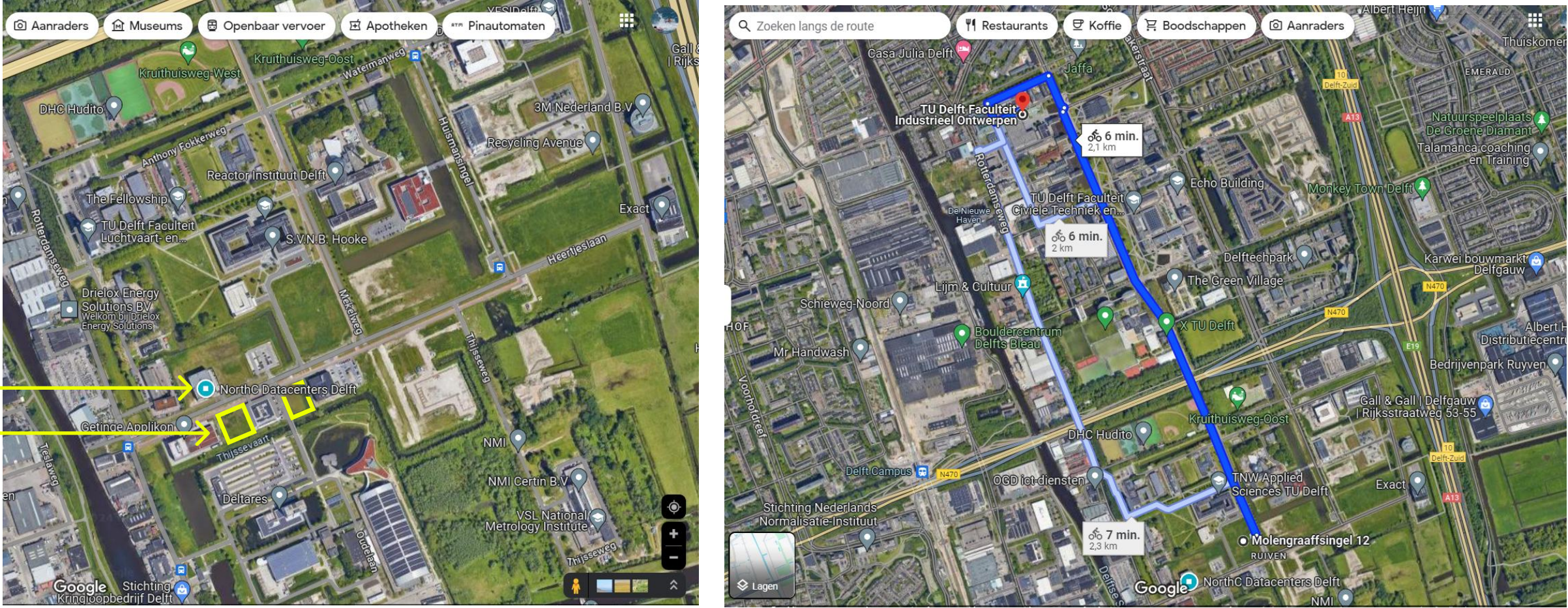


Fig 47: Google maps images, pointing out desired loaction and the route from the IDE faculty

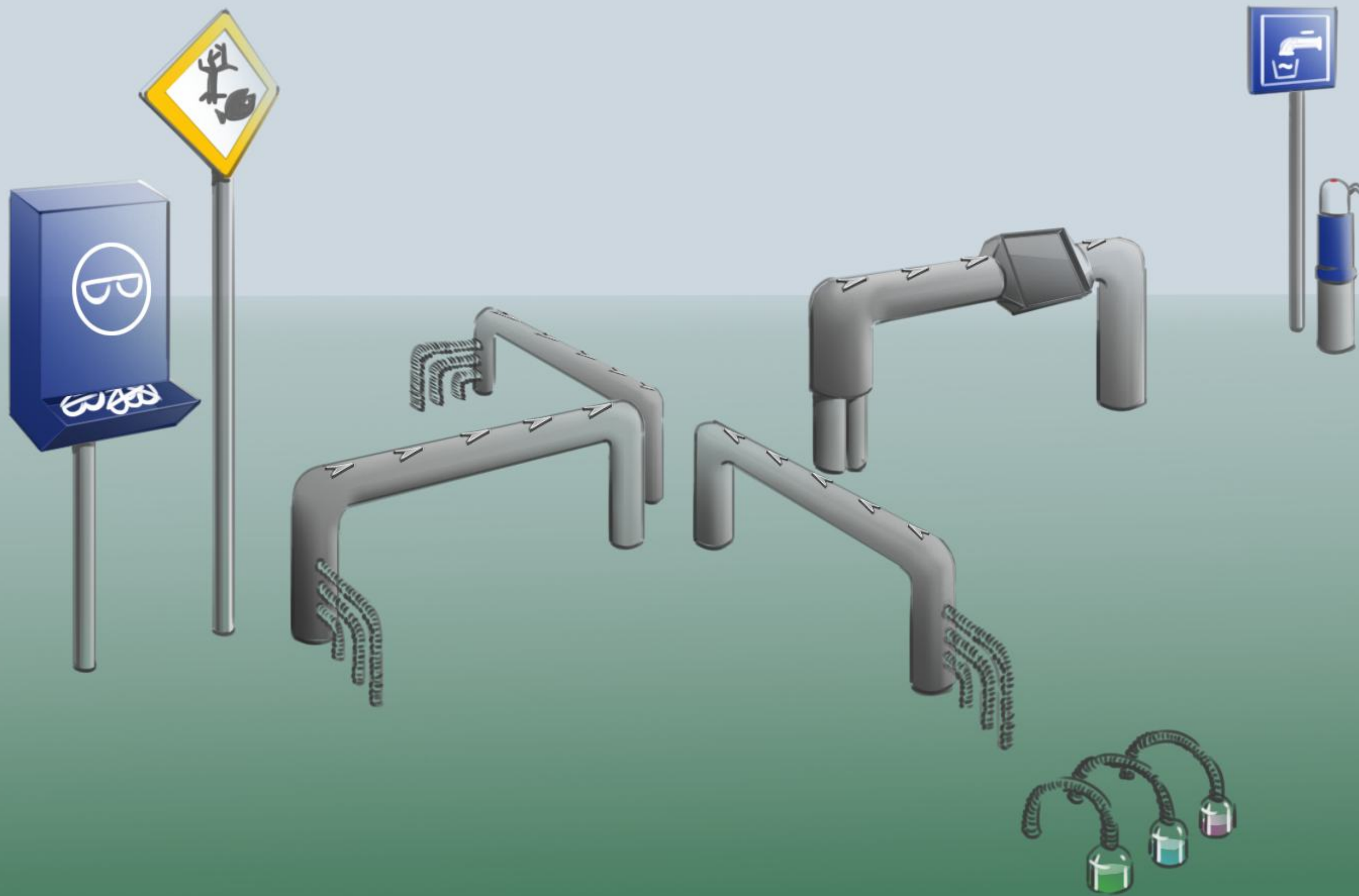


Fig 48: The final concept as imagined, sketched out

Final design of the installation

In the image on the right, Fig. 49, the final design of the installation can be found. Here I will discuss how all the individual parts contribute to the whole.

a. Eye protection: The eye protection is a reference to industrial zones and hazardous materials. In this case it protects against imaginary additives. The glasses provide a starting point for visitors. Before they wander through the rest of the installation they will have to put on the glasses. At this point they will learn that AI is physical.

b. Hazardous substances sign: This sign is used in places where substances hazardous to the environment are used. I might want to place this near the reservoirs with the coloured liquids. At this point, data centres are checked on their disposals, and yet they are very intransparent about the additives needed. This sign warns against the things untold.

c. Guiding arrows: The arrows on the tubes support the idea of flowing water. To me the sound of water is more important and engaging, that is why I choose to use arrows instead of focussing my energy on creating a flow with leds e.g. The arrows go from the source to where the water is needed, a data centre, a refinery, a energy generation plant, and from there to the ipad and to the water tap point.

d. Pipes with additives: The smaller tubes are the additive tubes. There are three for every bigger grey tube at the beginning. Small reservoirs with coloured liquid are placed in the field. The same black tube visually connects the containers with the liquids to the grey pipes. People can see the coloured liquids, but I will not give an indication on what is exactly inside.

e. Coming together of water streams: Here three tubes come together in one. It visually connects the streams to each other and emphasises that several streams of water are needed for the users interaction with a tool like ChatGPT

f. Integrated interface: The ipad shows an altered chatGPT interface. On the interface the user will find a few prompts to choose from. The interface can be found in appendix A. The answers on the prompts give some necessary background knowledge on physical AI and steer the users to think about the industry assessed through Gen AI tools. In this installation water will be simulated through sound. the sound will flow from the left of the ipad to the right. This highlights the direct connection of using Chat GPT and water use. A direct action-reaction.

g. & h. Water tapping point: The water tap point is ideally the last point for users to come past, but I make the installation so that it does not have to be walked through in one direction. The water point is an alternative to water streaming back into open waters. Since drinking water is used for cooling, it would make sense to actually drink it. But then again, by now visitors know that substances are added to the water, although it is not sure what these are. The tap is a point for them to question whether they would actually want to drink it or not.

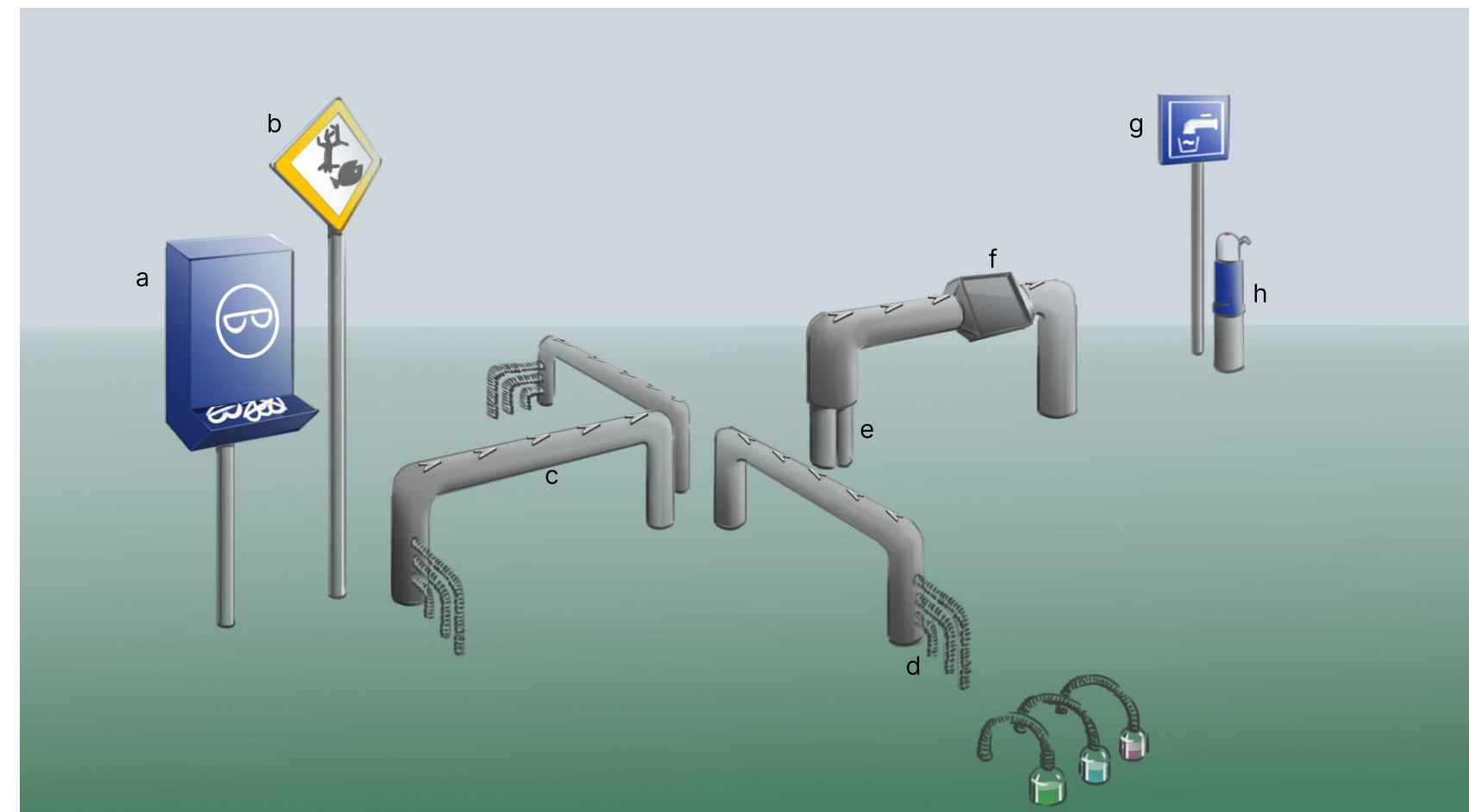


Fig 49: The final concept as imagined, annotated with explanation per part

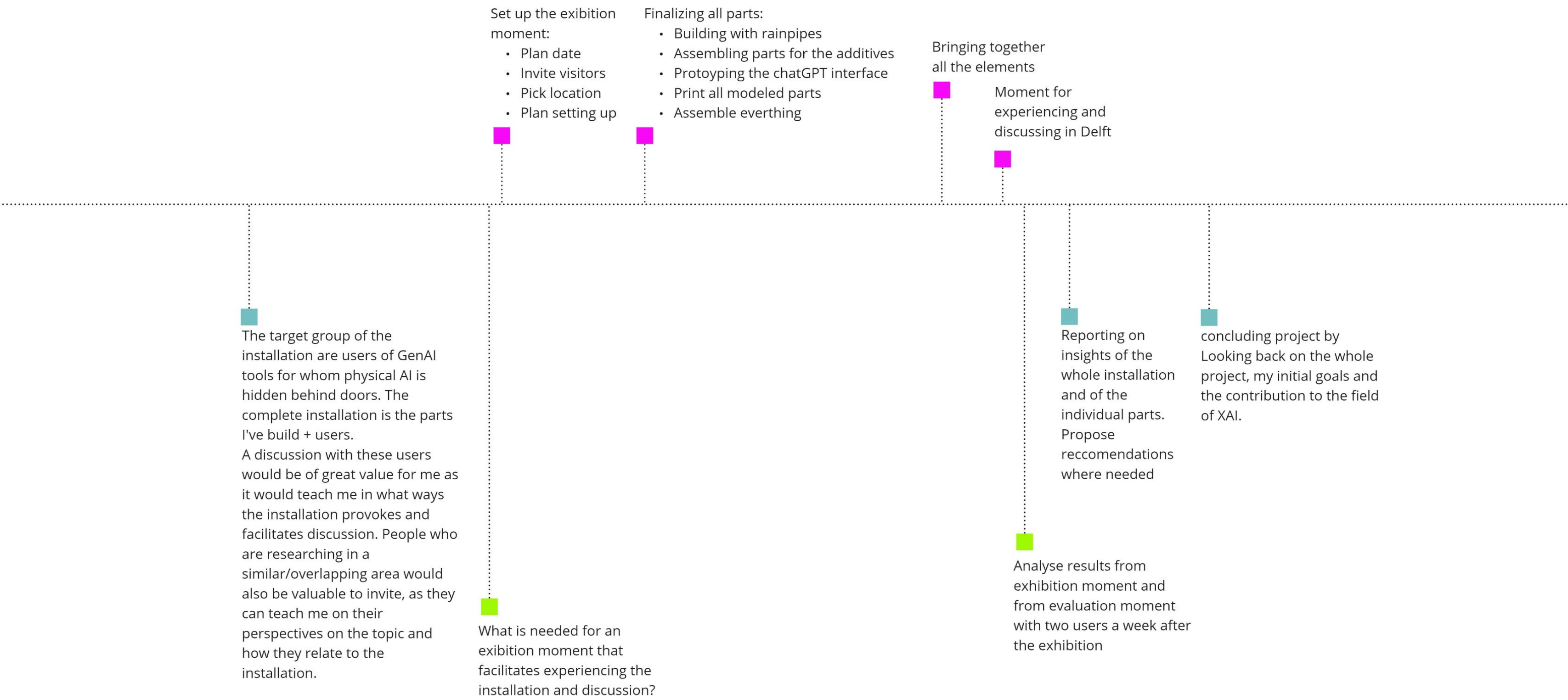




Fig 50: The installation set up in a field, ready for visitors to walk through

EXHIBITION

Aim

A moment is organised for the installation to be visited, I labelled this the exhibition and will refer to it like that here. In this chapter, first the setup of the exhibition will be discussed. This is followed by presenting the parts of the installation and the whole in the form as found by visitors during the exhibition. Next the results of the exhibition are reported. Finally these results are analysed, coming to conclusions and formulating recommendations where needed.

The goal of the exhibition moment is to bring the installation to its full potential, which is in use. As the aim is to contribute to explainable AI, the value is in the understanding of the user. This will be assessed through their understanding of the installation as a whole and its individual parts contributing to the whole. As well as through the quality of the discussion following the visitors wandering through the installation. In the discussion it becomes clear whether the information is accessible enough to make sense of. The discussion, and experience, will also be evaluated with two visitors some time after the exhibition has taken place to allow for reflection.

Set Up

The installation will be set up in Delft on the 7th of may. This will be done on the TU Campus near a data centre, at Heertjeslaan 4. A group of people is invited consisting of: 3 people with knowledge in the field of research, water usage and AI; 2 people in the human AI interaction field; 3 people without knowledge in related research areas, representing the initial target group of the installation.

Visitors will be handed a glass on arrival and after having put on safety glasses, are then free to wander through the installation.

As a last part there will be a group discussion, with two goals. First, through this it can be assessed whether the information is conveyed properly for this discussion to arise. Does the experience allow the understanding of new information so insights and interpretations can be exchanged? Second, The installation is not only about what I mean, it is about the piece of information in the user's life context.

How does it fit in their minds reference on this topic and related topics? Does it connect topics that were not connected before? What are those connections?

Users give meaning to the installation by giving it a bigger context, then just that day and place. Their lived experiences and prior obtained knowledge all become part of the installation, especially when shared with me and other visitors.

To learn about this, a short Q&A is held, with a few visitors at a time, after they go through the installation.

The Q&A consists of the following open questions, but the discussion is open take the direction of whatever is brought up by visitors:

- What did you just do?
- How did you feel about it, what did it make you think?
- What did you learn?
- How do you feel about that?
- Is there anything you want to know after this experience, and what?

Fig 60: An Overview of the whole installation

Start of the installation
The installation is designed to make sense in any sequence after the starting point. The starting point is the point where users can take out a pair of safety glasses. This point can be seen here on the left, the blue box with the statement announcing the point of entrance of a physical AI area. Right behind that there is a first group of containers with liquids in them. To these black pipes are attached, visually indicating the connection to the bigger grey pipes, as in the back of fig 61.

Fig 61: The sign indicating hazardous substances placed next to containers holding those substances



Fig 62: Containers holding coloured liquids, with black tubes attached to them

Fig 60: An Overview of the whole installation

Fig 63: The sign indicating hazardous substance placed next to containers holding those substances



Hazardous substances
On the outer part of the installation users can find more containers, Fig.64, with coloured liquid. Here also a sign is placed, Fig. 63, giving some information about these liquids. The sign is used to indicate environmentally hazardous substances. Again, the containers are visually connected to the larger grey pipes.



Fig 64: Containers holding coloured liquids, with black tubes attached to them

Fig 60: An Overview of the whole installation



Fig 65:
Three pipes with
water flowing coming
together in one place



Three streams of water
Here you find the three streams of water coming together. Taking Fig 65 as a reference, the outer parts state the source of the water and the inner parts show the destination of the water. Below the three images show the destinations found on the pipes, Fig. 66, 67 & 68.
The arrows indicate the direction of the flow of the water. From here, as the arrows show, the three streams of water move on to the Ipad.



Fig 66: Pipe with water flowing towards a energy generation plant



Fig 67: Pipe with water flowing towards a data centre



Fig 68: Pipe with water flowing towards a factory

Fig 60: An Overview of the whole installation



The water needed for use of AI tools
From the three pipes in the overview above moving to the right, you will find the pipe with the ipad integrated into it. The side of the ipad-pipe seen on the left in the overview, shows the three streams of water coming together. Below is shown what that looks like from closer up, Fig. 70 & 71. Here again the destination of the water is shown on the pipe parts. These pipes together continue as one, to show that all these three streams are needed for the interaction with the Gen AI tool. After the ipad, the side seen on the right, on the pipeline the destination of the water can be found, which is a nearby river, Fig. 72.



Fig 69: The pipe with the integrated screen for using Chat GPT, positioned in the field



Fig 70: Three streams of water together



Fig 71: Three streams of water flowing into one



Fig 72: Destination of the water after the interface

Fig 60: An Overview of the whole installation



Fig 73:
The pipe with
the integrated
screen for using
Chat GPT



Chat GPT interface

On the ipad the interface of Chat GPT can be found. The interface is an altered version from the original Chat GPT interface, as explained on page 52. The interface is integrated into the pipeline, as seen in Fig. 73.

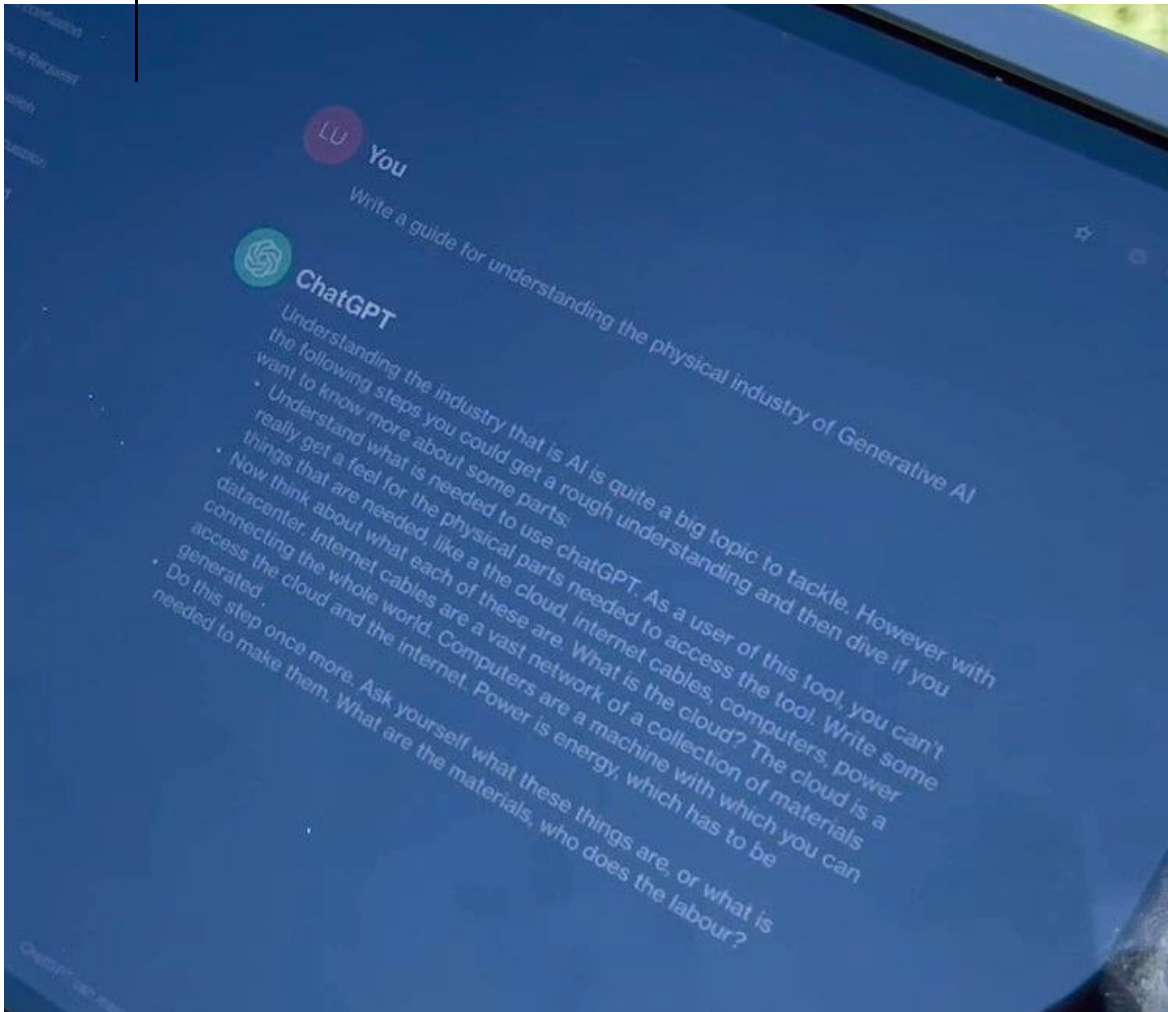
The interface provides the visitor with a few prompts to choose from, see Fig. 74a. When clicking on one of the prompts, Chat GPT will provide them with an answer, see Fig. 74b At the time of clicking on the prompt, water starts to flow. Or so it seems, as this is imitated by the sound of water coming from the left side in the pipe.

After someone has read the answer they can return to the previous page and select another prompt if they like. The prompts fill in the user on some background knowledge, useful for making sense of the installation.

Fig 74: The Chat GPT interface on the iPad, displaying the initial screen (a), and the screen when selecting a prompt (b)



a



b

Fig 60: An Overview of the whole installation



Fig 75: Water tap for use by visitors with a drinking water sign placed next to it



The water tap
Finally on the right end side of the overview above, there is the water tap. The water tap is accompanied by a sign informing visitors that the water in question is drinking water. This is a point for users to reflect on the water that they are tapping and drinking. The tap is positioned in a way that the user looks at the installation when tapping. This is done deliberately so the user looks back at the resource of the water.

Context: Data centre
The installation has been placed in a field near a data centre, pointed out in Fig. 76. The proximity of this grey, blocky building makes for an intriguing context. The installation is a representation of an industry, and the data centre gives a feel of how real that industry is.



Fig 76: Pointing to the data centre next which the installation was placed



Fig 77: Visitors exploring the parts of the installation

Results

The visitors arrived at intervals at the site. The first one had the chance to explore installation on their own. Soon after this the second person arrived, followed by more. I positioned myself on the side, wearing a yellow vest. Ready for questions if people wished to learn more, or didn't understand something.

When asked what users had just done they commented with things like 'exploring', 'investigating a scene', 'getting to the bottom of it' and 'tracing water'. Going through the experience of the installation during the exhibition in the same sequence as in the previous pages, I will discuss what was observed by me or brought up by visitors.

Starting at the point where users could get their glasses, users felt something was about to happen. The glasses and the sign obliging people to wear them, communicated that something unsafe was around. Furthermore, it was commented that it felt like they became part of the installation, which felt fun and exciting.

Right next to this first introduction to the installation, were the first pair of containers with black tubes attached to them. Here the wandering began, as visitors asked themselves what these were. Some felt they couldn't grasp the meaning and others had their own interpretation. Only a few understood that the containers held chemicals.

Moving on, users found more containers with tubes attached. Next the sign indicated the presence of hazardous substances. This was linked to the containers by some, but not everyone connected these two to each other. For some the sign was a warning for the entire scene, referring to the water sources where ecosystems might be harmed or to chemicals, or to the industry as a whole.

Next were the three grey pipes with the smaller black pipes inserted into them. This was a point where users felt they could connect parts of information, seeing a bigger theme; water and AI. In this they felt guided by the arrows and informed by the statements on the grey pipes. The pipes and names also provoked the thought that this industry extends itself outside of this installation, which is where the nearby located data centre became interesting and subject of conversation. Visually it was clear that there were several different streams of water and that they came together in the middle of these three pipes. Following these, was the pipe with the ipad attached to it. Here again, visually, the streams of water came together. For some this was a confirmation of something they already found earlier, while for some it was a useful addition of information to the whole story. The interaction with the ipad itself provided a background story as well as some deepening knowledge. To the few participants who conduct research into this topic themselves, this information was redundant. To others it was necessary knowledge to give context to the information and connect the pieces to each other. The group visiting the installation felt they were in different degrees knowledgeable in this topic. No one felt they knew nothing, which brought up the question if another group of people might need a bit more information then provided now in the interface.

Following up on the ipad, was the piece with the water tap. The connection to the pipeline was very clear to users. Also the question of whether or not to drink the water prompted by many. This was due to a few factors; the installation itself, giving a questionable background story to the water; the taste of the water, which was unintentionally plasticky;



Fig 78: Part of the visitors of the 7th of may, having a group discussion

and the warmth which differed from the regular tap water temperature. All added to the questionability of the drinkability of the water.

Finally the discussion took place. The discussion was held in smaller groups, to allow everybody to share their experience. Initially, the discussion was facilitated by me asking questions to the group. Meanwhile I looked for opportunities for reflecting with the group, catching on to what they brought up. During the discussion the visitors also asked each other questions, wanting to understand each other and the installation better.

In the next part the results will be analysed, drawing conclusions and where needed proposing recommendations.

Conclusions & recommendations

After analysing the results some conclusions are stated. In this part of the report I will go through these, first discussing more general conclusions, followed by comments on specific parts of the installation. Where needed, these conclusions will be extended into recommendations.

During testing of the concept, the users showed me new perspectives which I had not yet considered myself. Here I will draw conclusions from the test considering these perspectives and propose improvements where needed.

Besides the new perspectives, I also evaluate to what extent the interpretation of the user is in line with my intended message. I will do this for the installation as a whole, as well as the specific parts on their own. Finally, I look at the concept in relation to the design goal as initially stated in CD1. As understood throughout developing the concept, the statement includes the wish to inform on the material stream, as well as on the secrecy in the industry.

Together these evaluations guide me towards reaching my goal of contributing to explainable AI. With this in mind, recommendations will be proposed.

Design goal:

Making the invisible visible: Engaging users in a direct interaction with a material flow of AI.

First, the installation as a whole will be considered. I will propose general recommendations which aid in reaching the design goal. After this, I will look at the separate parts of the installation and suggest improvements where desired.

Exchange of opinions | conclusions

One of the users said they would now think twice about using AI tools. She admitted she uses a lot of chatGPT for her own project, as it is focussed on our interactions with such tools. Because of the installation, she reflected on the use of AI. As I am always afraid to tell someone what is right and what is wrong, I replied saying the installation is not made for lecturing. She pointed out that maybe for some it is. This is actually what I meant when I said the value of the installation is in the experience of the user. It is their interpretation. Placing the information in their own context.

I am learning that the installation communicates my opinion, while at the same time it invites others to share theirs.

All connected | conclusions

Some users were knowledgeable on use of water by AI and others on AI in general. They greatly appreciated how different pieces of knowledge came together in one installation. Where until now, knowledge on water in AI is presented as separate parts which are unrelated to each other, here the relations became clear. This has been the value of taking a more holistic approach on the system, as discussed in the chapter on explainable AI. I feel this is where I contribute to explainable AI. The ecological view allows for the holistic view necessary for fully understanding (gen) AI tools. The interface, the infrastructure, the mathematical models, the data, it all exists because of the interactions between them.

Water as a metaphor | conclusion

Some visitors saw the water as a metaphor. One person took it as a physical representation of the energy use in the AI industry. After engaging in conversation with other participants, while exploring the installation, she understood water is also essential in the AI industry. Another visitor saw the different sources of water as levels on which we can think of AI systems. From a more local use, eg. the individuals who interact with local data centres, to global use, which are the big companies dominating the AI industry scene. Another visitor told about her interpretation of the different colours of the liquids representing additives. She had learned there are three kinds of water; Blue: aquatic water, Green: rainwater and Grey: industry water. This is what she saw when she looked at the bottles, a representation of those streams of water.

Behaviour change | conclusion

One of the visitors researches water use of data centres specifically. For him most information covered in the installation was not new. We discussed tools like chatGPT and whether our own use has changed, knowing about the industry behind our screens. He told me his use hadn't changed despite this knowledge. He argued that awareness and behaviour change are two different things. This I agree with, but it makes me wonder what the intention of his research is. That question popping up, revealed my own intention: my research and findings are objective, yet the installation shows my opinion, and feeling I have to act upon the newly gained knowledge. Then again, thinking back on the interview with the forest rangers, they felt they had no choice in utilising AI tools. Having to keep up with new technologies and the workspace that comes with it. Maybe I have been misled by people's genuine interest during the project and while going through the installation. It led me to believe that with the acquired knowledge people would fuel their moral compass, as they were there out of their own interest.

Behaviour change | Recommendation

Naturally there will be more people who feel the same way as this visitor. To learn more about this, I recommend a follow-up discussion after a certain time period. This could result in increasing my knowledge of humans, their drivers and how they mentally process insights gathered during the installation. I wonder if people wish to be presented with an alternative instead of just with knowledge. Such a discussion session can provide me with useful information to integrate into the installation, or could even inspire a new project. I experienced the discussion with other visitors to be an important part for more reflection on what the information could mean for someone after the installation. The discussion reflects the quality of the installation and an insightful discussion adds meaning. Increasing the experience of meaningfulness, contributes to the desirability of the installation. In the installation this discussion could be facilitated without me being present. This could be a valuable addition in a future version.

Location / conclusion

Finally placed in context, the installation becomes a piece for thought. As it stands out in the open, in a plausible context, many people passed by while setting up and during the time visitors were there. Not only was the installation a conversation starter for those invited, but also the installation was curiously eyed by people passing by. Some came to have a closer look, resulting in conversations about the piece. As this was the first time it was standing, the installation was something new for passersby. It can be questioned how people will engage after the installation has been in the same place for a while, where mostly the same people pass by every day.

For now it can be concluded that the installation attracts attention and people are curious to know more. This quality can be used when thinking about the future of the installation. Relating this reaction of passerby's back to the maps, one of the conclusions was that one can not interact with the invisible. This created the desire to make the invisible visible. Visible it is! Even more so, it sparks conversation, adding to this visibility.

Another point relating to the location, is the time visitors have to have to go through the installation. This installation demands users to take time to explore. Only then they can get a grasp of what is going on at the scene.

Finally, also commenting on location, there is the desirability for the data centres. I position the installation next to a data centre, for it to become part of the installation. This has been done without the consent of (the people of) the data centre. Wondering how desirable the installation is for them, I can only conclude there is no incentive for them to allow this to be set on their ground. Besides maybe transparency, which by now I have learned, is not a typical motivation in this field.

Location / recommendation

Apart from the data centre creating a realistic context, the location limits the type and amount of people passing by and visiting.

In this I see an opportunity for the development of the installation in general. I do feel the context now added to the experience, therefore I propose that the installation could travel to different data centres and be a pop up exhibition. For this more centrally located data centres can be chosen. Today there are many data centres located in cities. In Amsterdam alone there are 28 data centres. Per location the installation's placement has to be considered. It could be that not all are surrounded by grass patches. A visual integration for a smoother, harder surface has to be thought out.

To elaborate on desirability for data centres and the location, I want to consider what are more feasible options for placing the installation. Considered are educational museums with an outside area, as I feel that outside contributes to the realness of the installation. As discussed, often industry interrupts nature.

Maybe the installation does not always have to be that public. It could be temporarily placed in the garden of an office where there is a wish to learn more about the gen AI industry, or at a school. Lastly, Olya imagined the installation to be in a place where many people pass by, as she focuses on visibility. To me this is an option that is in line with my wish to contribute to XAI. It would not be fair if people have to look really hard for the

information, it has to be easily available so people can decide themselves what to do with it. For this part I conclude that I see a lot of potential in a travelling installation. With this the robustness of the installation will have to be improved, for travelling purposes, as well as for visitors use purposes. The installation contains fragile parts which are prone to misuse. I tend to believe people would treat the material with respect, yet it has been proven that this belief is a bit naive at times.

Contextual information / conclusion

Interest was expressed to understand the installation in context, even more. Where the data centre provided some context on the reality that the installation represents, the reality of the actual water sources was missing for some. This is an opportunity to make the information more personal and add to the feeling of urgency of the current situation. Especially when considering the installation could be travelling around, sometimes missing the context of the data centre, i think it is important to provide context in another way. Contextual information | recommendation

Contextual information / recommendations

The Ipad would be a suited place for integration of this knowledge as it would not disturb the representation of the real industry. On the other hand, this might not fully contribute to personalising the information found. As images on a screen do not foster a relation with the locations of extraction of water. Even more so, the ipad would be overloaded with information, which might result in users skipping or missing parts. An external addition, of a pipe, leading to these open waters e.g. where info can be found on the locations of those open waters and their size, and scale of the infrastructure. On page 51 I propose to look at the addition of pipes to embody the vastness and complexity of the system. With the idea of adding pipes, there are two valuable contributions; the one of embodying the vastness of the system *and* the possibility of offering more context to the user on the information in the installation.

Additives / conclusion

Looking at the design goal stated, repeated at the beginning of this chapter, there is the interaction with a material flow, water, in the AI industry specifically. A balance I wanted to strike, is the balance between representing the facts about water in the AI industry and the secrecy in the AI industry. The installation critiques both, but the one goal hinders the other and vice versa. In de installation the flows of water were easy to discover with the use of arrows and the words on the pipes. Some intentions behind parts were harder to decipher, due to the secrecy I wanted to embody.

This was the case for the bottles with additives. Here I hinted to chemicals by using coloured liquids and the sign informing on hazardous substances. Yet the interpretation of this part was very wide and not always related to chemicals.

Additives / recommendations

This could be improved by using icons on the additives bottles themselves. The icons that would suit this context and purpose are shown in fig. 79. Using icons indicates more clearly the purpose of the containers and their contents, but does not reveal every little detail about them.

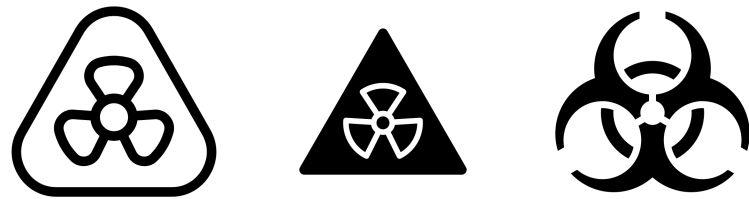


Fig 79: Icons informing on harmful substances

Also concerning the additives, are the black pipes visually connecting the additives to the grey pipes. Both the parts connected to the bottles and the grey pipes can be seen in Fig 80. Despite not being commented on, for myself I would like to improve the visual connection. This can simply be done by aligning the pipes going into the grey pipes with the direction of those attached to the additives.



Fig 80: Black pipes attached to additives and grey pipes

Knowledge required / conclusion

At the end of the chapter of XAI, I say I emphasise with the user, but after all the research done, I am not sure I can still say I do. The field specific research and knowledge has shaped my view on what has to be explained and what not. Something the installation also requires of users is some knowledge on AI. Having some knowledge provides the visitor with quite some recognizable reference points. At the Ipad just some information is provided, giving a bit of a basis to understand the installation.

Knowledge required / recommendations

Improving this, makes the installation accessible to a bigger audience. In providing more information, I still want to harness the secrecy of the industry. More research into the understanding of users has to be conducted.

I do imagine the best place to integrate this information is in the Ipad interface. This way the installation can be kept to represent the actual industry, as opposed to having more explanatory information on the pipes for example.

Water qualities / conclusions

Many commented on the taste of the water coming out of the tap, this is a side effect which I had not accounted for. However this added great value to the user experience. The water had been sitting in a plastic bag, and the outside temperature was quite hot. These two conditions resulted in water that tasted off and which was warmer than visitors were used to. This was an extra incentive to check where the water has been, and try to understand the water story.

Learning how people interpret the different parts of the installation has been very refreshing and insightful. This showed me that the installation can make sense in many ways. It does not matter if every single part is understood as I meant it to. The bigger message of something being off does come across and visitors find this in different parts of the installation. When sharing with each other, during exploration or after, they enrich each other's findings and learn from each other.

Water qualities / recommendations

On the day of the exhibition the water was lukewarm due to the outside temperature. Besides this it had a taste of plastic as a result from sitting in the plastic bag in the pipe. Both these characteristics contributed to experiencing the drinking of the water as being unpleasant. Therefore I want to implement these into the installation permanently. I can do this by making the water taste off with artificial flavouring, instead of steering on the suggestion that plastic is an additive in the water. The temperature can be regulated with a heat element.

Truthful versus metaphorical | conclusion

Following up on the interpretations of users, this also confirmed the value of the decision to not approach the topic in a poetic way. As expressed by the visitors, there are many ways of looking at the installation. Many metaphors to be seen and room for mind wandering. I feel this space is there, because I don't present a metaphor to the visitor.

Representation of the industry versus an intervention | conclusion

After an evaluation with two of the visitors I can conclude that it was not clear to users that the tap is the point where the representation of the real system ended. The installation as a whole was understood as a representation of the real thing and the tap was found to be an interactive way of making visitors think about the cleanness of the water. Here I missed the opportunity to point out that in the current system, this polluted water is dumped in natural ecosystems. The water tap provides an alternative to this current system, which is a point I do want to get across.

Representation of the industry versus an intervention | conclusion

The users ofcourse realise this is not how things actually are, but see this more as just a way of making them think about the journey of water. Where it comes from, what is added, what it is used for. By letting the pipeline stop here, there is no consideration of where the water ends up. This is an important part of my message which is why I propose improvements on this part. In the improvements I do want to keep the tap itself, as it is a great tool for provoking thought in the user. The goal is to integrate the discarding of water.

Discussion | conclusion

The discussions on the 7th of may were interesting on their own and interestingly different from each other. The first discussion was with a group of three who were randomly selected from the visitors who were ready to have a discussion. This discussion was rather short as the visitors provided short answers to the questions I asked them. Some effort was made to deepen the conversation, but either it was too soon or the installation did not resonate as I hoped. The following group was bigger, 5 visitors. An interesting discussion arose. Many of the group shared how they experienced the parts, what they interpreted and what their insights were. Interesting metaphors were shared and followed up on by others. The visitors asked each other questions as well, making a valuable contribution. One visitor of the previous discussion group even decided to join in the discussion again. From their comments and insights I concluded that parts of the installation came across as intended and left room for the user to think about the bigger system. Every discussion will always be different, but I do wonder how in the first group an interesting conversation could have been sparked. Thinking about the development of the installation, I wonder how this can be done without me there.

Discussion | recommendations

In the future, the discussion ideally is facilitated through the installation itself instead of by me. The installation invites the user to interact with the parts, but not necessarily with each other. I recommend choosing a part to facilitate interaction with other users as well. For example, at the tap the button can be placed elsewhere. So someone who wants to tap has to ask someone else to push the button while they hold their glass under the tap. Or, the other way around, someone can offer to push the button for someone else. This interaction can be the start of a conversation, especially because this was a point where users tasted the water and commented out loud about the taste and temperature because they were so surprised by it.

In this chapter I have discussed all conclusions and recommendations as a result from the exhibition day on the 7th of may. In some of the paragraphs the relation to the bigger goal is mentioned. In the next chapter I will elaborate on this in a more general conclusion.

Fig 81: visitors engaging with the installation and each other



GENERAL CONCLUSION

This project is an exploration of gen AI and the possibilities for understanding that technology from an ecological perspective. At the end of the ecology chapter I proposed a view on Gen AI, from an ecological perspective. This is my interpretation of a more holistic view on Gen AI and on what should be included in XAI-GAN. With the goal of contributing to XAI, and XAI-GAN more specifically, I positioned myself in this field as someone who does not fully understand the workings of models. Despite this being a limitation, I hope to enrich and broaden this research field nonetheless.

Aiming to understand the composition of both the physical and digital side of gen AI, mapping was found as a suitable method; a subjective exercise allowing the exploration of the components making up gen AI and their relations. The process of mapping and the outcome of this method, the maps, provided valuable insights in understanding this technology. I appreciate how the maps facilitated the exploration of the gen AI ecosystem on different levels of detailing, bringing different parts of it into focus. Also, as the maps show the relations between factors, it explains a user's interpretation of such a technology. It was found that users of gen AI tools have little access to the industry behind their screens. As a reaction I formulated the goal of making the invisible visible by engaging users in a physical material stream of gen AI.

Finally water was chosen as a physical material stream to continue with. It receives little attention when the sustainability of AI tools is questioned, while it is a natural resource we rely on daily.

To make this material stream and its ways in the AI industry tangible, I wanted to move the interaction, between a user and the knowledge on water, away from the screen. To create an interaction, first research was conducted into water and the aesthetics of the gen AI ecosystem. Through research I learned that water is needed for cooling data centres, cooling energy generation plants, refining processes and manufacturing processes. The water sources range from drinking water to open waters. To use the water in the processes mentioned additives are needed. These are substances like chloride, phosphorus and chemicals for treating salmonella. After being used for its purposes in the industry the water is disposed of in natural ecosystems.

The findings were shaped into an installation in which the user could experience and discover for themselves. As I am opinionated on the things I learned throughout research I sought to find a balance between communicating that opinion and leaving room for users to shape their own.

The final installation increases awareness about the infrastructure powering gen AI tools. Both the ways of water in the system as well as the secrecy of the industry were conveyed. It resulted in an interesting discussion in which visitors expressed the wish to learn even more. However, whether this awareness results in behaviour change is unclear. Maybe behaviour change is an unrealistic goal, but gaining momentum for change is not. Looking back at the goal stated in the beginning of this project, I wanted to contribute to explainable AI.

In this project, both the process and outcome exposed a physical industry behind gen AI tools. In general this industry is not accessible to users, both physically or through desktop research. As mentioned by users, the experience provided in the installation was very insightful. Especially because it puts individual pieces of information in relation with each other. The notion that everything is entangled and in a relation with other things, comes from ecology and is expressed in the installation. I deeply believe ecology as a science contributes to explainable AI. Ecology necessarily broadens the methods of explainable AI providing a more holistic view. This holistic view proves useful in reaching the goals as stated in the field of explainable AI: opening up the black box to build trust in the users. I believe trust is built on transparency.

The form of an installation also proves to be valuable for users' understanding of (gen) AI. With this I offer another enrichment of the field of XAI: physical XAI.

That is not to say I am the first one attempting to make methods of gen AI tangible, but I do want to argue this should be considered as a valid and valuable part of XAI. A physical thing effectively facilitates discussion by providing reference points.

The recommendations proposed, lift the installation to the next level. Making it more stand alone and bringing across points contributing to a more complete understanding of the industry.

Furthermore, the recommendations fostering discussion will increase the value of the installation. This discussion is a part of coming to an understanding of the industry as well.

PERSONAL REFLECTION

Since the introduction to generative AI tools, I have been fascinated by their output and workings. I have been able to explore some parts of it in courses over the last few years, and getting to build my graduation project around it, connecting many of my interests, is something I am very grateful for. This project allowed me to take nature as a main inspiration to speculate, wonder and dive deep into generative AI.

The research phase felt natural, mapping being an intuitive tool. In my brief I stated I wanted to challenge my own thinking, developing my critical attitude also towards myself. Sometimes I make naively big statements, limiting myself to one truth. With the help of my supervisors I was able to navigate my own mental pitfalls, and develop a rich view on the topic.

Taking the findings from the research and shaping them into an installation where information can be experienced I felt challenged. Again looking back at my brief, I mention the challenge of knowing when to stop digging deeper and take learnings into practice. With this I struggled, but I am proud that I took a lot of time to work on the installation. I feel I was able to take in depth knowledge, and make it tangible. However this remains a point for learning and practising.

In my brief I formulated the ambition to “develop my understanding of generative AI, to come to a point where I am able to explain generative AI, and be able to formulate an educated opinion about it”. Finalising the project, I feel I succeeded in my own goals. I understand generative AI, in a way which makes me feel like I knew nothing before. Besides that, I feel comfortable to share my opinion about it. This is a personal accomplishment, as I am not one to go and proclaim my opinion to everyone. In this project I learned how formulating your own opinion, can invite others to share theirs. Where I first stayed far away from forming my own opinion on something, this insight allows me to feel more comfortable in designing. I think formulating an opinion aids the development of a design, as it facilitates the exploration of multiple perspectives. This was one of my personal goals as well; coming to a design that allows for people to form an opinion about generative AI. In the installation ofcourse the presented knowledge is very focussed, limiting the opinion visitors could form. But the exhibition showed that my opinion on this specific knowledge came across and others still felt free to share theirs.

Throughout the project some more general insights and questions arose, both small and big ones, which I would like to shortly elaborate on as I consider them important to me as a designer. If anything they show how much there is still to discover and research within the field of gen AI.

The ecosystem behind every/any -thing

Something that became evident is how generic the insight of the complexity of the ecosystem of gen AI is. The specific complexity of the GenAI system is not generic, but the unveiling of á complex ecosystem is.

A friend of mine, Hannah Kleijne, did an amazing project about a pear. An everyday object, which generally does not invite the consumer to engage in a deeper relation. She looked for ways in which we could do this, as consumers. In this quest she found this immense journey the pear makes before it enters our body. With this journey parts of the ecosystem

of that pear were exposed, or maybe even more so, the many ecosystems which are relevant to this pear were exposed. So by eating pears, these ecosystems, and everything happening in those ecosystems, keeps on happening. The consumers put that into action by consuming. The same goes for GenAI tools and many, many others things.

Shared language

Already briefly touched upon, in design projects I am always cautious to not force my own view on others. This is something I struggled with in this project as it is a project critiquing something, which requires me to formulate and present my own opinion. I feel I have learned a lot and gained confidence in that area. Instead of scaring away from this, with the help of my supervisors, I found a way to do this. I understand and can argue my position in the field of gen AI, resulting in an opinion on the field. Fully understanding my own views, aids openness to other positions taken by other people.

The interpretability of the installation and the views from visitors, taught me that to me personally the value of designing and design is not agreeing with each other, but having a shared language to have a discussion with each other and learn from each other. In this case the shared language is the installation, the physical things that one can point at and talk about.

Terms and their implications

Terms used for the parts that make AI, are extremely important for how users will understand this technology. An important example is the term ‘the cloud’. This term is used to describe in some ways the opposite of an actual cloud. This term is so broadly adopted that it seems ridiculous to dream about introducing a new term. Despite this, I think it would be very valuable to use a term that describes what ‘the cloud’ actually is.

Privilege of using (gen) AI

I feel Generative AI should not be used lightly. Lightly, to me, means using it for finding a recipe for spaghetti bolognese, which someone once told me about. But what else falls under lightly using it? Does finding information for a thesis project fall in this category? Does finding information for policy making do? What goals justify the means of using (generative)AI? Who gets the privilege of using it? I could imagine that the people who already have power and privilege would be in the position where it is considered justified to use such means, but that hardly seems fair. This question is a very important question which arose during this project, which I think should be subject of research.

I look forward to learn how our interactions with gen AI tools will develop in the future, in ways that foster our connection with nature. And maybe contribute to it, as I am not tired of this topic still.

All Watched Over By Machines Of Loving Grace

I like to think (and
the sooner the better!)
of a cybernetic meadow
where mammals and computers
live together in mutually
programming harmony
like pure water
touching clear sky.

I like to think
(right now, please!)
of a cybernetic forest
filled with pines and electronics
where deer stroll peacefully
past computers
as if they were flowers
with spinning blossoms.

I like to think
(it has to be!)
of a cybernetic ecology
where we are free of our labors
and joined back to nature,
returned to our mammal
brothers and sisters,
and all watched over
by machines of loving grace.

- Richard Brautigan

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ChatGPT

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77

New chat

Previous 7 Days

Ajuda com Sumarização

Random letters confusion

Morning Assistance Request

Random string confusion

Random characters discussion

Random String Summarized

Confused user seeks guidance.

Random Letter Sequence

User request: summarize convers

Summarize SCVD request.

Request: summarize convo lololol

Previous 30 Days

Interfaz de ChatGPT.


2023

Light Themes Across Disciplines

Upgrade plan
Get GPT-4, DALL-E, and more

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ChatGPT 3.5



Would any of the suggestions below be of interest to you?

Explain the purpose
of water usage in generative AI

Write a guide
for understanding the physical industry of
Generative AI

Suggest some ideas
for a user integration in the physical
industry of AI

Show the source
of the water used in the AI industry

ChatGPT can make mistakes. Consider checking important information.

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ChatGPT

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 New chat



Previous 7 Days

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Previous 30 Days


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ChatGPT 3.5

 You


Explain the purpose of water usage in generative AI

 ChatGPT


That very question needs water to be answered, as you can hear in the pipes. I believe it's drinking water. actually, but there are different sources saying different things

Anyway, drinking water is needed in the following parts of the AI industry:

- Cooling data centres. Tools like this one, chatGPT, run in a datacenter. This costs computing power, which generates heat. To keep everything running the temperature can't go up too much. Therefore cooling is needed, which is done in many cases with drinking water.
- The energy needed to run a datacenter is generated somewhere. This process also needs cooling, done with water
- Manufacturing processes also utilise water. Manufacturing comes in many forms and in the process of building the things needed in the AI industry requires many things to be manufactured. Its first requires the mining and refining of materials. Then the materials need to be manipulated into usable parts and these parts need to be assembled. These steps are all examples of manufacturing, needing water



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ChatGPT

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79

 New chat



Previous 7 Days

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ChatGPT 3.5


 You

Write a guide for understanding the physical industry of Generative AI


 ChatGPT

Understanding the industry that is AI is quite a big topic to tackle. However with the following steps you could get a rough understanding and then dive if you want to know more about some parts:

- Understand what is needed to use chatGPT. As a user of this tool, you can't really get a feel for the physical parts needed to access the tool. Write some things that are needed, like a the cloud, internet cables, computers, power
- Now think about what each of these are. What is the cloud? The cloud is a datacenter. Internet cables are a vast network of a collection of materials connecting the whole world. Computers are a machine with which you can access the cloud and the internet. Power is energy, which has to be generated
- Do this step once more. Ask yourself what these things are, or what is needed to make them. What are the materials, who does the labour?



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Previous 7 Days

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ChatGPT 3.5

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You

Suggest some ideas for a user integration in the physical industry of Generative AI



ChatGPT

The physical industry of AI can be seen as the infrastructure needed to make Generative AI work.
User integration into this infrastructure needed for generative AI tools, like this one, can be approached from different perspectives. You can look at the different buildings and supply chains to find opportunities for user interaction:

- Data Centers: These buildings are physically very closed off to the outside world. This makes for a great opportunity to integrate users. Data Centers could also present themselves as the new library; a place for people to interact with data
- Lithium: Batteries are needed for many things in the Generative AI ecosystem. The supply chain connects all parts of the world, making it an interesting material representing the vastness of the industry. As the material presents itself at many places in many forms, there are many opportunities for user interaction.
- Data: The data needed to feed a model before it is useful in a tool, is another resource of the generative AI industry. This presents itself less obvious compared to tangible materials like lithium, metals, plastics or water. Yet data is extracted from real life moments, in the physical world. This makes for interesting crossover between the digital and physical parts of the generative AI system. These points of interaction can be valuable user integration points

ChatGPT can make mistakes. Consider checking important information.

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ChatGPT

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 New chat



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ChatGPT 3.5

 You

Show the source of the water used in the Generative AI industry


 ChatGPT

As a language model, I am not able to present visuals. However, I can describe the sources from which water is used in the Generative AI industry. Water is needed in several processes which keep tools like this one, ChatGPT, running. For different parts of the system, there are different sources for water. Also, the location where a process takes place is a determining factor for where the water comes from.

In a datacenter, the place where we access Generative AI tools via the internet, water is used for cooling the servers. This water comes from local drinkwater sources.

A datacenter is made of materials which need to be manufactured. Also, the device on which you use this tool right now needs manufacturing. Actually, almost all things needed in the AI industry needed manufacturing. In general, manufacturing processes need water in the process, for cooling or other purposes, like refining of a mined material. The process as well as the location determine the water source.

To run data centres, factories and your device, energy is needed. Generating energy is a process which also needs cooling and therefore water. As manufacturing takes place in many locations, the sources of water differ greatly. It can be local drinking water, or openwater from which water is used.



ChatGPT can make mistakes. Consider checking important information.

