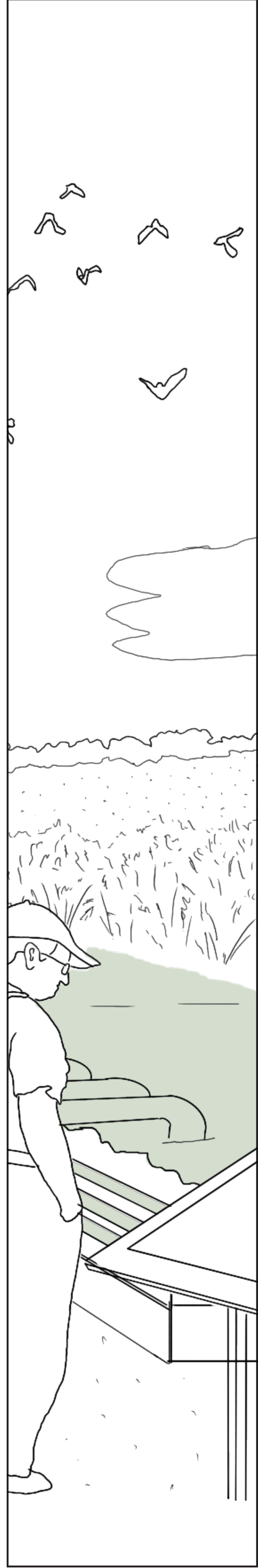
From Algae to Thread

A deepdive into a more circulair textile industry



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Abstract

Plastic is one of the most visibly polluting elements in our environment. From big plastic accumulation zones at sea to microplastic entering our everyday drinking water, plastic is becoming a more evident pollutant every day, which is damaging ecosystems, marine life and human health.

This paper will envision a possible solution for plastic pollution in North West Europe, through the retrieval and recycling of plastic, and by proposing an alternative for plastics in the current textile industry; algae. The strategy of this project aims to create a more circular and local economy by envisioning how substituting bio-plastics in a specific industry can be a solution towards minimising overall plastic pollution.

Drawing on climate change as an environmental impactor; algae bloom, which is seen as a negative climate change product, will in this project become a catalyst for a change within the textile industry by making bioplastics.

Through introducing a new perspective on how the relationship between consumer hubs and production hubs could be adjusted to become more sustainable, this project aims to showcase a solution that could be implemented in other areas with plastic pollution, by taking North-West Europe as a test case. Simultaneously, the project aims to pinpoint how crisis can become an opportunity in times like these.

Fig. 2, Nuns walking past garbage in Rome, Italy.

Actuality: A global issue of waste management

As of April 2023, the Amsterdam waste company AEB is incinerating waste for the city of Rome. 900 tonnes of garbage is transported by train from Rome, travelling 1600 kilometres before being incinerated in the Western Amsterdam harbour. Rome will pay a fare of 200 euros per tonne of waste, making it a very lucrative endeavour for the AEB (Van Gool, 2023). Rome has been struggling with the disposal of its waste ever since EU regulations forced the city to close their dumpsite, which was the largest of Europe (WMW, 2022). The current national government is opposed to waste incinerators (Van Gool, 2023; WMW, 2022), and therefore no local solutions to the waste problem have been found yet.

This example not only shows the multitude of problems governments have in the transition towards more sustainable methods of waste management and the vast amounts of waste humans can create, but it also illustrates how one city's waste can be another player's income.

This opens up the question: how can we imagine the waste in the world to be used for opportunity?

content

Plastic pollution

Currently, 150 million tonnes of plastic is 'floating around' in the sea, taking up the space of about 1.6 times the Netherlands. Plastic pollution, originating on land and always ending up in the sea, is harmful to both humans and marine life. Both larger and smaller increments of plastics can kill fish due to entanglement, lacerating their insides or by making them feel full so they will not eat anymore (United Nations Environment Programme, 2021). Even without physically harming fish, plastic can be a danger as it can also act as a carrier for chemical pollutants, which can poison fish or make them poisonous to humans who might ingest them (MacLeod, et al., 2021). Plastic can also distribute chemical compounds to different locations, increasing the chemical pollution in different parts of the world.

Plastic pollution is a worldwide problem: plastics have been found in even the most remote places on Earth, from the bottom of the ocean to the top of Mount Everest (Napper et al., 2020). It is transported through winds, ocean tides, waves, accumulating in specific places that now have to deal with the problems. In the Mediterranean sea for example, its enclosed nature capturing marine plastic, which then poses a threat to millions of people and a large amount of marine life (UNEP, 2021)

Plastic as a pollutant is a key marker of the Anthropocene, as it is one of the few pollutants that is completely man-made. Unlike carbon, phosphorus and nitrogen, plastic compounds do not have regular chemical or biological decomposition pathways in nature. (MacLeod, et al., 2021). Adding to that, plastic takes hundreds of years to break down and decompose. As a result, plastic accumulates in the environment, harming ecosystems for a long time (United Nations Environment Program, 2021). Unlike other forms of pollution, such as chemical pollution or oil spills, plastic pollution is extremely difficult to clean up, especially microplastic pollution. Once plastic waste is in the environment, it's challenging to remove it completely. (MacLeod, et al., 2021)

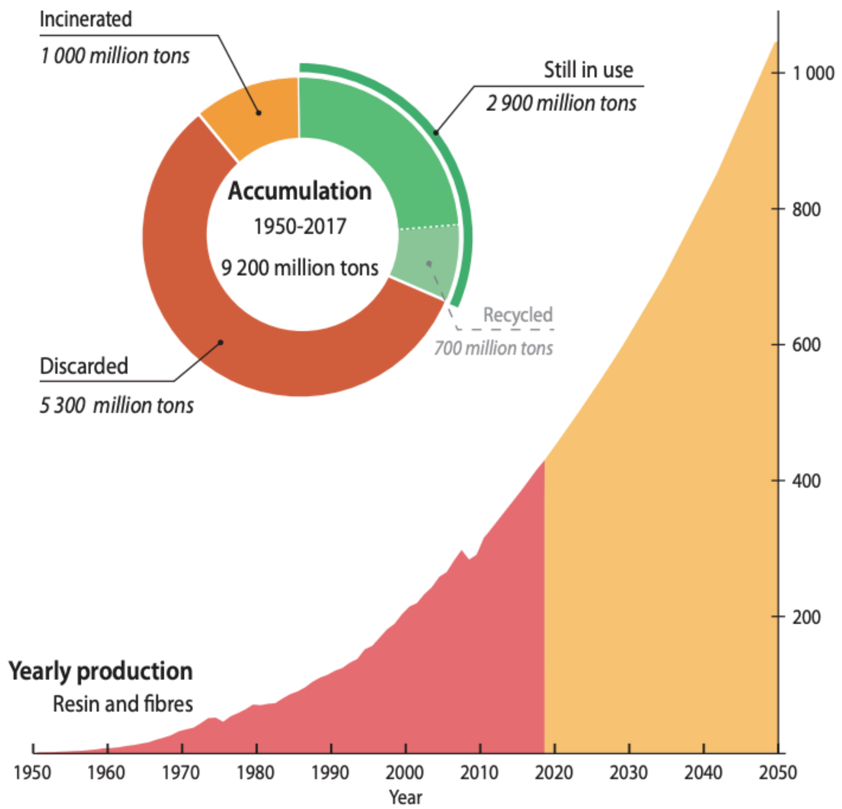

Fig. 3, Global plastic pollution and accumulation (and future trends)

The cycle of plastic pollution

The process of plastic begins in a plastic factory, where a series of processes combine petroleum with other chemicals to create a raw material. This base material is moulded into different types of products, from water bottles to car parts (PLASTICSMarCom, 2021). After these plastic products are used and discarded, some are collected by waste management companies for recycling. Others are transported to energy recovery facilities and incinerated, while a significant amount of plastic waste is not properly disposed of and ends up in oceans and waterways, contributing to macroplastic pollution (UNEP, 2021).

Plastic waste gets broken down into increasingly smaller pieces, creating microplastics (UNEP, 2021). This happens at many occurrences in the plastic cycle, from the production of plastic up until its disposal, and even after, while it is a pollutant in the sea. During the production process, fumes emitted by factories contain a high concentration of microplastics. When plastic is used and washed, microplastics enter the water, and during incineration, microplastics are released into the air. These microplastics can then end up in the water when it rains. All of these occurrences massively increase the amounts of microplastics in the water, which only has negative effects.

Microplastics in the water are ingested by fish and other marine creatures, which are then consumed by larger animals, resulting in serious consequences for the entire food chain (UNEP, 2021). Unfortunately, water treatment plants are not equipped to filter out microplastics, meaning that increasing amounts of plastic are ending up in our drinking water.

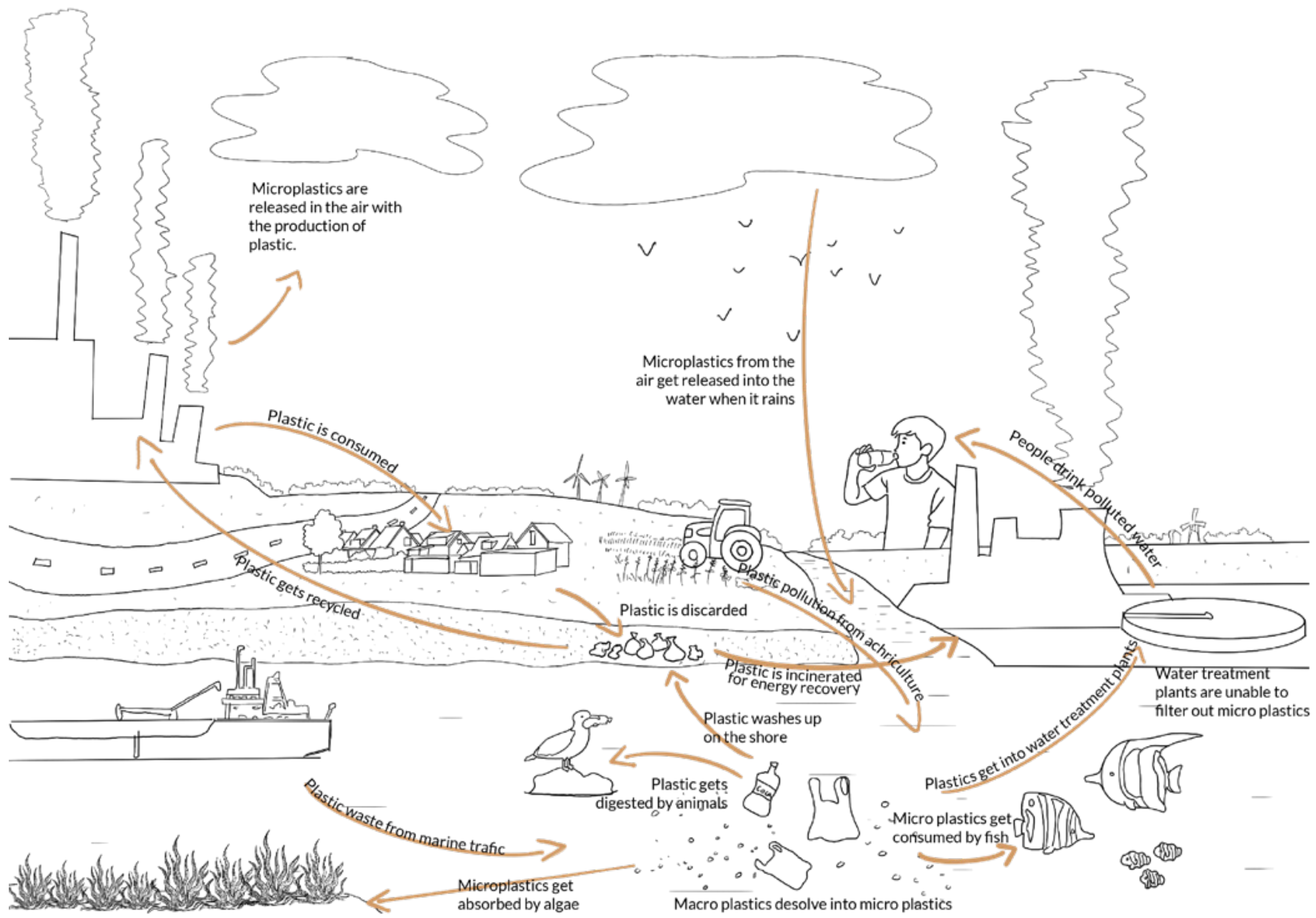

Fig. 4, The plastic pollution cycle from production to waste.

Plastic in the North Sea

This map visualises the spatial plastic accumulation in the North Sea. Visualised by pie charts throughout the North Sea, it is easy to see that most of the litter material in the North Sea is artificial polymer, and plastic is present all over the North Sea.

The plastic bag density has a clear concentration around the channel, where in most of the tidal zones of the surrounding countries large amounts of plastic bags have situated in the water. Another concentration of plastic bags can be seen in the area of the North Sea which houses wind farms, plastic accumulating around those structures.

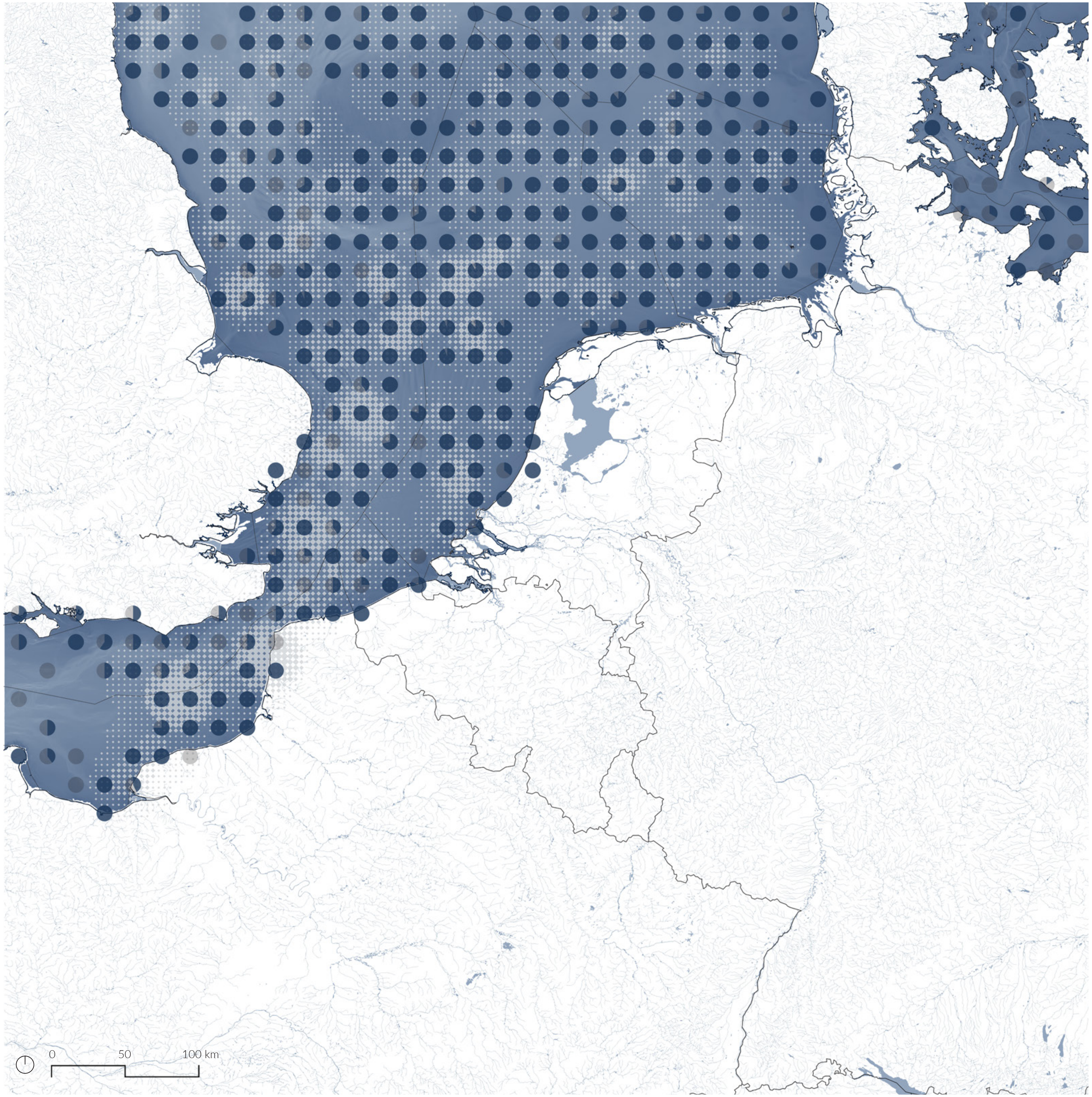

Fig. 5, Plastic pollution in the North Sea.

Water

Sea

Coastline

Exclusive economic zone

Administration boundaries

Litter material types (%)

Artificial polymer

Others

Flood Depth (m) - once every 10 years

<25

25-100

100-1000

>1000

Source of the pollution

Almost all marine plastic litter originates from a land-based source (UNEP, 2021). Often, this is due to badly controlled waste streams, or because plastic is directly discarded in the environment, marine or other. Plastic discarded in inland environments gets flushed down to rivers because of rainfall or due to winds, and accumulates in the oceans and river deltas (UNEP, 2021). As a result, there is an estimated 4.8 to 12.7 million tons of plastic per year which is transported via rivers towards the ocean (UNEP, 2021). As can be seen in the figure, all types of rivers (large and small) contribute to 80% of plastic inputs in the ocean (Ritchie & Roser, 2018). This tells us that a large part of the marine plastic pollution problem can be addressed in our inland river systems.

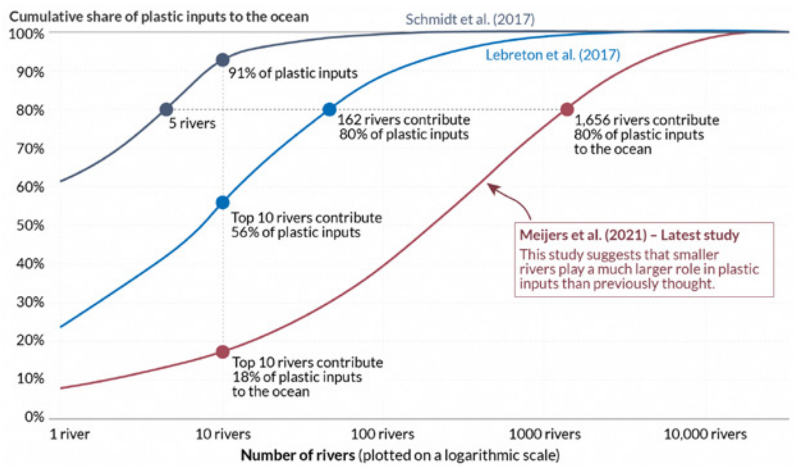

Fig. 6, Cumulative share of plastic inputs to the ocean.

Who are behind the pollution

It is hard to pinpoint exactly which parties are responsible for marine plastic litter, but we can look at which sectors are responsible for the most plastic waste in general.

Research by Ritchie and Roser (2018) tells us that the three sectors which produce most are packaging, building and construction, and textiles. However, when we look at the sectors that generate the most waste, we can see that while packaging is still the largest contributor, the textile sector becomes the second largest plastic waste generating sector (Ritchie & Roser, 2018). From a production of 59 million tonnes to waste generation of 42 million tonnes, the textile industry has a waste generation rate of 71%. The textile industry, therefore, can be seen as a big contributor to plastic waste in our waters.

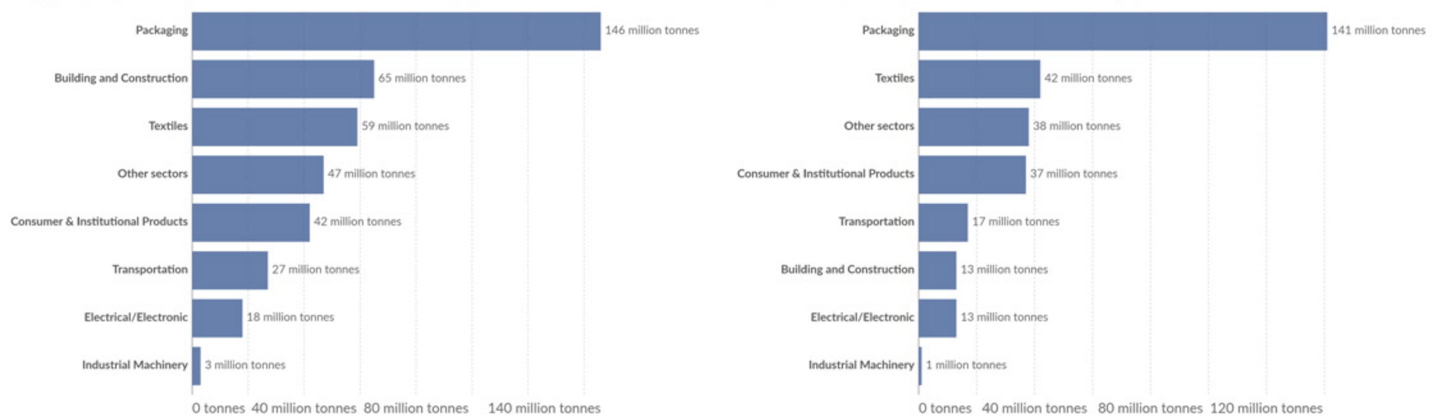

Fig. 7, Primary plastic production (left) and generation (right) by industrial sector in 2015, measured in tonnes per year.

Existing initiatives

At the moment, a small 10 percent of plastic waste is recycled, and the other 90% is incinerated or discarded (in landfill or in the environment). Though in the past couple of years many national and regional efforts to minimise plastic waste have been made, there is no international target connected to the limitation of plastic waste (UNEP, 2021). There have however been initiatives to limit plastic waste in certain sectors, such as the European Green Deal initiative to limit plastic packaging specifically (European Commission, 2022).

As the EU has found reducing the overall amount of plastic waste the 'most important step' (UNEP, 2021), there are no important policies or governmental initiatives that deal with the retrieving of plastic currently in the ocean. There are however, many NGOs and citizen initiatives that aim to retrieve plastic from the ocean, such as The Ocean Cleanup, who aim to clean up 90% of floating ocean plastic pollution (The Ocean Cleanup, 2023). This initiative deals with macroplastic, large visible plastic debris, which is easier to see and therefore to clean up.

Fig. 8, Tools and machines for plastic capturing used by Ocean Cleanup.

Towards a focus on pollution, The European Green Deal

The European Green Deal has set some ambitious goals to reduce plastic pollution, by making drastic initiatives such as banning single-use plastics, and promoting towards a more circular transition. Through a circular economy action plan, there will be a focus on taking resource-intensive sectors, such as textiles, construction and plastics and developing requirements within these sectors that would foster a transition towards biodegradable and bio-based plastics (European Green Deal, 2019).

As a way to empower this transition, the consumers will have a particular focus, as they will become a more visible chess piece on the board. Through consumer policies and concepts as "right to repair", the European Green Deal empowers consumers to make informed choices and become an active role in the ecological transition of these industries (European Comission, 2023).

Lastly, there is a big focus on plastics and the Circular Plastics Alliance aims to boost the EU market for recycled plastics to 10 million tonnes by 2025. This alliance holds 300 organisations representing different industries from academia to public authorities. Alongside the Circular Plastic Alliance, there will be a follow up on the 2018 plastic strategy, which focused on tackling micro plastics and unintentional releases of plastics, especially from textiles (European Green Deal, 2019).

The European Green deal and the section before summed up a number of challenges that this project will have to face. As one cannot find a solution to everything, this project will tackle the most urgent ones seen from the perspective of the textile industry in North West Europe.

North West Europe and South Holland

This project will jump in a variety of scales, to showcase and explain the complexity of different factors in a better way. Most of the analysis will be made on the scale of North West Europe, where our main focus will be the 'mainland: Netherlands, Germany and Belgium. Although not mentioned, Denmark and the UK will not be forgotten but will be taken more into account in the reflection and afterthought related to upscaling the project. Simultaneously, the smaller-scaled maps will be a leading tool to showcase the different interventions made based on our conclusion and how, or if, they potentially will change the landscape.

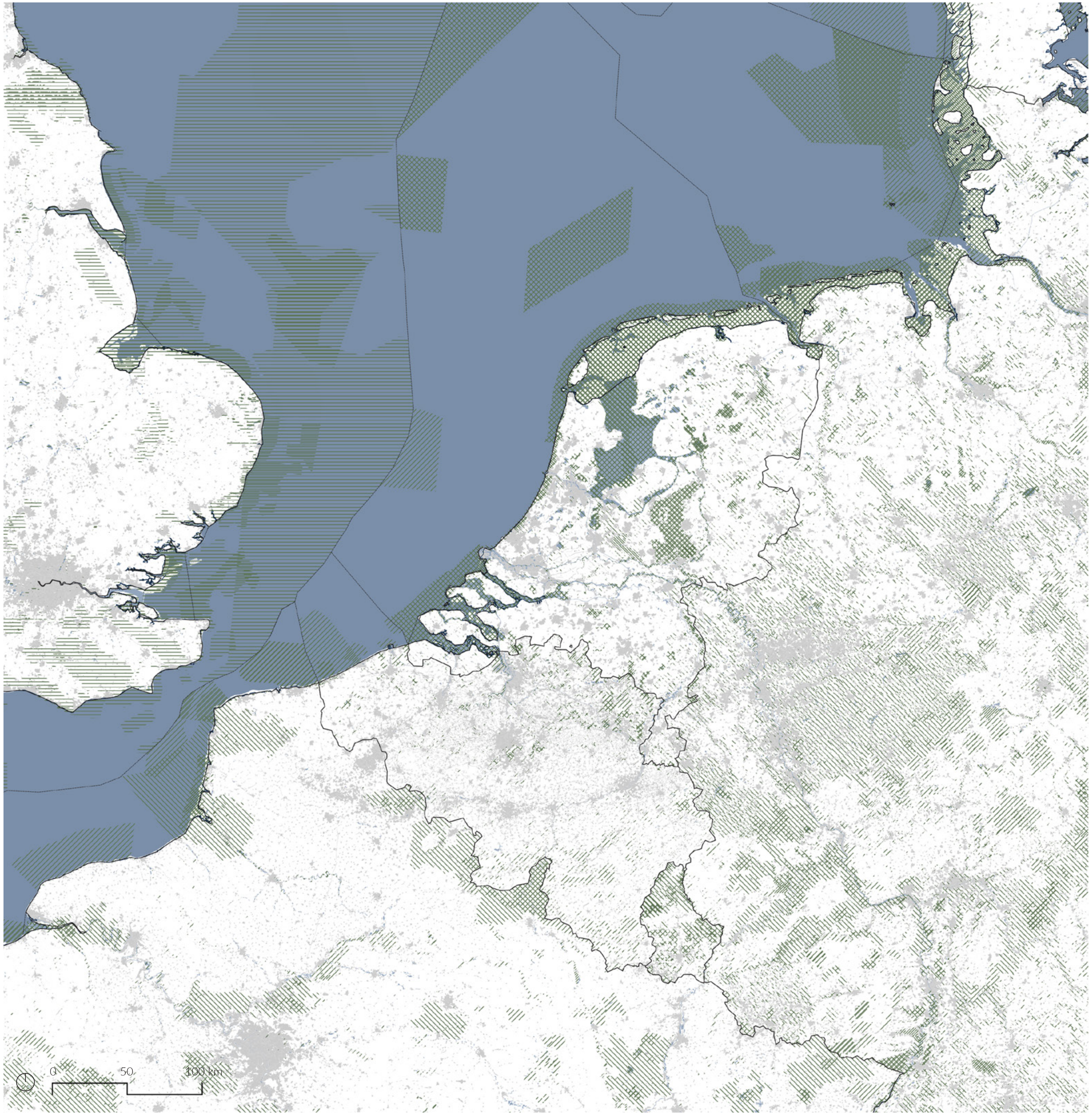

Fig. 9, North West Europe with borders and protected areas.

- Urban fabric
- Water
- Sea
- Coastline
- Exclusive economic zone
- Administrative boundaries
- Protected area - CDDA
- Protected area - Natura 2000
- Protected area - WDPA

Problem statement

The vast amount of micro- and macro-plastics in the European water systems is a threat to marine life, biodiversity and human health. Besides 'plastic islands' of macro-plastic, smaller pieces of microplastics present in the sea pose an invisible danger. On land, plastic litter accumulates in natural and man-made environments and often harms our different landscapes and wildlife through chemical pollution in soil and water. Plastic on land eventually ends up in the sea, which leads to plastic becoming a significant source of impact on marine life, through entanglement, ingestion, and disruption of the food chain. It can also affect human health through the ingestion of microplastics, water contamination, and economic impact on industries.

The packaging, construction and textile industries are the main plastic-polluting actors. With the new wave of sustainable thinking, a lot of plastic is being recycled or reshaped. However, approximately half of the plastic waste is still incinerated. In this process microplastics and other pollutants are again released into the air, and through that, when it rains, are released into the sea. This leads to a lot of microplastics ending up in the sea through incinerating facilities, washing of clothes and construction sites. In all steps of the plastic chain, from production to usage to disposal, harmful plastic particles wind up in the sea, threatening marine and human life.

Our main interest is to research how we can regulate plastic pollution in water. We do this through a deep dive into the textile industry, investigating one of the industries contributing to the alarming amounts of plastic waste. By exploring the application of cutting-edge technology in the textile industry, this project aims to utilise plastic pollution through spatial and policy interventions.

Research questions

How can a circular textile industry in South Holland be a catalyst for re-envisioning the use of plastic in North-West Europe?

How, and to what extent, does the textile industry contribute to plastic pollution in North-West Europe?

How can we decrease the amount of plastic pollution in the textile production process?

How can spatial and political interventions be a simulant of a better regulation of plastic pollution?

methodology

This section unfolds an overview of the methods and frameworks employed in this project. It describes the conceptual framework, where it becomes visible how different themes intertwine with each other. Simultaneously, it presents the main concepts that are used, discussed or criticised throughout the project.

Conceptual framework

In our conceptual framework, we attempt to combine and interrelate the different concepts and challenges we address in our Algae Project. The main challenge we aim to address is that of plastic pollution. There are two solutions to the problem of plastic pollution, being: cleaning up plastic that is in the sea right now, and the sustainable production of new plastic entities. However, the essence of our project lies at the intersection and the integration between the phenomena of plastic and algae pollution. Using algae as a biobased plastic material, we aim to provide a solution to both problems, using phenomena which are currently seen as problems and turning them into opportunities for our envisioned project. Within this opportunistic way of thinking, we aim to create the industrial ecology for a circular textile industry. With a configuration consisting of production and consumer hubs, we hope to simultaneously decentralise and deglobalise the textile industry.

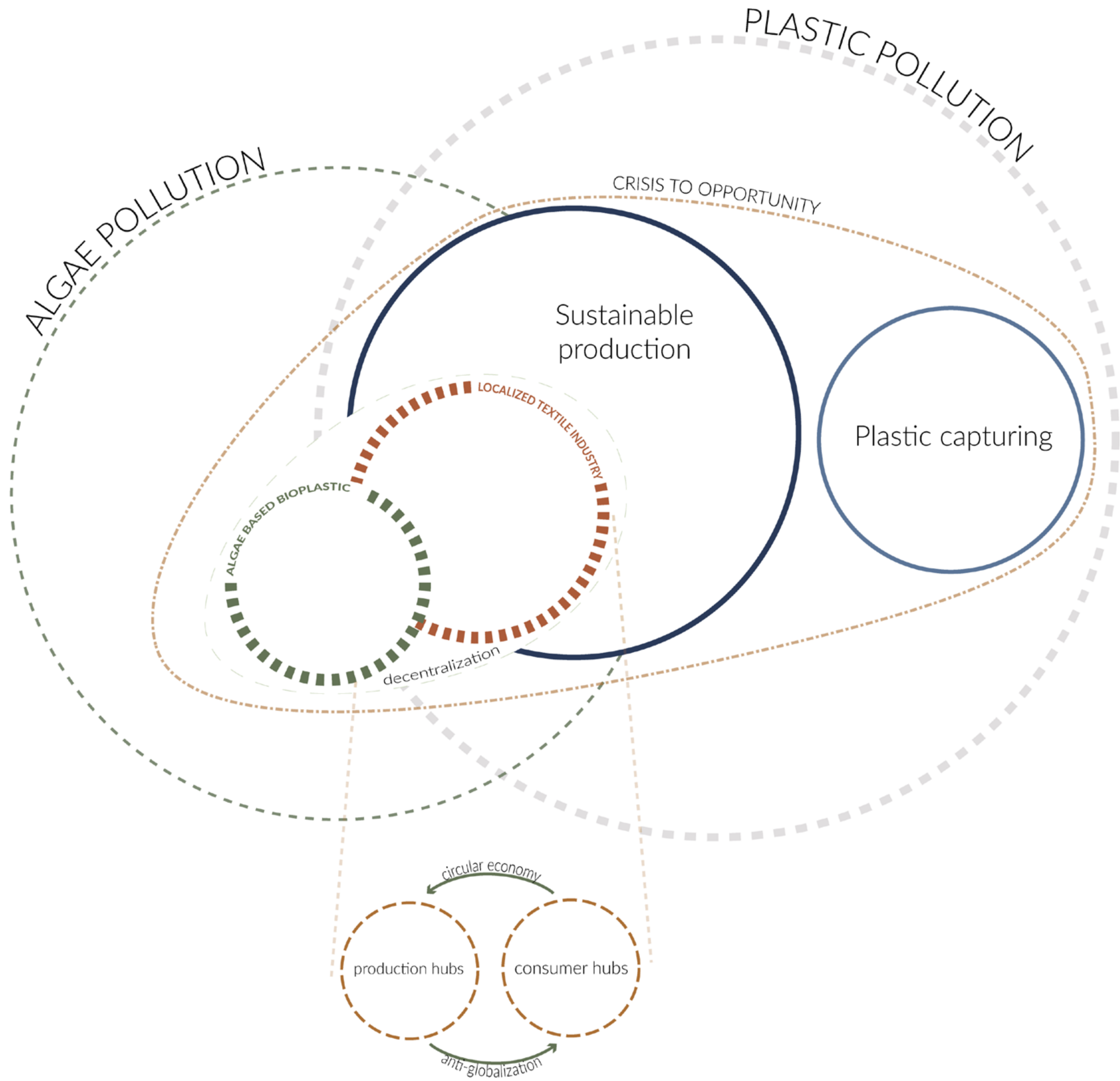

Fig. 10, Conceptual Framework diagram.

Theoretical Framework

Regenerative Circular Economy

'In order to be sustainable, the supply systems for energy and materials must be continually self-renewing, or regenerative, in their operation' (Lyle, 1994) The traditional circular economy calls for the reuse of materials. However, this closed-loop, low-incremental approach is relatively difficult to integrate into modern society's economic model, which has a constant demand for economic growth (Korhonen et al., 2018), causing ineffectiveness when it enters the market or planning. In addition, the traditional circular economy is relatively inefficient in achieving a fully sustainable future because of its simplification on societal and environmental aspects (Corvellec et al., 2021).

Therefore, we integrate the concept of regenerative to propose the concept of regenerative circular economy. Regeneration is a step further than recycle and reuse. The term 'regeneration' refers to two concepts: one is the shift toward renewable material in industry, the other is to promote the regenerative capacity of water, soil and ecology systems (Morseletto, 2020). Regenerative circular economy can introduce new materials into the market to stimulate the emergence of new industries, and enhance the environmental and social sustainability in a holistic way.

Decentralisation and centralisation (industry integration)

In the process of globalisation, the high competitiveness of metropolises sometimes devours the developing space of regular cities and towns. Decentralisation is a concept that reverses this negative effect. By distributing companies, decision-makings and administrations, decentralisation constraints unbalanced growth in centralised areas and gives cities autonomy. It also reduces the dependence of cities on global networks and increases their self-sufficiency. Industry integration is the spontaneous convergence tendency of separate firms in the same industry. (Gordon, 2023) At regional planning scale, industry integration intensifies the hierarchy and emergence of metropolisation. But it increases the production efficiency and reduces development costs, which are essential in beginning phases of a new regenerative circular economy.

Marine justice

The idea of marine justice is introduced as a means to connect and collaborate various approaches to knowledge creation and dissemination, with the goal of advancing and enhancing fairness in the face of current environmental challenges affecting oceans and coasts such as overfishing, rising sea levels, ocean acidification, and other related issues. This concept serves as an opportunity for scholars, activists, and policymakers to work together towards a common goal of promoting justice amidst global environmental change. (Martin, et al., 2019) As our design touches upon marine areas it is vital to hold these theories into account.

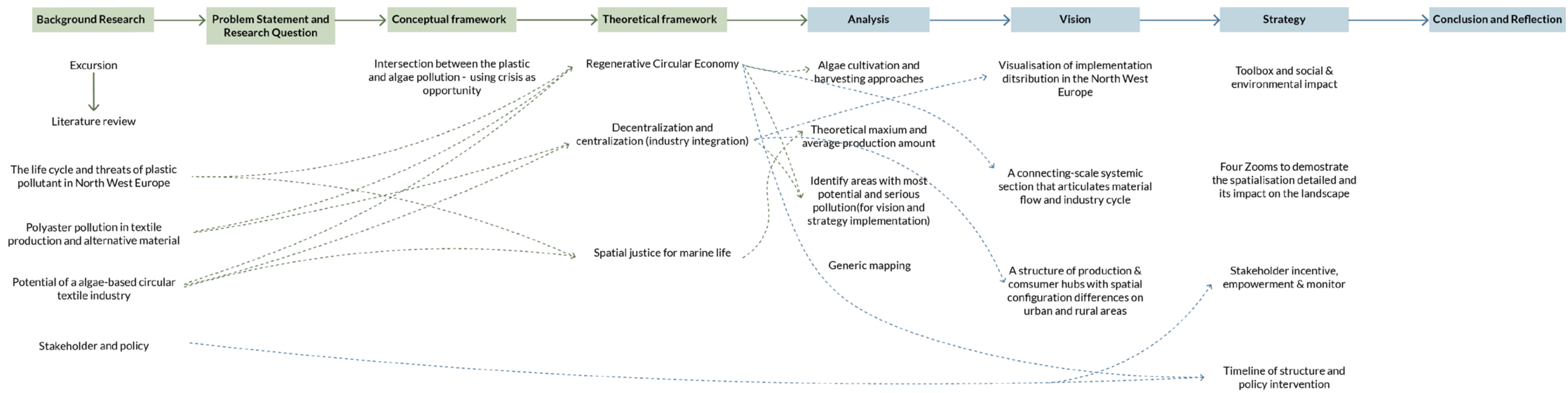

Fig. 11, Theoretical framework.

analysis

In the upcoming section, the historical context of textiles and their daily contribution to plastic pollution will be explored. Furthermore, we will discuss current research and alternatives to substitute plastics with a transition into algae as a potential bio-based alternative to plastic.

History of textiles

The production of textile was once a thriving industry in Northwestern Europe, particularly in Britain, Belgium, and the Netherlands. The raw materials used were primarily wool, flax, and cotton, sourced locally. Wool production began in Britain and Belgium during the early Middle Ages, with Belgium exporting wool as far as Russia. Dutch textile exports started to grow in the late 17th century, with production mainly concentrated in small towns in North Brabant due to the availability of cheap labour (Van Boom, 2009).

Initially, textile production relied on imported raw wool, mostly from Spain. The first spinning mills were established around 1800, powered by wind and water energy, with the first textile factories appearing in 1850 (Van Boom, 2009). At the start of the 18th century, almost a third of the labour force was employed in the textile industry.

This declined rapidly during the 20th century, as in order to keep textiles affordable with wages getting higher in Europe, producers had to relocate to places with cheap labour. In the 20th century, this cheap labour was found in South-East Asia (Van Boom, 2009). In 1950, the textile industry accounted for over a fifth of the domestic product in the Netherlands, but by the beginning of the 21st century, it had declined to just 2.3 percent (Van Boom, 2009). This globalisation added the extra negative effect that the production chain of textile had become more spread out increasing the amount of transport and transport connecting emissions within the cycle.

Another major shift in textile production in the 20th century was the invention of nylon, the first synthetic textile (Van Boom, 2009), which has increased the polluting aspects of the textile industry, seeing as synthetic fibres are made from plastic (and therefore fossil-fuel based) material. Just as with the production of regular plastic, these plastic based textiles emit microplastics at every step in the production process. Adding onto that, every wash of a nylon or polyester based piece of clothing emits more microplastic in the water system, making plastic-based clothes polluting from creation to disposal.

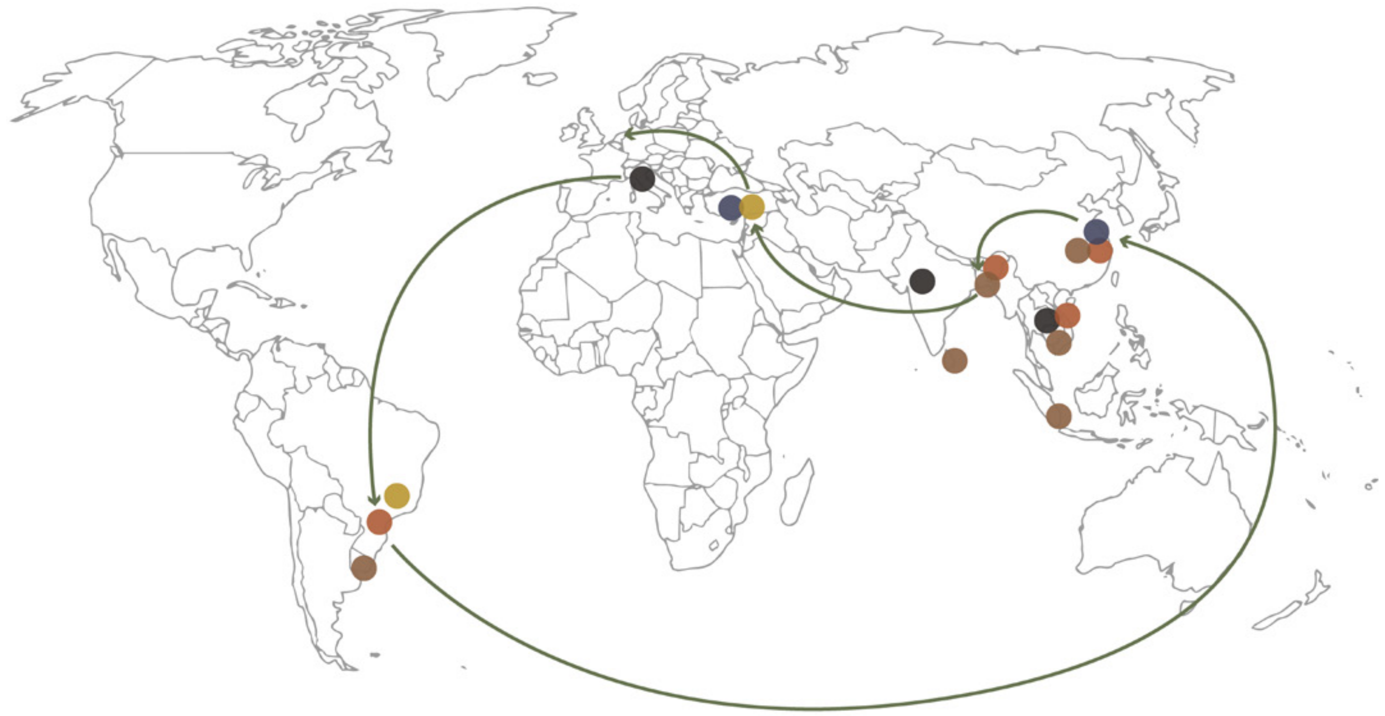

Fig. 12, World map of the globalisation of textiles.

- Raw material processing
- Textile / material production
- Dyeing
- Final product assembly
- Warehousing

Historical textile towns

This map shows the many historical textile cities that are situated in North West Europe. While none of them produce textile as a main industry anymore, they have derived much of their identity from this once-thriving industry.

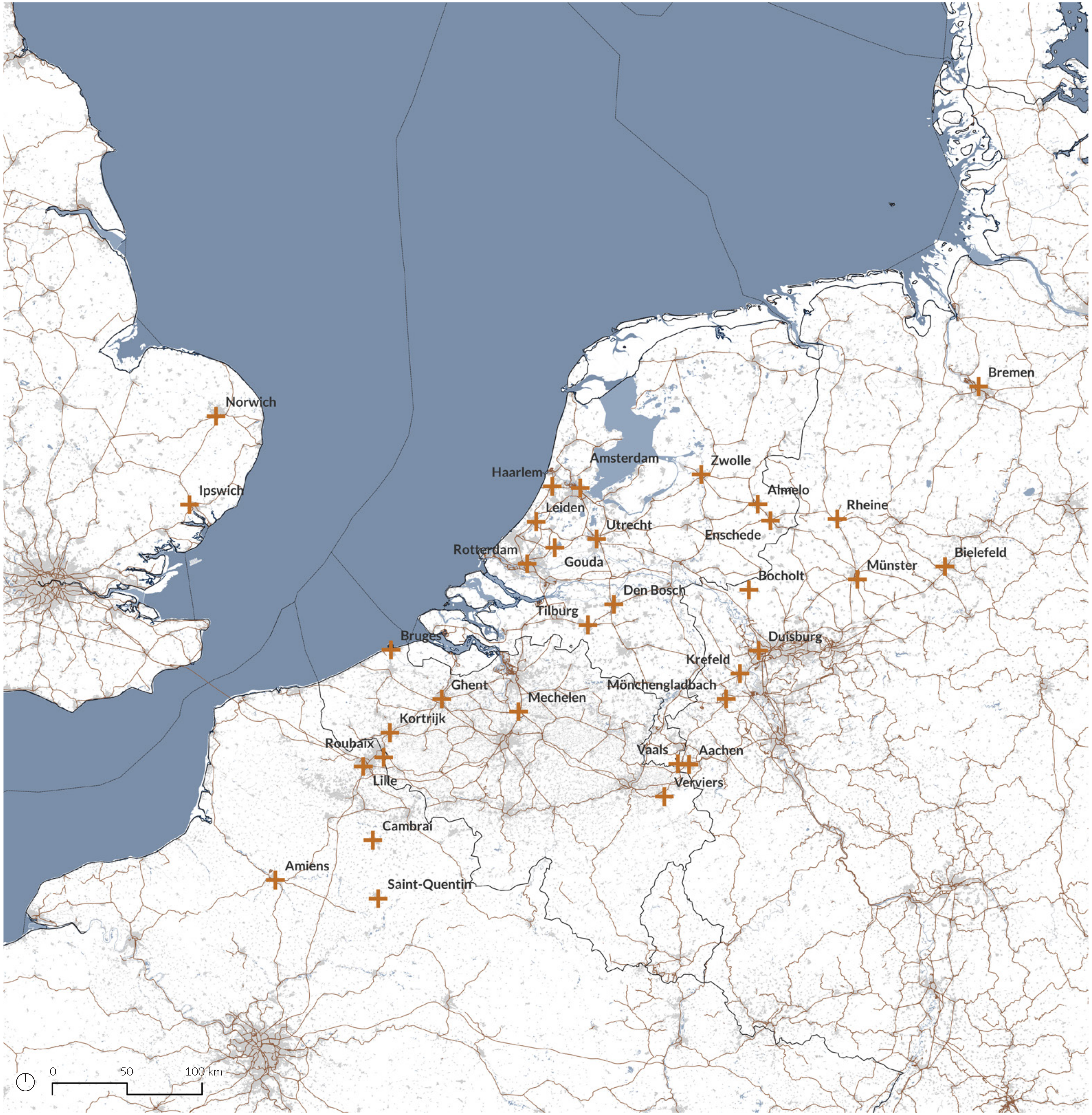

Fig. 13, Historical textile towns.

- Urban fabric
- Water
- Sea
- Coastline
- Exclusive economic zone
- Railway
- Administrative boundaries
- Historical textile towns

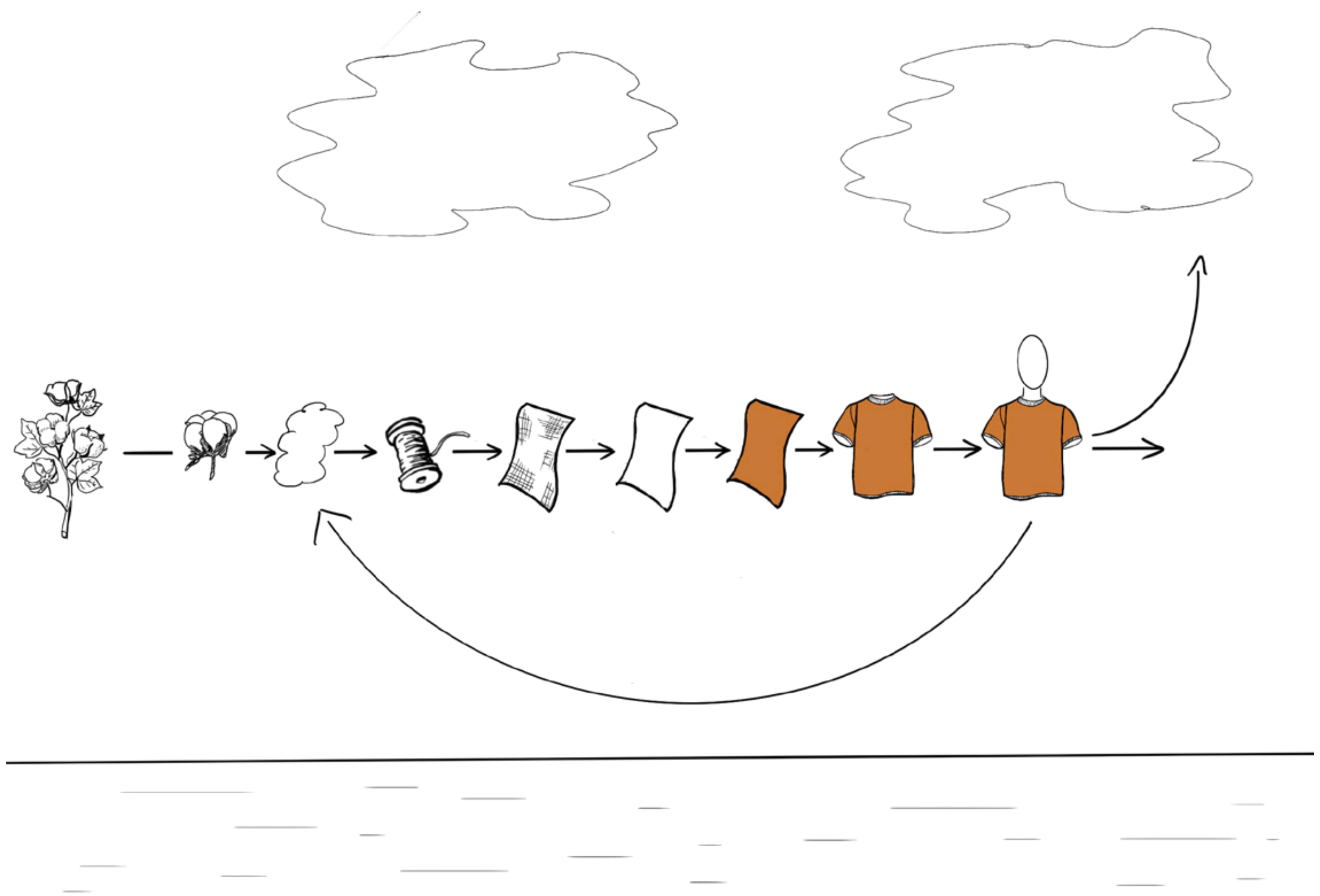

Fig. 14, Textile production in the 17th century.

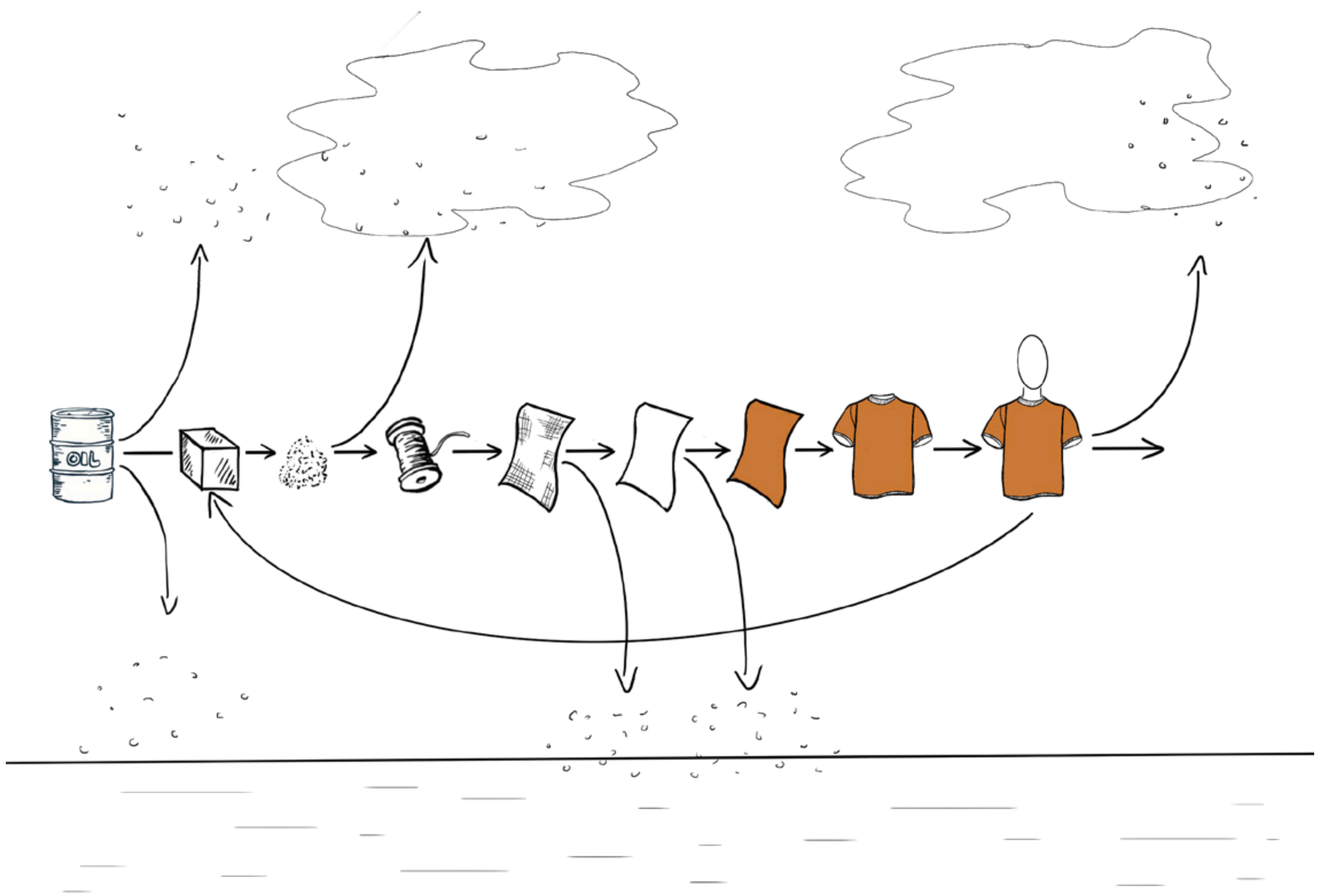

Fig. 15, Textile production in the 21st century.

Textile production in the 17th century

The textile production process in the 17th century is a very straightforward process. This example is using cotton as the raw material. In order to create fibres from the raw cotton it is spun into thread, and the threads are woven into fabric. Afterwards, this fabric may be dyed and it is then sewn into an item which gets worn, often until it cannot be used anymore. This is then discarded into landfill or parts are recycled (both 'in house', by the consumers themselves, and for general production).

Textile production in the 21st century

Even though the process of creating textiles has not changed a lot, there have been some changed elements which have had a large impact on the polluting aspects of the textile industry. The first being that the raw materials have become fossil-fuel based, with plastic fibres that are created from oil and other polluting materials. This has an added effect in the rest of the process that with every step in the process (spinning, washing, drying, dyeing), microplastics are released in air or water. Another thing to note is that these process steps have changed locations to be all over the world, adding transportation emissions between each step. After use, which is generally a much shorter time span than it used to be, the clothing is either recycled into new plastic materials, or it is discarded in landfill or incinerated, releasing harming toxins into the air. (Manshoven, et al., 2022)

How can it be less polluting?

The textile industry is currently immensely polluting due to the usage of fossil-fuel-based plastics, and the globalised nature of the industry. In order to decrease the amount of pollution, an alternative to plastic-based raw materials needs to be found. In addition, we need to look at how to de-globalize the industry, decreasing transportation in between steps of the production process.

Adding onto that, the process of 'fast-fashion', where clothes are worn for shorter amounts of time before being discarded, has also propelled the textile industry into its polluting characteristics. The globalisation of clothing and textile manufacturing has played a significant role in this rise of fast fashion. As manufacturing shifted to countries with lower labour costs, such as China and Bangladesh, it became even easier and cheaper to produce clothing quickly and in large quantities (Van Boom, 2009). This has led brands to be able to produce 52 mini-seasons per year, launching a new collection per week (Stanton, 2023). Clothing brands produce 53 million tons of clothes annually, and this amount is projected to reach 160 million tons by 2050 (Stanton, 2023). Therefore, another solution to make the industry less polluting is to decrease this amount of clothes that get produced and discarded.

Alternatives for plastics - bioplastics

In the search for an alternative to plastic-based raw materials, bioplastics can be used.
Bioplastics offer a sustainable alternative to conventional synthetic materials. By using renewable resources and biodegradable materials, bioplastics can help reduce the carbon footprint and plastic pollution associated with textile production (EUBIO, n.d.). While there are already some bioplastic-based fabrics available in the market, more research and development is needed to make them more cost-effective and accessible for widespread adoption(Döhler et al., 2022). As society becomes increasingly aware of the environmental impact of textile production, bioplastics offer a promising solution for a more sustainable future.

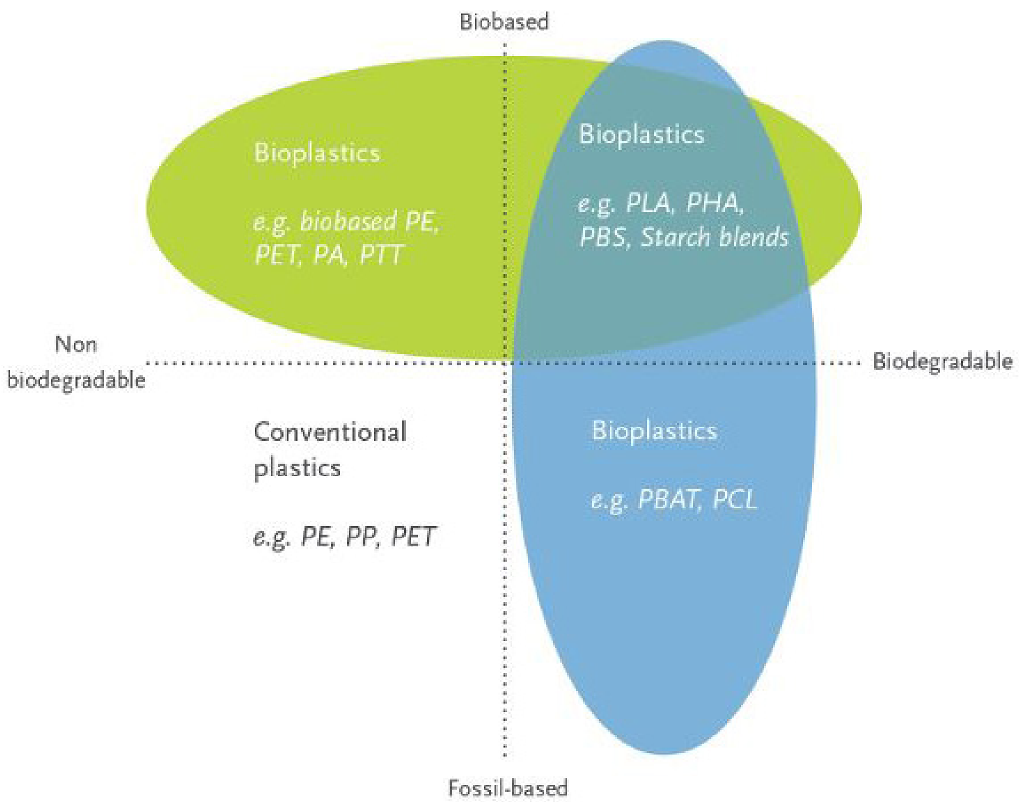

Fig. 16, Material coordinate system of bioplastics.

Algae as a substitute to plastic

Algae-based bioplastics possess the potential to serve as a sustainable substitute for traditional plastics, primarily due to their unique characteristics. Bioplastics can be manufactured using algae as a raw material and subsequently transformed into diverse products through processing and moulding techniques. The bioplastics can also be returned to algae, which facilitates the breakdown of the material into new raw materials (Kumar et al., 2017), thereby promoting waste reduction and stimulating the implementation of a circular economy. Specific strains of algae can even grow on plastics and decompose them into nutrient-rich compounds.
Although algae-based bioplastics have a shorter lifespan compared to fossil-based plastics, they are well-suited for the fast fashion industry due to their ability to quickly renew and biodegrade, aligning with the industry's rapid production and disposal practices. With advancements in technology, the scope for diverse applications of algae-based bioplastics is set to expand, indicating a promising alternative to conventional plastics.

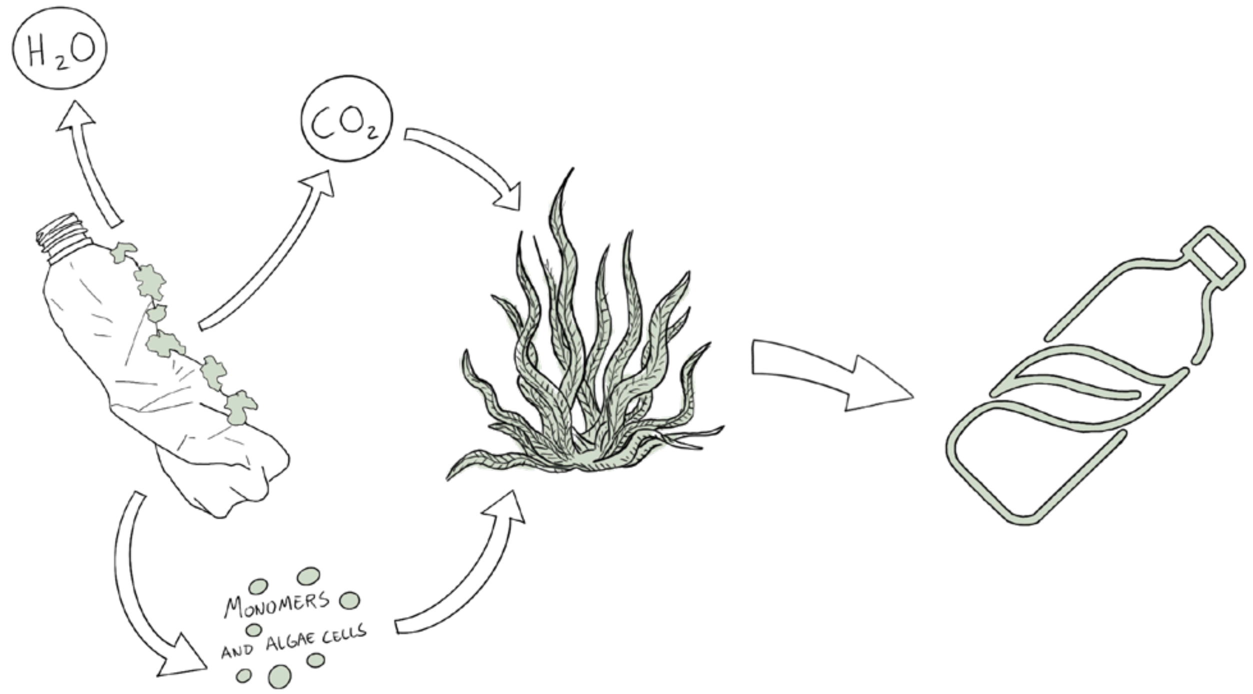

Fig. 17, From algae to bio-plastics.

Algae production

This map shows us the current locations of algae production by open ponds and photobioreactors, and places of aquaculture and algae harvesting. It shows us there is already quite a backbone of algae-based infrastructure, throughout all parts of North West Europe.

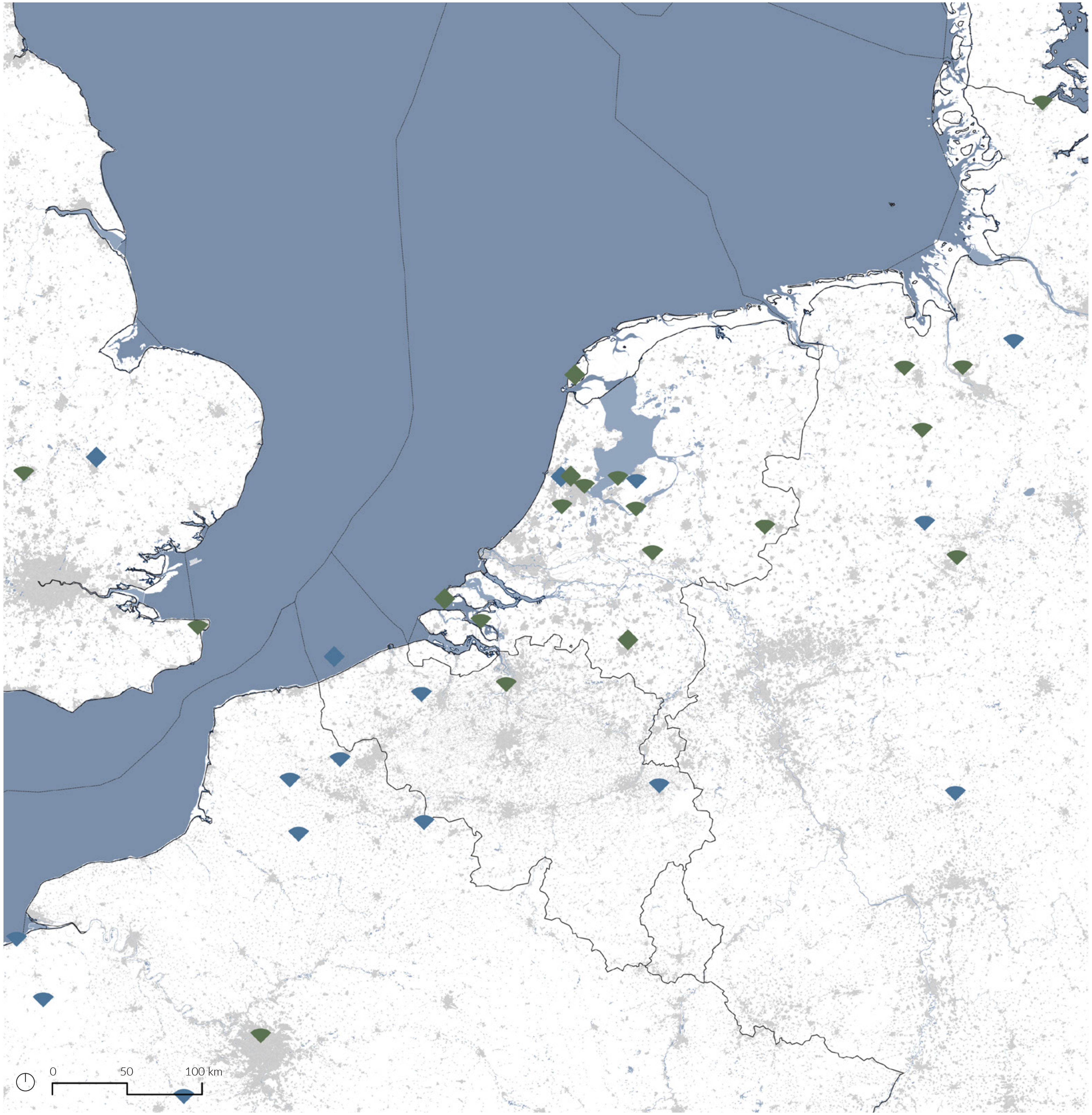

Fig. 18, Algae production

Urban fabric
Water
Sea
Coastline
Exclusive economic zone
Administrative boundaries

Algae production - macro
Aquaculture
Harvesting

Algae production - micro
Open ponds
Photobioreactors or mixed

Exploring algae

Algae, traditionally viewed as a notorious element causing water pollution, has come to be recognized as a promising source of sustainable raw materials, with numerous potential applications. Algae can produce harmful toxins, create dead zones, and cause negative economic impacts on various sectors. This has become even more prevalent in the current times of climate change and temperature rise, seeing as algae thrive on warm water conditions (CDC, n.d.) and the algae bloom has become an increasingly prevalent problem. However, with appropriate cultivation and processing methods, algae can mitigate various other types of pollution, including CO2, nutrients, heavy metal, and air pollution, as algae can grow on these nutrients and filter them out of the environment (CDC, n.d.).

Algae can be broadly categorised into two types: microalgae and macroalgae. Microalgae are single-celled organisms found in various aquatic environments, capable of colonising and aggregating microplastics to help remove them from water (Lagarde et al., 2016). Meanwhile, macroalgae are larger and more complex multicellular seaweeds that can grow in both marine and freshwater environments, with a wide range of applications such as food for humans and animals, fertiliser, biofuel, and bioplastics (Chia et al., 2020). Algae can be produced through various methods, such as aquaculture, photobioreactors, and Filamentous Algae Nutrient Scrubbers (FANS) (Hariz et al., 2023). The process and the workings of the FANS can be found in fig. 19.

Algae-based bioplastics, in particular, have garnered significant attention as a sustainable substitute for conventional plastics. The potential of algae in promoting sustainable development through the reduction of pollution and the production of renewable materials is immense, and further exploration of this resource is critical for a sustainable future.

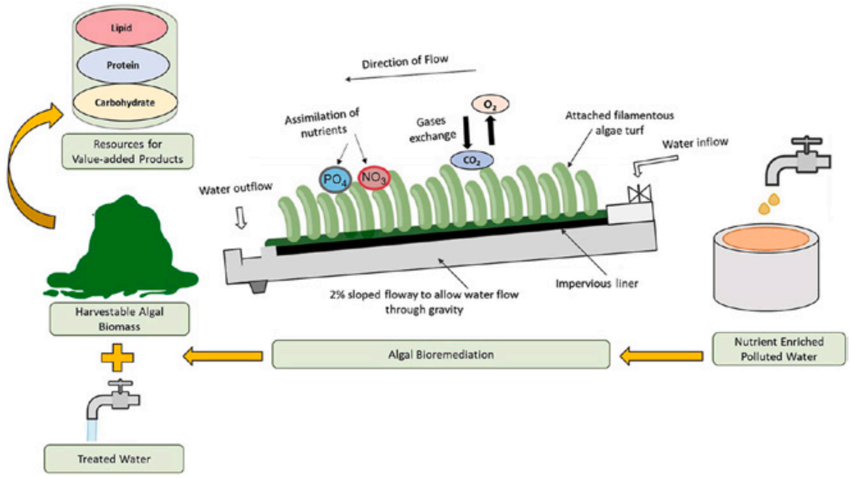

Fig. 19, Filamentous algae nutrient scrubbers (FANS)

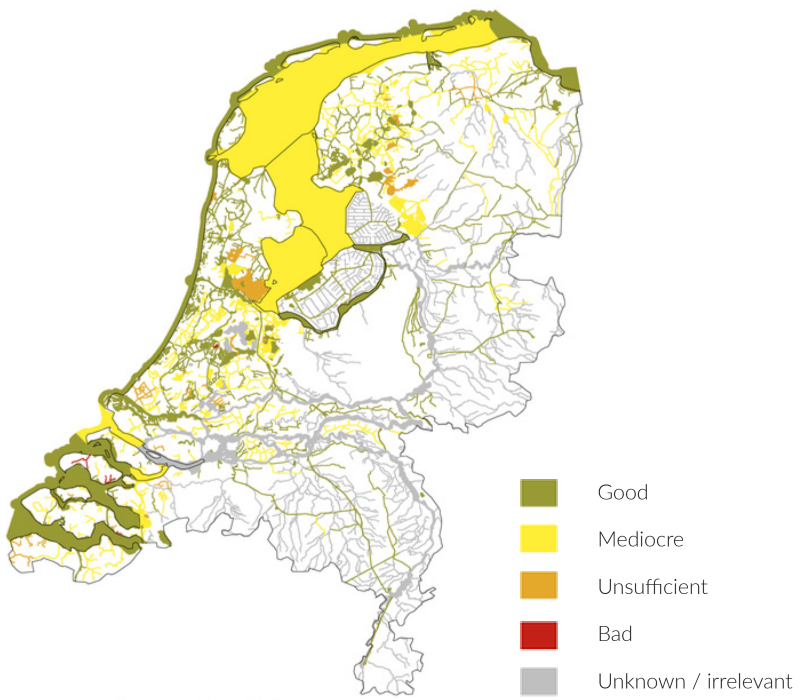

Fig. 20, Algae bloom assessment map.

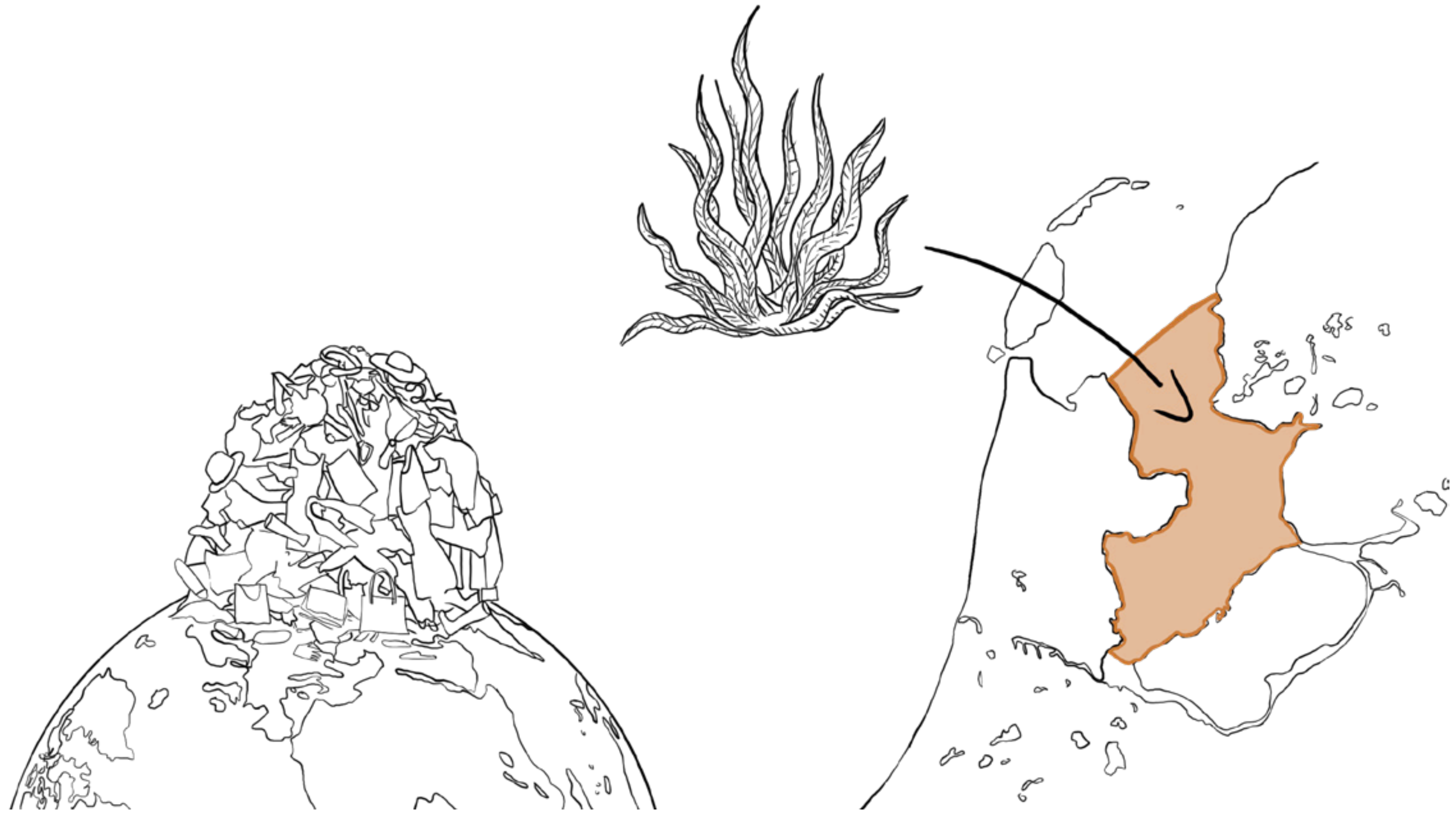

Fig. 21, Algae and the IJsselmeer.

Making algae quantitative

The amount of algae needed to produce a certain amount of bioplastic can vary depending on a variety of factors such as the type of algae being used, the cultivation method, and the bioplastic production process.

Because the production of algae textile is still in its early stages, there are no hard general numbers. However, most algae can already produce up to 60% of their biomass as biopolymers, which can be used to produce bioplastics. In the future, when more research is being done, this number will almost surely grow. (Fernández, et al. 2021)

As there are multiple ways of growing algae, we will do calculations for the two most conventional methods, open ponds and photobioreactors (photobioreactors have the same yield as the FANS) (Hariz et al., 2023).

In closed photobioreactors or FANS, algae yield can range from 50 to 200 g/m2/day (Krovi, et al., 2022). 100 g/m2/day x 365 days/year x 0.6 biopolymer content = 21,9 kg bioplastic/ m2.

This means that with a surface comparable to a football field (5000 m2) you would be able to produce more than 100 tons of bioplastic in a year. Per ton of plastic you can produce approximately 800-1000 kilograms of nylon or polyester (Manshoven, et al., 2022), and we assume the same can be said for bioplastic. This then indicates that with one football field of algae farm, you could produce at 800.000 to 1.000.000 t-shirts in a year.

In open ponds, the average yield of algae biomass can range from 5 to 25 g/m2/day (Fernández, et al. 2021). So in good conditions in a natural setting you could make 5,5 kg of bioplastic per year per m2.

These calculations show that, with North West Europe consuming approximately 4.888 million kilograms (Manshoven, et al., 2022) of clothing every year, you would theoretically need 1859 km2 of open algae farm, which is about as big as the IJsselmeer.

Nitrogen and phosphorus run-off

This map shows the accumulation of nitrogen and phosphorus release in water in Europe. It can clearly be seen that agricultural areas have a higher release of these nutrients in water.
As algae grows on nitrogen and phosphorus, this map is a very clear indicator on where algae bloom area (might) occur within our region, and which areas will have high yields of algae in natural waters and with the use of the FANS.

Fig. 22, Nitrogen & phosphorus release in water.

- Agriculture
- Pasture
- Water
- Sea
- Coastline
- River bassins

Agglomeration of nitrogen & phosphorus release in water

- Low
- High

vision

In this section, all research and analysis will be integrated into a future vision that encompasses both North West Europe and smaller regions such as South Holland and the Center of Holland, around Utrecht.

Vision

There are two methods to minimise plastic pollution in the ocean: one involves collecting and removing plastic already present in the North Sea, and the other replaces the use of plastic in various industries, such as the textile industry.

As mentioned before, there are current initiatives that go about collecting existing plastic in oceans and recycling it. A problem with these initiatives is that they are not done in equal amounts to the growth of plastic in the oceans. Each initiative is helpful, but we need a bigger force to tackle the growing zones of accumulated plastic in the oceans.

Our vision entails two main ways of capturing and retrieving already existing plastic in the North Sea and inland water bodies. By bringing a bigger focus on the existing EU Action Plan “Towards Zero Pollution for Air, Water and Soil” (European Commission, 2021), which is part of the European Green Deal, the local governments for each country in North West Europe should be pushed more and funded to take on initiatives to assign pilot ports to dedicate boats for ocean cleanup. These boats will be connected to a recycling facility and will have the duty of going to the accumulating zones in the North Sea. The European Action Plan will act as an adjustable vision for the European Union, and fund initiatives, like the CleanAtlantic Project (CleanAtlantic, n.d., 2023), to take more action within the North Sea. Another initiative will be more locally bonded, as tidal zones will become areas for plastic capturing as well. In these zones, plastic-capturing booms, which is an existing invention, will capture a smaller amount of plastic and lead them to land. From this point, people from the big cities or smaller towns, located around the tidal zones, will be able to pick up the captured plastic on their own and bring it to the recycling facilities. Through this, they will be able to earn points that in the end can be turned into a plastic recycled chair or any other locally manufactured object. This part of our vision seeks to showcase that there is a huge need in maximising our capturing and retrieval of plastic, but that it can be done not only through governmental big action plans but also locally by people who live nearby as long as there is a wish to act.

On the other hand, we propose to end the use of plastic in the textile industry by substituting the raw material from traditional plastic for algae-based plastic. It is the qualities of algae that currently cause problems, which we use as an opportunity - adaptability to the environment and rapid growth rate (Upadhyay et al., 2019), making it a raw material with large yields and a wide selection of producing locations. In our proposed sustainable textile industry, we combine the advantages of centralisation and decentralisation. On the large scale, we propose a configuration consisting of production and consumer hubs, aimed to decentralise the existing textile industry, and reverse its globalised state. Scaling down to a smaller scale, one singular production hub consists of a centralised area where the entire industrial process of this circular economy is located. Decentralisation on the regional scale contributes to a more democratic administrative pattern and balanced regional development, while centralisation on the local scale provides cities with a specialised production structure that stabilises yearly production.

In order to facilitate this transition, some implementations have to be made.

First, we need areas for the production of algae. We produce / collect algae in three different ways. Firstly, we harvest algae from locations that, at this moment, deal with natural algae bloom complications. Secondly, we implement the FANS alongside water in areas that deal with nutrient runoff. Here, the algae grow on the nutrients that leak into the water. Lastly, we utilise Open Ponds to produce micro-algae in a more controlled manner.

Then, we need to allocate locations where the algae is processed into bio-plastic, and eventually gets made into textile products. This is done by allocating city hubs, which house research and bio-plastic facilities and where a textile industry location will be implemented. This in order to keep the distances between steps in the production process as short as possible, in order to eliminate negative impacts of long / far transportation. The selection procedure of these hubs is discussed in project CITY HUBS, where you can more specifically see how our vision of a decentralised bio-based textile industry is spatially configured.

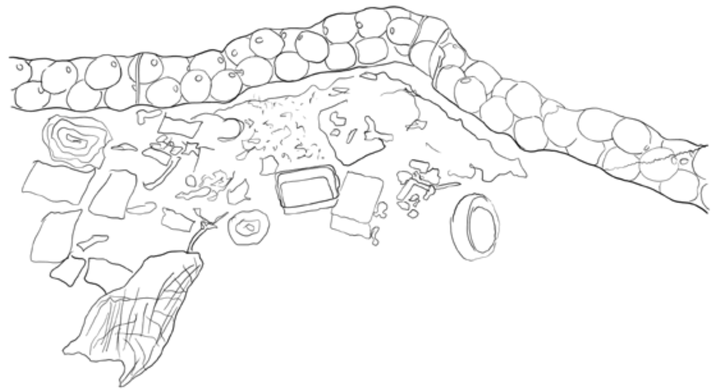

Fig. 23, Capturing and retrieving existing plastic

Fig. 24, Towards a sustainable production.

Overall vision

This map showcases the overall vision. It is meant to showcase how there are a action on the coastal line and the North Sea and specific inland areas, like around Utrect and Zealand.

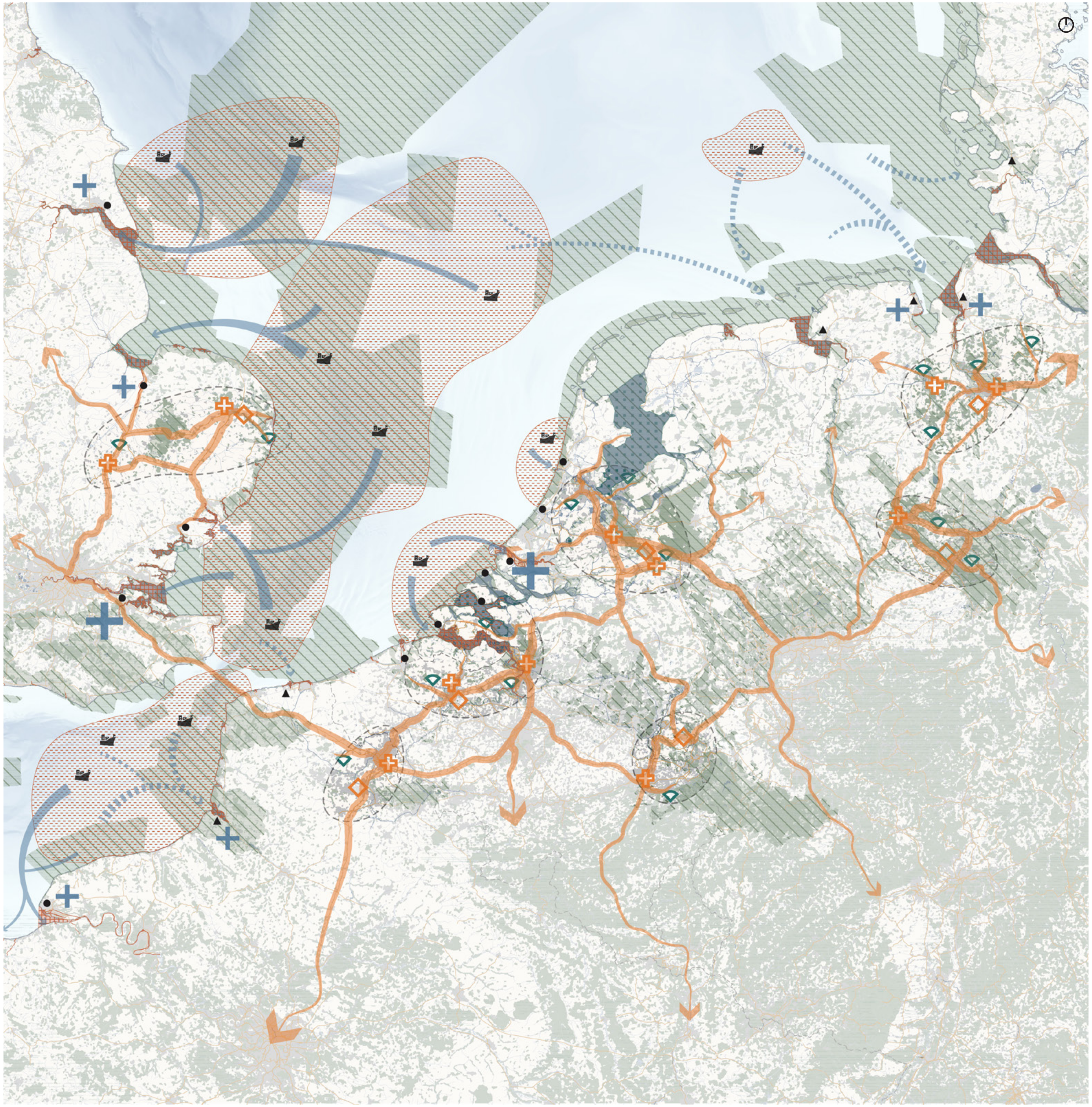

Fig. 25, Overall vision map showcasing the main interventions visible in North West Europe.

- Protected areas
- Country borders
- Main rivers
- Tributary rivers
- Inland waters
- Forest
- Agriculture
- Urban fabric
- Railway
- Algae bloom harvest
- Open pond
- Flow of cleanup vessels
- Bio-plastics facility
- Textile facility
- Benefited protected habitats
- Benefited waterway/waterbody
- Potential traffic concentration
- Clusters of intervention
- Plastic capture, boats
- Tidal zones / booms
- Important cities for recycling
- Exis. / new recycling facilities
- Potential future flow of cleanup vessels

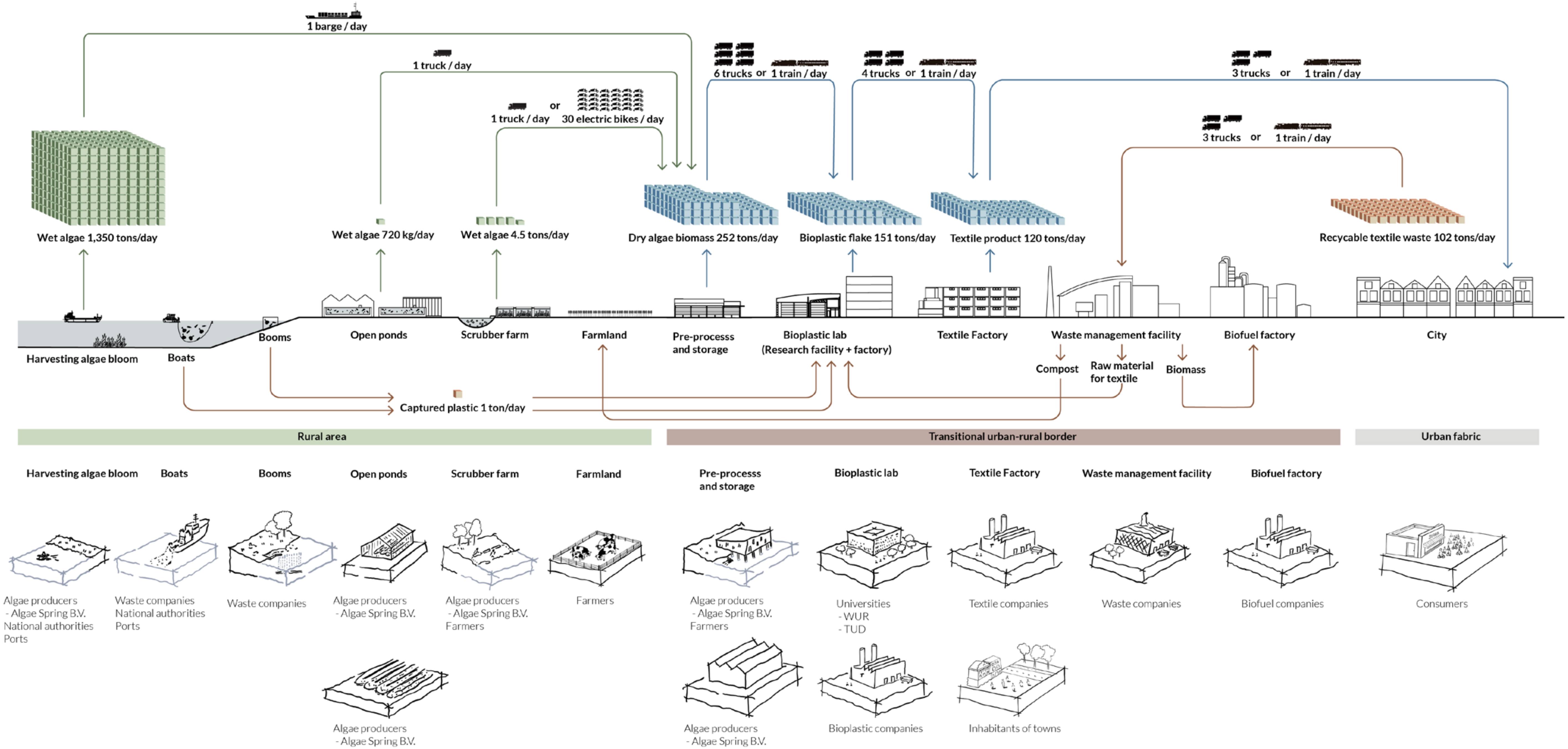

Fig. 26, Systemic section.

Systemic section

The systemic section shows the production steps, material flows, and physical facilities of our two-sided vision. It connects multiple scales from regional locations to urban fabric to building typologies, demonstrating the full spatial picture of this project.

The upper flowchart is the industrial cycle of the sustainable textile industry. Algae produced in or collected from algae bloom areas, open ponds and FANS are transported to nearby pre-processing and storage facilities to dry. Dry algae biomass is then delivered to the bioplastic labs, where clusters of research facilities and mass production factories are located around a university for the production of bioplastic flakes. These bioplastic flakes are transported to textile factories where they are made into bioplastic based textile products, and these products are shipped to nearby consumer cities. After the textiles have been worn and have turned into waste, their recyclable parts are disposed of in three ways at a waste management facility: compost, raw material for textiles and biomass, which is used to produce biofuel in factories.

The lower flowchart concerns the capturing and recycling of plastic. Plastic captured by booms and boats is transported to the bioplastic labs, from where they enter the sustainable industry cycle by being processed into bioplastic. The plastic pollution in the sea is either recycled in the chain or becomes biodegradable waste.

The two-sided strategy is decentralised in the North West of Europe, forming a structure of production hubs and transportation backbones, which is explained in the City Hub map. The three coloured strips in the middle of the section indicate the detailed spatialisation of these facilities: mostly on the edge of the urban fabric. Algae production and plastic capturing activities are usually located in or near water rural areas, while factories are in urban-rural interfaces. Underneath this we connect the 'human' scale, which shows the typologies of the landscape from an individual's perspective, and what kind of, not necessarily spatial, impact they have on the environment and society.

Plastic capturing and retrieving

The first part of our vision focuses on capturing and retrieving existing macroplastic in the North Sea, which accumulates mostly in the southern part of the Sea and coastal zones of the Netherlands. It presents us an opportunity to not only use this plastic in the textile industry but also to build on and embrace existing initiatives to clean up the planet.

Collaboration among North West European countries (and the UK) will be necessary to capture and receive the plastic, but with already existing pilot cities, like Rotterdam and Brugge, it can become clear how it doesn't require much. Boats, a dock and a recycling facility nearby come a long way.

New recycling facilities are needed in the northern part of North West Europe, and lots of smaller harbour or port cities, including Emden, Wilhelmhaven, Bremerhaven and Esbjerg, have the potential to boost their economy by establishing new recycling facilities and joining the initiative.

Additionally, the vision activates the tidal zones to prevent plastic from ending up in the North Sea. Here, most cities are already part of the first part of the initiative, meaning that the recycling facilities would have to accommodate a flow of plastic not only from the boats but also from booms (The Great Bubble Barrier, n.d.), which would be a more bottom-up approach of retrieving macro-plastic for reuse.

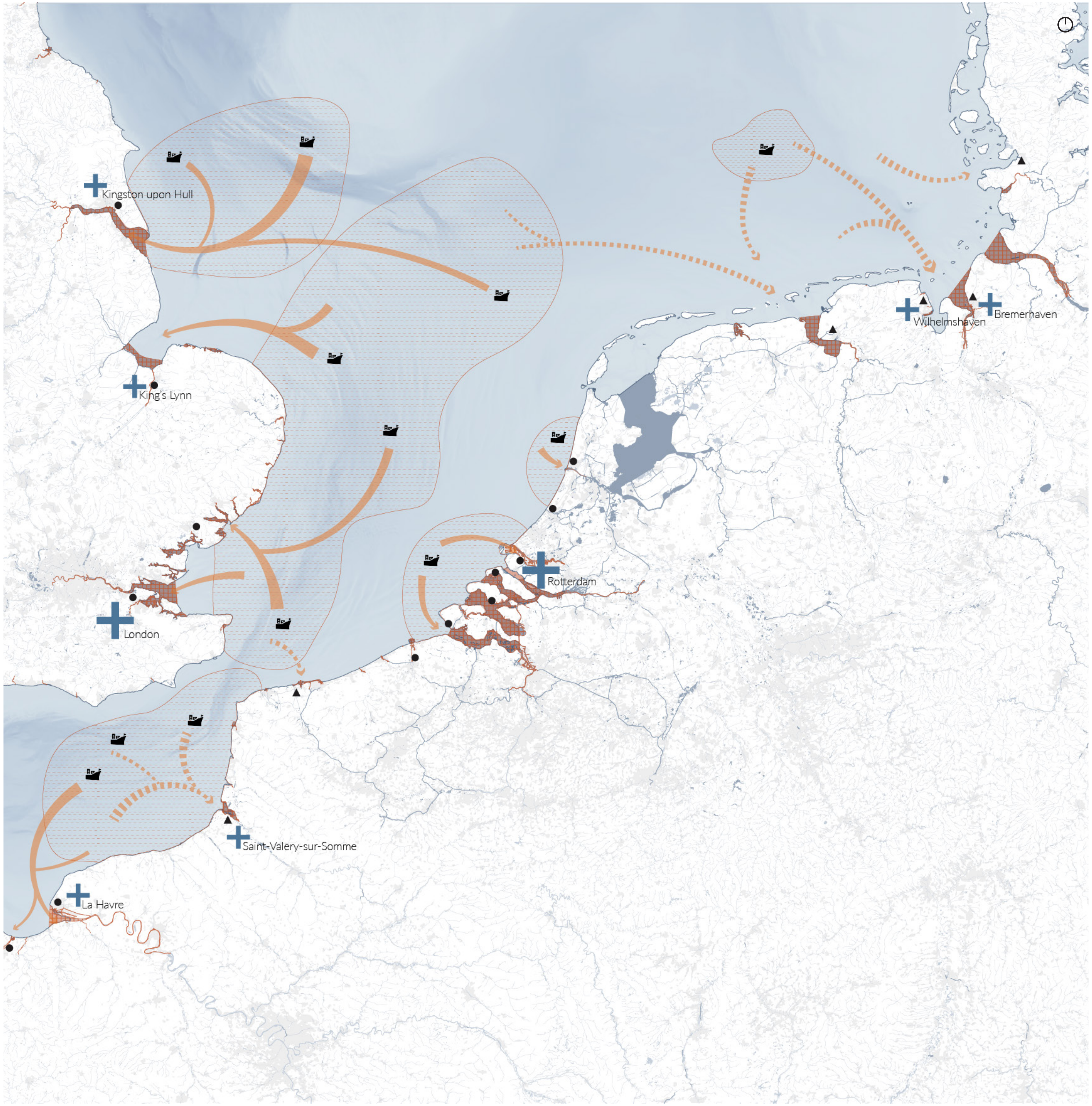

Fig. 27, showcasing the coastal and North Sea connected vision of capturing plastics.

- Inland waterbodies (rivers, canals)
- North Sea and bigger inland waterbodies
- Urban Fabric
- Tidal zones / areas of booms
- Plastic accumulation
- Existing plastic recycling facilities
- New plastic recycling facilities
- Flow
- Potential future flow
- Important cities

City hubs

The second part of our vision focuses on forming a sustainable textile industry in North West Europe. We envision a structure of production hubs and transportation backbones. A production city hub is a cluster of multiple cities where algae is processed into bioplastic, and this bioplastic is used for textile products. The transportation backbones are railways connecting our city hubs as well as being able to distribute the products to non-textile producing cities (which are called consumption hubs in the project).

The reason we propose this configuration of production hubs is efficiency and stabilisation. Cities can share the research centres, logistics, and general infrastructure. As the production of algae can fluctuate, when one city may be unable to achieve adequate raw material, nearby cities can provide it. City hubs need certain prerequisites to function the upgraded industry. We have selected cities because of the following requirements: close distance to algae bloom harvesting or plastic capturing zones, the presence of an existing open pond facility, the presence of a former textile town (that may have lost identity), and the presence of a bioplastic research institute and university.

The transportation backbone is not only used by our production hubs but also by the consumer hubs, seeing as textile products need to be transported to all cities, and their recyclable waste has to be delivered back to the production hubs.

Within this structure of city and consumer hubs throughout North-West Europe (and more specifically the Netherlands, Belgium and Germany), there is a difference between the spatial configuration of these hubs and areas of production and consumption. We choose to point out these differences by elaborating the vision in two different 'zoom-ins', which are located in different types of regions. One, around the middle of the Netherlands, is a more urban situation and shows us the more crowded configuration of multiple production and consumer hubs, with more cities and less natural area. The second focus is one of the more rural situation. Around Zeeland and with the northern part of Belgium, we showcase the way our system works with less cities and more agricultural lands.

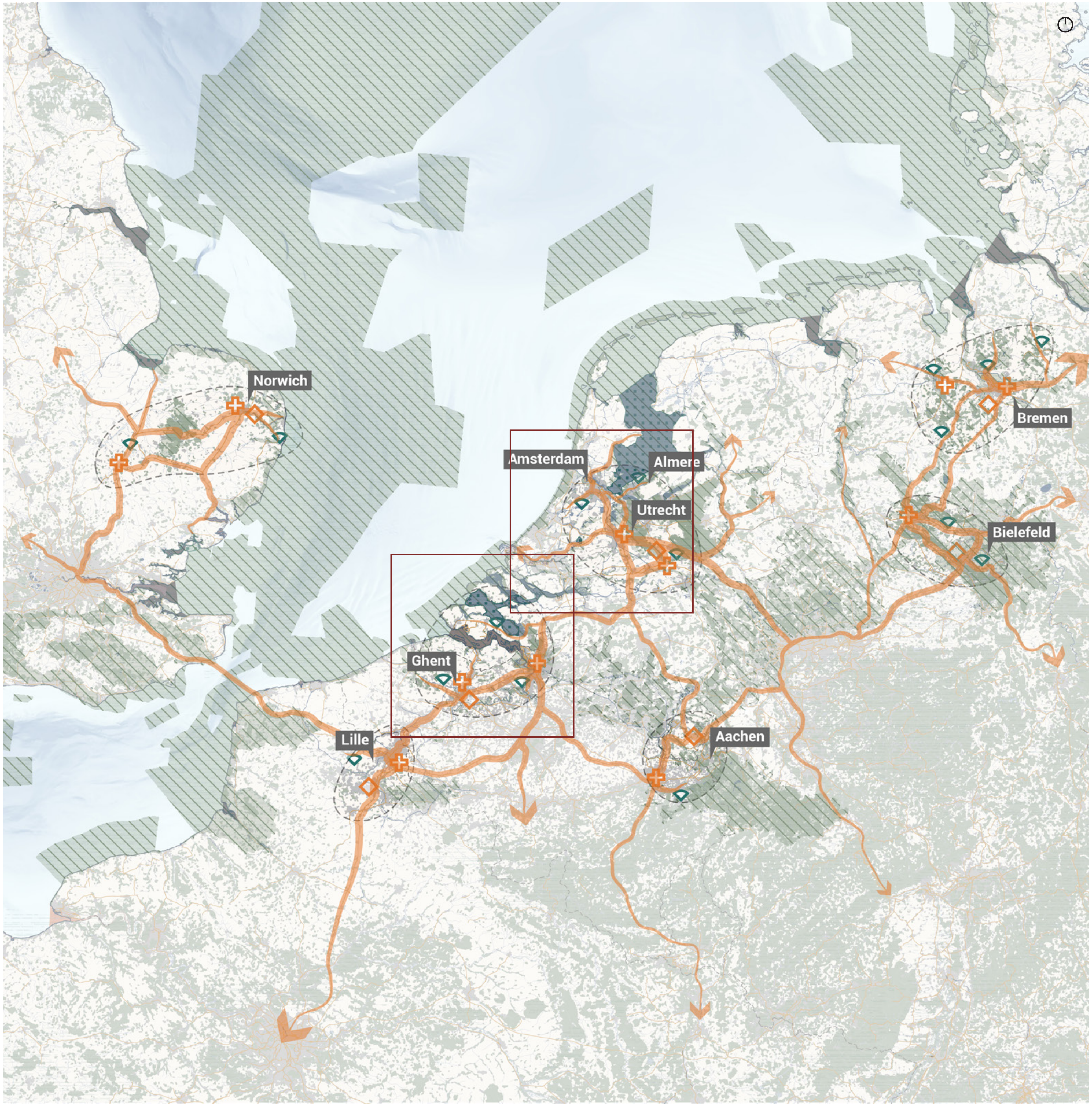

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Fig. 28, showcasing the coastal and North Sea connected vision of capturing plastics.

- Protected areas
- Country borders
- Main rivers
- Tributary rivers
- Inland waters
- Forest
- Agriculture
- Urban fabric
- Railway
- Bio-plastics facility
- Textile facility
- Benefited protected habitats
- Benefited waterway/waterbody
- Potential traffic concentration
- Clusters of intervention
- Relevant historical textile towns
- Algae bloom harvest
- Open pond

Urban context

The 'urban' zoom focuses mainly on the cities and rural landscapes around Utrecht. Here, existing open ponds, water bodies with algae bloom, research facilities and historical textiles cities all lay the base for a new hub of textile innovation. From the north of Almere towards the south of Wageningen, the production hub combines existing cities and ties them together through bio-based textile production. As seen on the map, the main facilities fostering the new textile industry, like the pre-processing facility and recycling facilities all lay on the edge of the cities, making them a catalyst for creating a better transition between the urban and rural, and making space for new social and environmental interventions that foster the local communities.

Fig 29, showcase a zoom on the urban context, more concrete Utrecht.

Protected areas
Main rivers
Inland waterbodies
Forest
Wetland
Agriculture
Railway
Highway
FANS
Pre-processing facility
Recycling facility
Algae bloom harvest
Open pond

Relevant historical textile towns
Bio-plastics facility
Textile facility
Benefited protected habitats
Benefited waterway/waterbody
Potential traffic concentration
Clusters of intervention

Flood Depth (m) - once every 10 years
0-1
1-2
2-3,5
3,5-5,5
<5,5

Reflective thoughts...

How will the transition in and around Utrecht affect the other main cities of The Netherlands?

Amsterdam

The city of Amsterdam will still be a main tourist attraction for the rest of Europe and the world. Within our new textile industry, it will act as a consumer hub and foster awareness and spread algae products through smaller boutiques in the city centre.

Fig 30, zoom in the urban context.

Rotterdam

The city of Rotterdam will still be highly dependent on the port as a main economic driver. Just like Amsterdam, Rotterdam will act as a consumer hub and spread awareness and disturbed algae products in a variety of stores. Simultaneously, the biofuel that will be a waste product in the making of algae textiles will be stored in the port of Rotterdam.

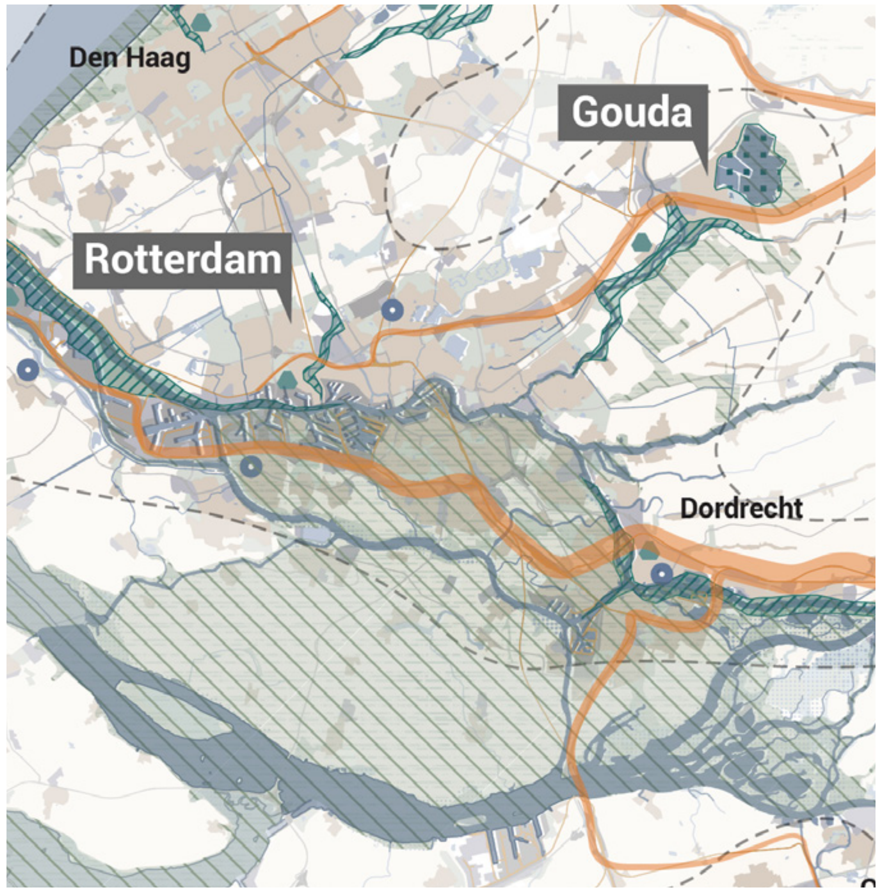


Fig 31, zoom in the urban context.

Rural context

The 'rural' map focuses on the area around Zeeland, taking the southern peninsula of South-Holland and the mainland of Belgium into account as well. Compared to the urban situation, we can see that the scrubber farms are more structurally prominent. They are situated almost everywhere along the Zeeuwse estuary, as these protected waters have to deal with a lot of negative pollution runoff from the agricultural lands in the area. In using this large amount of runoff, we can grow more algae in order to supply our bioplastic, while simultaneously improving the water quality in the protected natural area of the estuary. As can be seen on the map, traffic flows are less in the rural focus, as these areas have fewer 'large' cities that materials need to be transported to.
The locations of the new facilities we propose in the rural context is the same as in the urban context; on the edge of the cities, utilising the same opportunity of creating an improved transition between urban and rural.

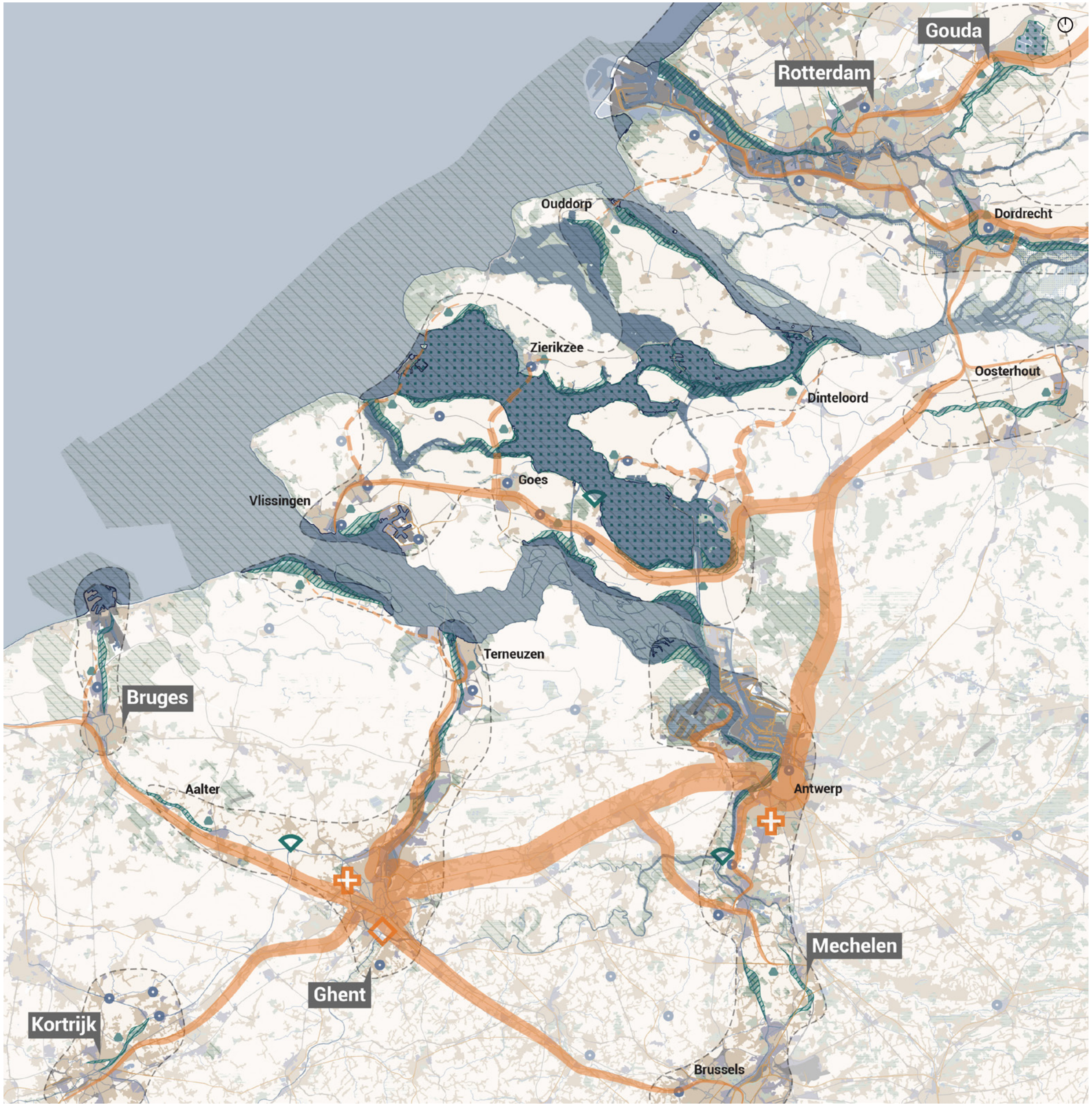


Fig. 32, showcasing the coastal and North Sea connected vision of capturing plastics.

Protected areas
Main rivers
Inland waterbodies
Forest
Wetland
Agriculture
Railway
Highway
FANS
Pre-processing facility
Recycling facility
Algae bloom harvest
Open pond
Relevant historical textile towns
Bio-plastics facility
Textile facility
Benefited protected habitats
Benefited waterway/waterbody
Potential traffic concentration
Clusters of intervention
Flood Depth (m) - once every 10 years
0-1
1-2
2-3,5
3,5-5,5
<5,5

Reflective thoughts...

How will the transition in and around Zeeland affect the other main cities in The Netherlands and Belgium?

Antwerp and Ghent

Antwerp and Ghent are at the moment large, historical and popular cities and will continue to be so. Antwerp will become a consumer hub and as a hip city will distribute algae products throughout the city in the forms of boutiques, and will at times host algae-based art and fashion shows. As a historical textile town, Ghent will be transformed into a producing hub. This means that the current textile and fashion tourism will get an extra boost from the renewed textile identity. There will also be a rise in jobs in the city, possibly inviting other urban transformations due to the increase in inhabitants.

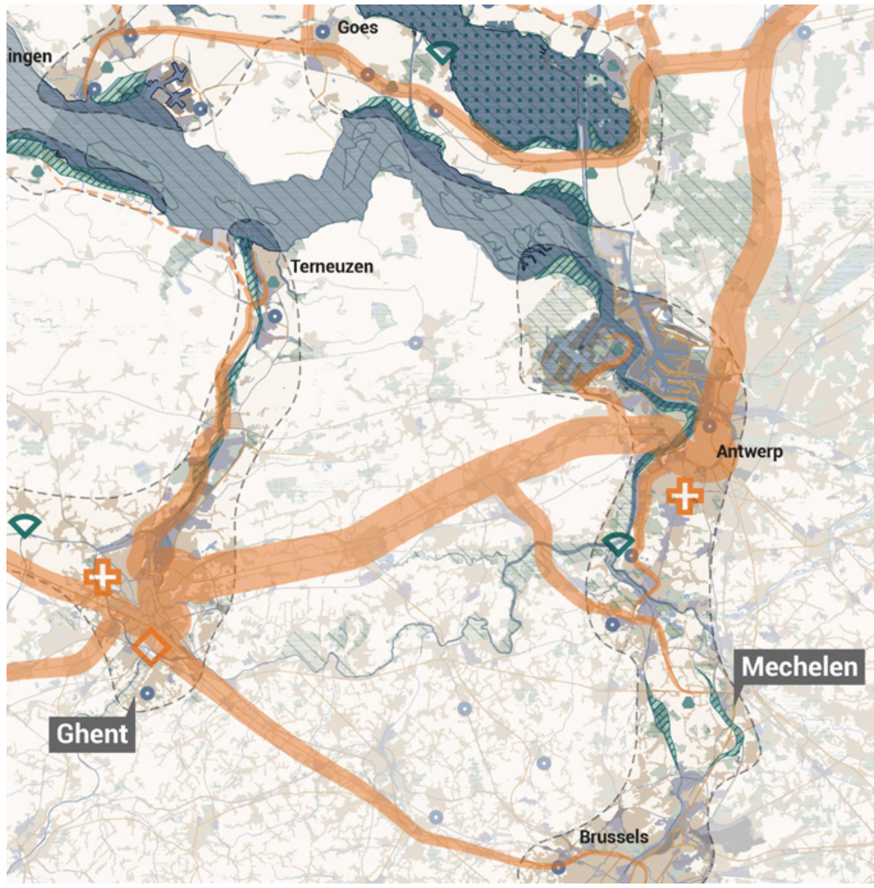


Fig 33, zoom in the rural context.

Goes and Zierikzee

As Goes and Zierikzee are rural towns, mostly connected to agricultural lands and functions, the transition will affect them greatly. They will have a new, different primary industry that will come with a large influx of new jobs, new landscapes and new urban spaces. Their towns will become more connected to the water, seeing as they will be the cities that extract plastic and algae from the estuary water. With this addition of industry and connected interest, Goes and Zierikzee will have an increase of people visiting or residing, perhaps inviting other urban transformation to accommodate this influx.

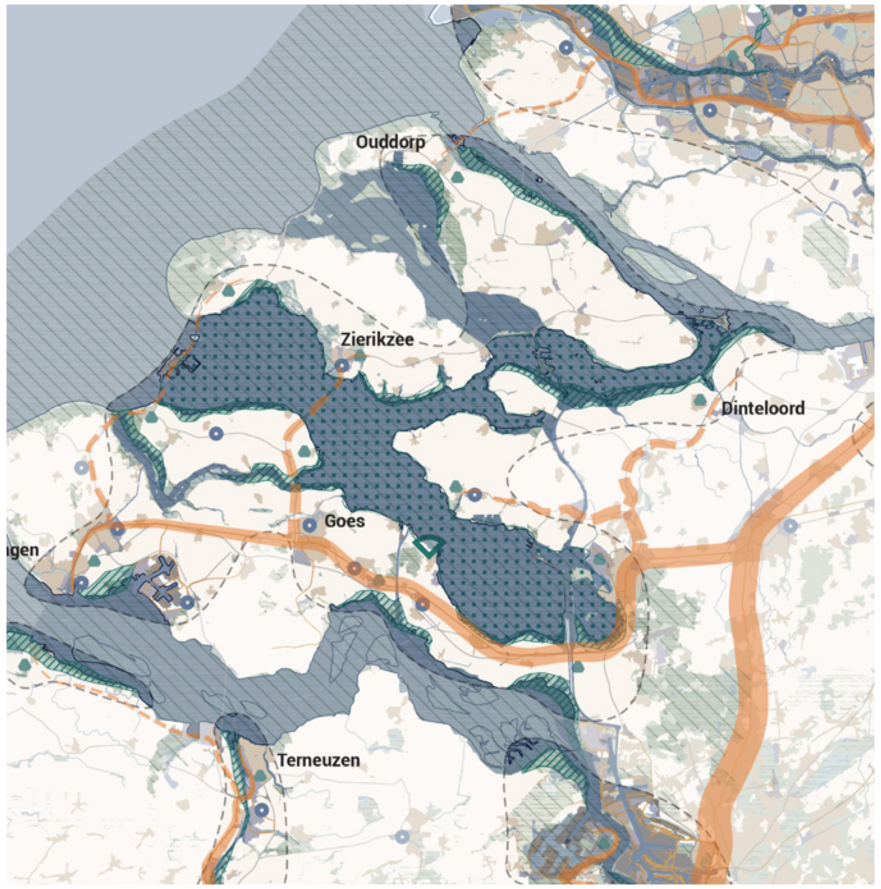


Fig 34, zoom in the rural context.

strategy

In this upcoming section of this report, you will deep dive into the interventions that are needed to realise the vision. Starting with an explanation of the toolbox that we use in the zooms, you will understand how they are closely connected with the existing SDGs, how actors work together, and how spatial and policy interventions assist each other. Then the report goes to the three zooms to see the spatialisation and its impact on the landscape. Next you will see the stakeholders and timeline that orders interventions over contributions and time.

Social and environmental impacts

We have selected relevant SDGs and connected them to the objectives of the project. These goals are achieved through a series of spatial and policy interventions, which are explained in detail below. Though these strategic interventions only take up minor space, they have large impacts on both society and environment. Most SDGs have their deadline in 2030, but according to our timeline, we estimate the transitions need more time to fully launch.

Minimising release and accumulation of pollutants in water

Through scrubber farms, harvesting dangerous algae blooms and turning crises into an opportunity, this project will lean on SDG 3.9 and 6.3, which contributes to substantially reducing illnesses caused by hazardous chemicals in air, water and soil pollution. In our case, the project focuses highly on making the water bodies a cleaner and better place for fish and other forms of marine life to thrive.

Providing equal opportunities for agricultural transition

Many farmers have lost their jobs or money due to their high nitrogen emission in traditional farming. This project will provide them with new types of jobs and policies to encourage an agricultural transition, which profits farmers and stops nature deterioration. Municipalities and algae producers cooperate with farmers by providing scrubber farm facilities and give them training. In addition to extra income, farmers will gain nitrogen points when they help collect and maintain scrubber farms, which contributes to their everyday farming. In this way, the project gives equal opportunities for a sustainable agricultural future.

Restoring river ecosystem

By allocating scrubber farms near rivers around farmlands, wetlands and forests, the project removes nutrient run-off and restores biodiversity and ecosystems. Although the average milestone of SDG 6.6 is 2020, the lagging-behind water-related ecosystems in the Netherlands still need enhancement. Our project combines top-down (government investment) and bottom-up (farmers and enterprises initiatives) financial resources to achieve SDG 15.a.

Cleaning up macroplastics from North Sea

The project cleans up macroplastics by booms and boats.

Providing sustainable bio-fuel sources

Waste from consumption hubs will decentralise in local waste management facilities, where part of them will be processed into biofuel. Biofuel is an important byproduct which is used for trucking and energy production, feeding back to the cycle of industry. In this way, the project increases the renewable energy share in the total final energy consumption.

Recycling waste into value

The project recycles waste into value in three ways, namely retrieving and recycling macroplastic in the sea, using microalgae to eat up microplastic in water, and reusing textile waste.

Restore marine biodiversity

Cleaning up macro and microplastic, algae bloom, and nutrient run-off will restore biodiversity in the sea.

Upgrading traditional industry

Our project expands existing textile factories in traditional textile towns. From one or two factories in mixed industry zones to a specialised industrial zone where textile is the main pillar, the project increases economic and innovation productivity through clustering effect (Lai et al., 2014). Also, the project upgrades the technology of the textile industry through creating spatial connections between research facilities and factories.

Bring back lost identity

By extending and adjusting the existing biking and hiking routes, this project proposes recreational and educational trails that spatially connect all steps from algae to textile. Thus, in addition to the updated industry, an algae-based textile culture will emerge to give an identity to the towns.

Enhancing scientific research

This project enhances scientific research in two ways: by encouraging big institutions/corporations to run the whole production chain, and by promoting collaboration of research facilities and industry. For example, Wageningen university runs an open pond, one research & mass production hub. In this way, it can individually manage the whole process from algae to bioplastic, which guarantees a fast speed in testing an innovative technology in production. Also, institutions can collect all the data into one database, making research easier. This project also encourages the establishment of large algae corporations. Because of its large scale and comprehensive impacts over the whole industry,their R&D departments promote scientific research from an industrial practice perspective. On a larger scale, the project forms city hubs, where research facilities and factories are located near each other. The traffic advantage shortens the lifespan of updating innovative technology.

Increasing resource-use efficiency

We maximise the usage of resources by making use of all the byproduct and waste. Sludge from the scrubber farm is processed into compost right on the spot, and then gets used in farmlands nearby. Waste produced from cities ends up as biofuel, raw material for bioplastic and compost. Cooperation between research facilities and algae producers will improve the yield, algae quality and lower the fluctuation of algae production. Research and innovation on technology in bioplastic & textile factories will increase the efficiency of producing bioplastic and textile.

Creating new jobs

In general, Algae Spring B.V. will become one large algae corporation, while small companies share the rest of the market especially in rural areas. The project aims to adapt existing traditional plastic companies into bioplastic companies. It also imposes policies to encourage the emergence of new bioplastic companies and textile enterprises. These companies won't take that much new space in the landscape, but they create considerable technical and innovative jobs.

Enhancing cross-municipal cooperation

On a larger scale, this project enhances cross-municipal cooperation through allocating different production steps in North West Europe. On a smaller scale, it links urban and rural areas by placing facilities at the urban-rural interface.

Spreading awareness

The project spreads awareness of sustainability through the spontaneous and inspired participation of people, education and recreation attached to the industry, and the establishment of an algae-textile identity for the towns.

Promoting local community engagement

There is local community engagement in scrubber farms and algae bloom harvesting.

Boost in recreation

Our interventions do not change the landscape that much, after it is fully implemented, most areas will still be typical Dutch landscapes. But this project combines production, education, environment protection and recreation to some extent. Interventions like biking routes, algae centres (combining algae harvesting and education), scrubber farms, open ponds and universities also provide public spaces to the public. Accessibility is also taken into consideration. In the zooms, there is no fence in the university, scrubber farms, and around open ponds with recreational functions. These spaces are owned by the institutions and companies, but it is both the profitability and regulations of the municipalities that make them open to the public.

Promoting inclusive and sustainable industrialization

This project initiates an economic, environmental and societal sustainable industrialization through the negotiations of stakeholders. The interventions are described in other text in this section.

Veendendaal

Textile and research hub

The zoom of Wageningen showcases an industry cycle in three cities, its spatial features and impacts.

The algae in this area are produced in open ponds run by Wageningen university and FANS in Binnenveldse Hooilanden, a more natural area in between the cities. The pre-processing of algae and the bioplastic production occurs in facilities run by Wageningen University. The textile production is located in Veenendaal, where a new textile factory is built to bring back their textile identity. Waste management facilities in the three cities process recyclable waste and transport that raw material back to the production locations in the cities. The material flow within this industry cycle mainly relies on trucks, and the algae from the FANS is transported by carrier bikes. In order to transport products out of the production hub towards consumer cities, trains and trucks are used.

The physical interventions are mainly located at the urban-rural interface. We propose a bike route from the open ponds in Wageningen University through the Binnenveldse Hooilanden (where the FANS are located) to the textile factory in Veenendaal. This recreational and educational route connects Veenendaal and Wageningen, and the urban and rural areas as well. The new industrial ecology also enhances the cooperation between the three towns.

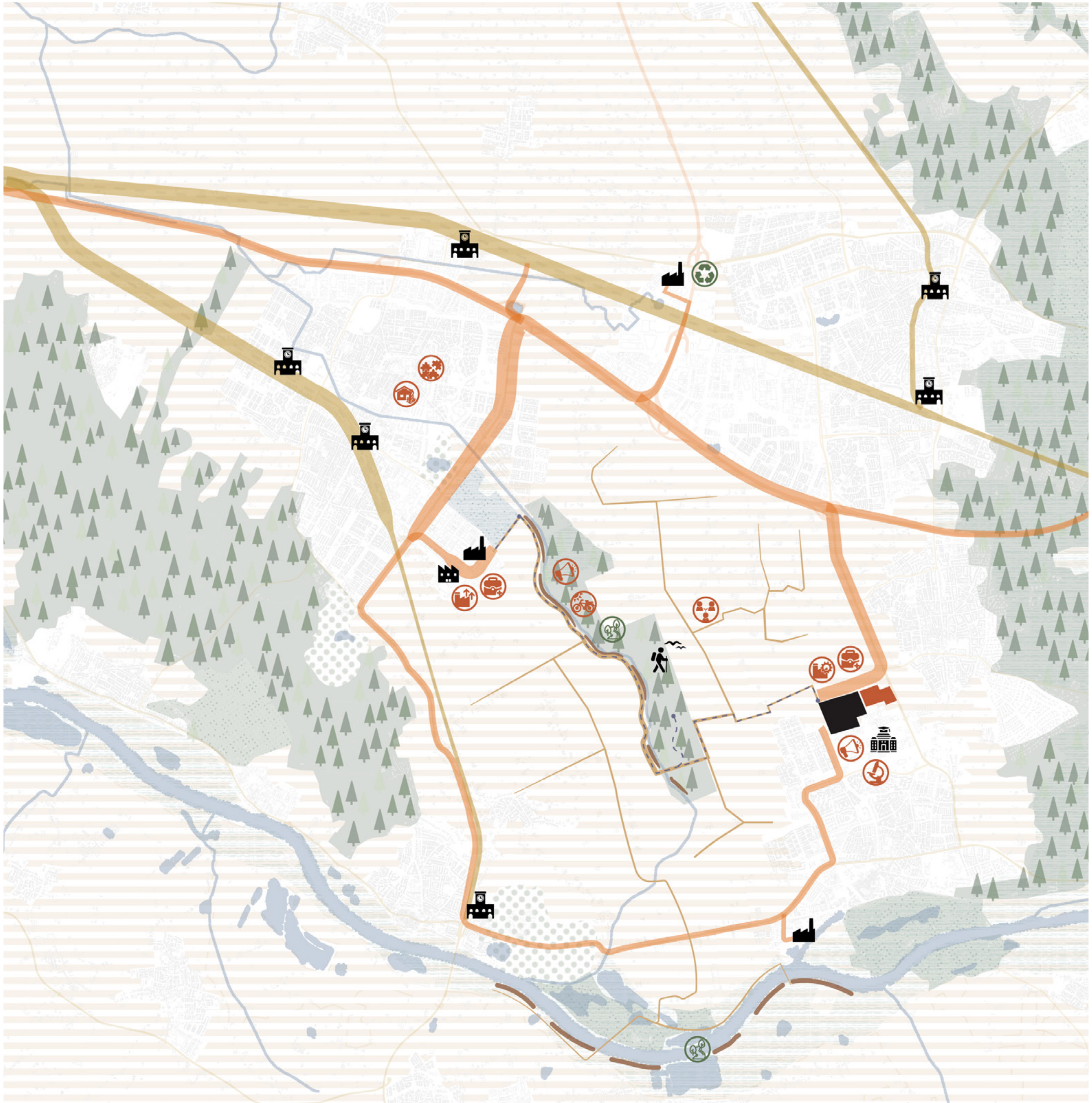
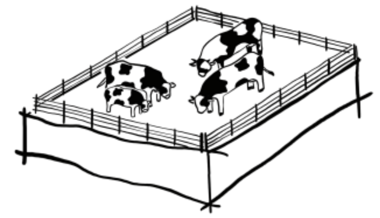


Fig. 35, Veenendaal strategy map.

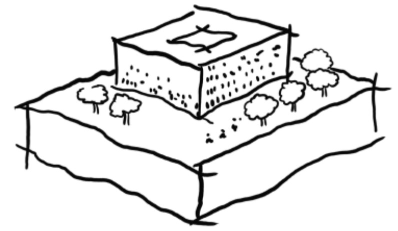
- Main rivers
- Inland water
- Forest
- Grassland
- Green urban spaces
- Wetland
- Agriculture
- Railway
- Highway
- Primary road
- Secondary road
- Recreational area
- Train station
- Expanded algae open pond (WUR)
- New bioplastics lab
- Scrubber farms
- Research facilities
- Textile factory
- Waste management facility
- Potential truck traffic
- Potential train traffic
- Potential bakfiets traffic
- New recreational path connecting to an existing one

Fig. 36, Veenendaal sketch.

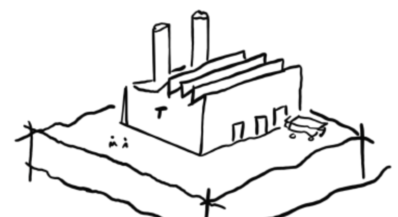


Farmland

FANS



Bioplastics LAB



Textile factory

Waste management facility

Social and environmental impacts

The new nature reserve park in the Binnenveldse Hooilanden will connect the towns of Veenendaal and Wageningen with a scenic biking route along the scrubber farms. Next to it being a recreational route and route for algae transport, it also functions as an educational route to learn more about the scrubber farms.

- Providing sustainable biofuel sources (SDGs 7.2)
- Minimising release and accumulation of pollutants in water (SDG 3.9 & 6.3)
- Restoring river ecosystems (SDGs 6.6 & 15.a)
- Recycling waste into value (SDGs 12.5)
- Providing equal opportunities for agricultural transition (SDGs 8.4)
- Promoting inclusive and sustainable industrialization (SDGs 9.2)
- Spreading awareness (SDGs 12.8)
- Upgrading traditional industry (SDGs 8.2)
- Creating new jobs (SDGs 8.3)
- Enhancing scientific research (SDGs 9.5)
- Bringing back lost identity (SDGs 8.9)
- Boost in recreation (SDGs 11.7)
- Promoting local community engagement (SDGs 11.3)
- Enhancing cross-municipal cooporation (SDGs 11.a)

Almere

Algae production in an urban context

This zoom in Almere showcases the smaller interventions made to upscale an existing Algae firm next to the IJsselmeer with a potential of becoming one of the bigger firms in acting upon algae bloom as a raw material for bio-based plastic production. On the edge of Almere, in the northern part, an existing open pond lies on the edge of the industrial zone, making a transferable boundary towards a prominent green area. The new facilities lie on the foot of a new canal that can accommodate the boats needed to harvest the algae and bring it to the pre-processing facility, using boats to take the unwieldy raw material. From the pre-processing facilities, the raw, now dried material is being transported by truck to the train, where it gets transported to the textile hub.

The pre-processing facility, or Algae centre, will also function for educational and recreational purposes, serving people from in- and outside of Almere. Also in this area the water will get cleaned, which also serves the recreational element.

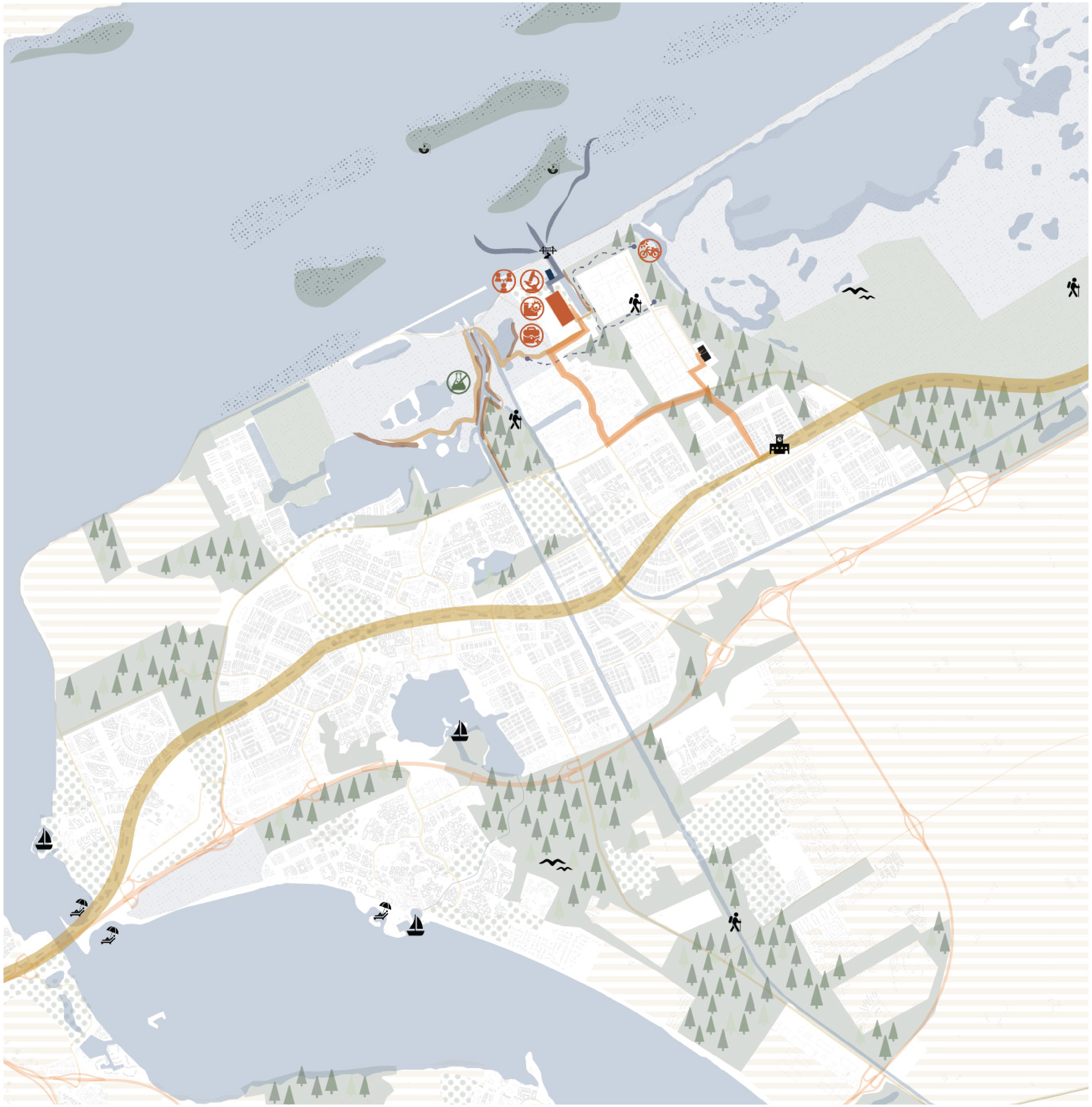


Fig. 37, Almere strategy map.

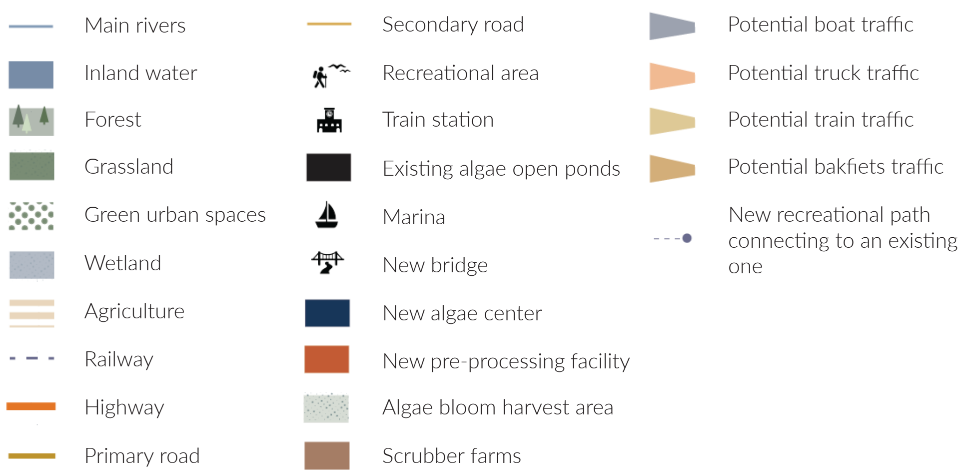
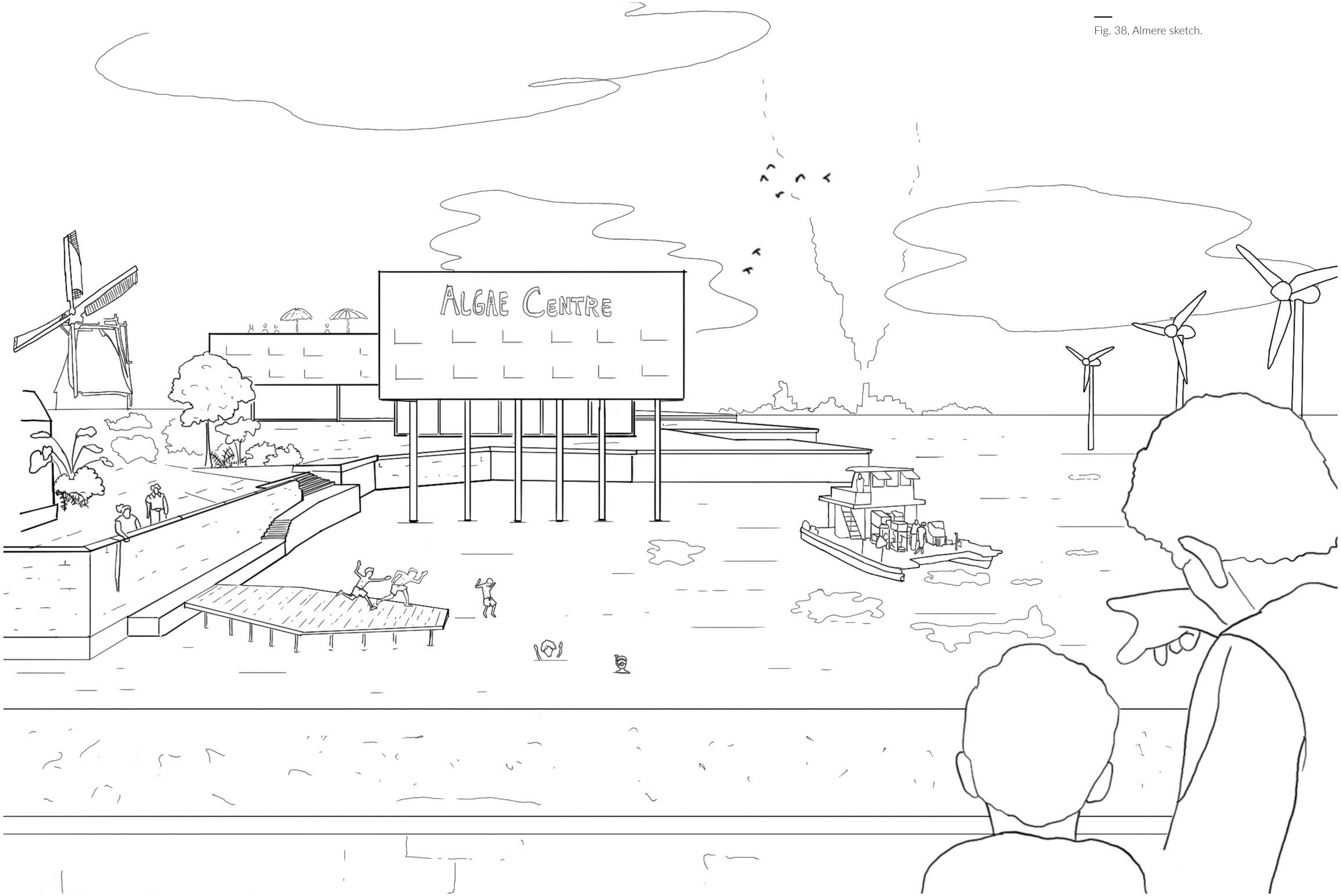
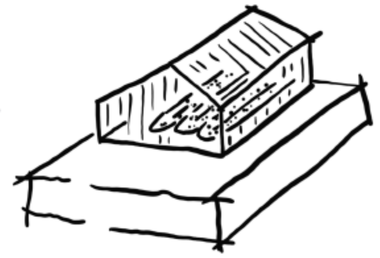


Fig. 38, Almere sketch.



Algae bloom harvesting

FANS



Open ponds

Algae Center

Social and environmental impacts

The existing harbour of Almere Buiten will be transformed into an algae hub. This hub will be formed around the algae centre, not only a location for the boats to transport the captured algae, but also a place for research, education and recreation.

- Promoting inclusive and sustainable industrialization (SDGs 9.2)
- Providing sustainable biofuel sources (SDGs 7.2)
- Upgrading traditional industry (SDGs 8.2)
- Creating new jobs (SDGs 8.3)
- Bringing back lost identity (SDGs 8.9)
- Minimising release and accumulation of pollutants in water (SDG 3.9 & 6.3)
- Restoring river ecosystems (SDGs 6.6 & 15.a)
- Boost in recreation (SDGs 11.7)
- Spreading awareness (SDGs 12.8)
- Promoting local community engagement (SDGs 11.3)

Zierikzee

Algae production in an rural context

The rural zoom in Zierikzee shows how our project and industry can be fully, newly implemented in an area. No facilities that we use and need in our process are already present, so in this area we needed to create those anew. Also, in the rural area, we can see (as pointed out before), that there is a larger amount of scrubber farms / FANS in order to offset all agricultural areas. This means that it has a larger spatial implication on the landscape than for instance the Almere zoom, where our new facilities fit in the existing landscape better.

Also to note; in the rural scenario, harvest from the FANS has to travel significantly larger distances, seeing as there are more of them and the processing facilities are more sparsely distributed. This means that the increase of bakfiets or comparable small transport is larger than it is in the urban areas.

The preprocessing facilities and algae farms are situated on locations that are easily reachable by boat, such as alongside the canal in Zierikzee, making it so the large amounts of algae that are harvested in the water can be transported by boat to the facility. As the estuary is also a tidal zone for plastic capturing, it means that the water can get busy at times, with both algae retrieval boats and the plastic booms taking up space.

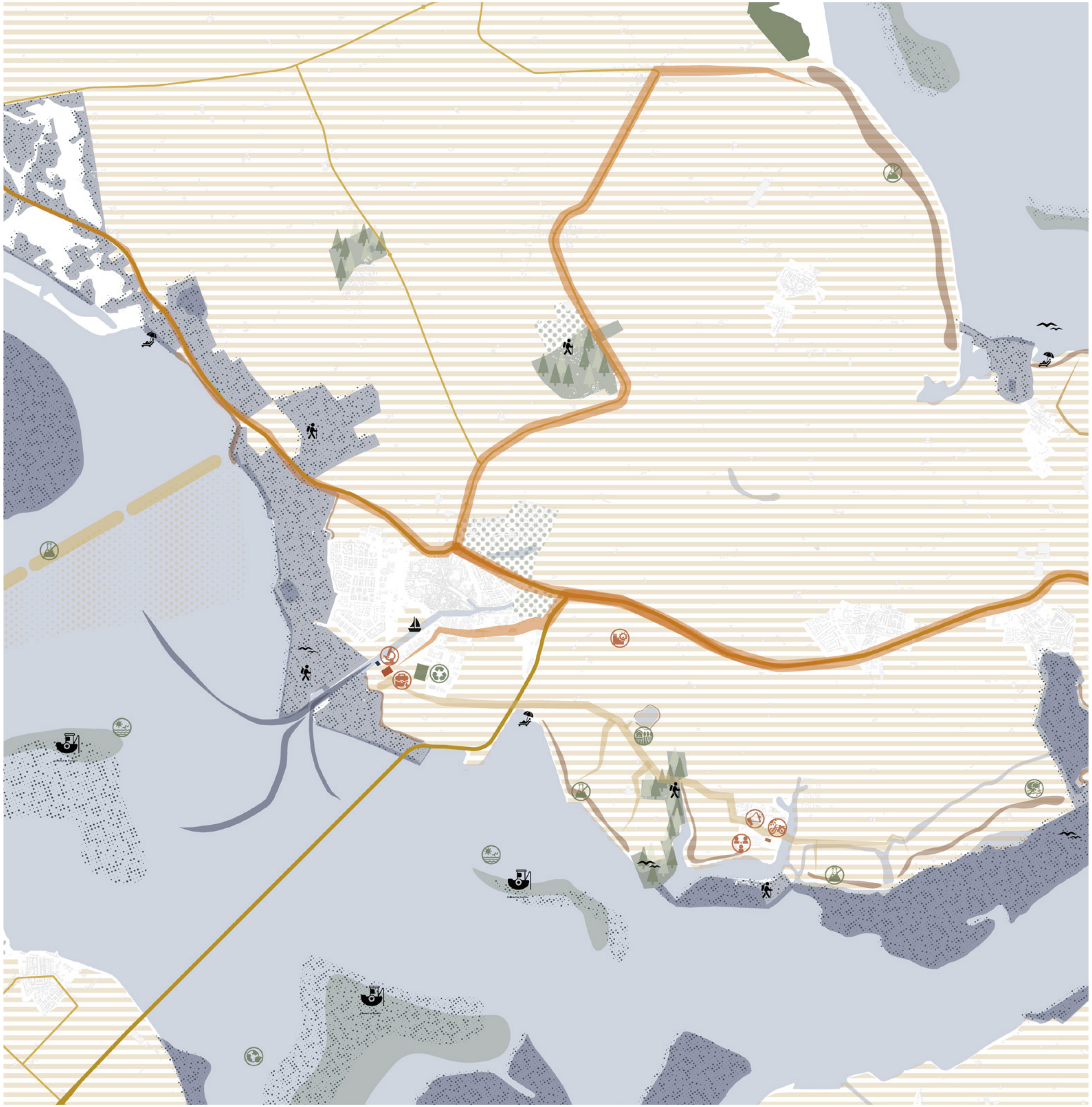


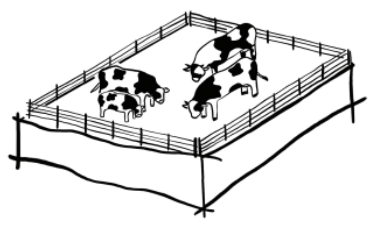
Fig. 39, Zierikzee strategy map.

Main rivers
Inland water
Forest
Grassland
Green urban spaces
Wetland
Agriculture
Railway
Highway
Primary road
Secondary road
Recreational area
Marina
New algae center
New pre-processing facility
Algae bloom harvest area
Scrubber farms
New museum
New plastic processing facility
Plastic capturing booms
Potential boat traffic
Potential truck traffic
Potential train traffic
Potential bakfiets traffic

Fig. 40, Zierikzee sketch.

Algae bloom harvesting

FANS



Farmland

Algae Center

Social and environmental impacts

In Zierikzee the implementation of a plastic recycling facility, a preprocessing facility and an algae centre gives the opportunity to rethink the transition from industrial area to nature and soften the edges, letting nature flow into the urban area.

- Promoting inclusive and sustainable industrialization (SDGs 9.2)
- Providing sustainable biofuel sources (SDGs 7.2)
- Upgrading traditional industry (SDGs 8.2)
- Creating new jobs (SDGs 8.3)
- Minimising release and accumulation of pollutants in water (SDG 3.9 & 6.3)
- Restoring river ecosystems (SDGs 6.6 & 15.a)
- Boost in recreation (SDGs 11.7)
- Providing equal opportunities for agricultural transition (SDGs 8.4)
- Spreading awareness (SDGs 12.8)
- Promoting local community engagement (SDGs 11.3)

Transportation and volume

In one city hub, algae bloom harvesting can produce 1,350 tons of wet algae per day on average, the daily yield of open ponds (36 km2 in one city hub) is 720 kg, and scrubber farm is 4.5 tons. A total of 1355.22 tons wet algae is processed to 252 tons of dry algae biomass, then to 151 tons of bioplastic flake. 120 Tons of textile are produced every day and delivered to cities, 85% of which is recyclable. Transportation routes and volumes are shown in the diagram above, which is a combination of barge, train, truck and bakfiet. Our interventions have no major impact on the total volume of traffic and freight, existing roads and railways can take up the incremental traffic.

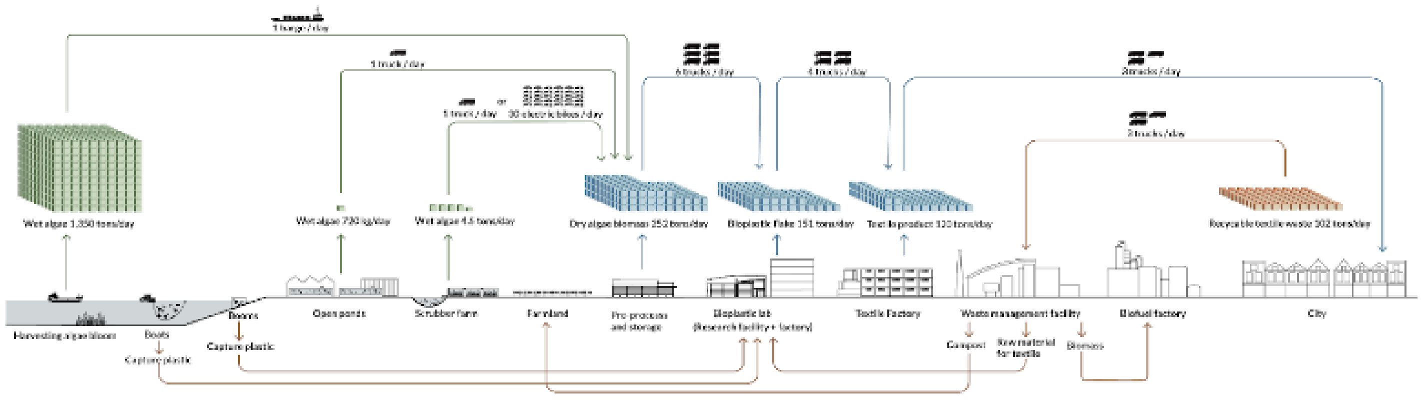


Fig. 41, Zoom systemic section.

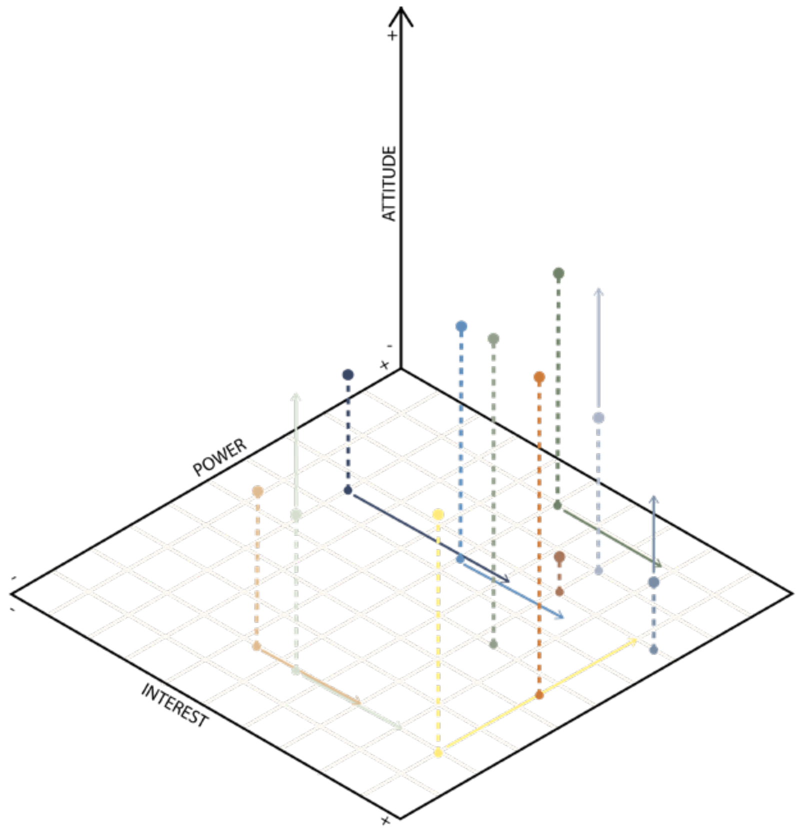


Fig. 43, Stakeholder direction.

Stakeholders analysis and timeline

Looking at the stakeholders, in order to make our plan executable, we need to raise the interest and attitude of some of the stakeholders.

The main danger lies in the existing plastic and textile companies, who could block algae based clothing from establishing on the market through, for example, lobbying. In order to prevent this we give them incentive to transform into biobased plastic factories and algae based textile companies through funding.

The other main pitfall could be the farmers not being willing to use their land for algae farming. In order to prevent this we give incentive through the introduction of nitrogen points, so they don't have to transform their businesses in order to keep up with the nitrogen norms. Added to that, they can use the algae as fertiliser, which also reduces nitrogen emissions.

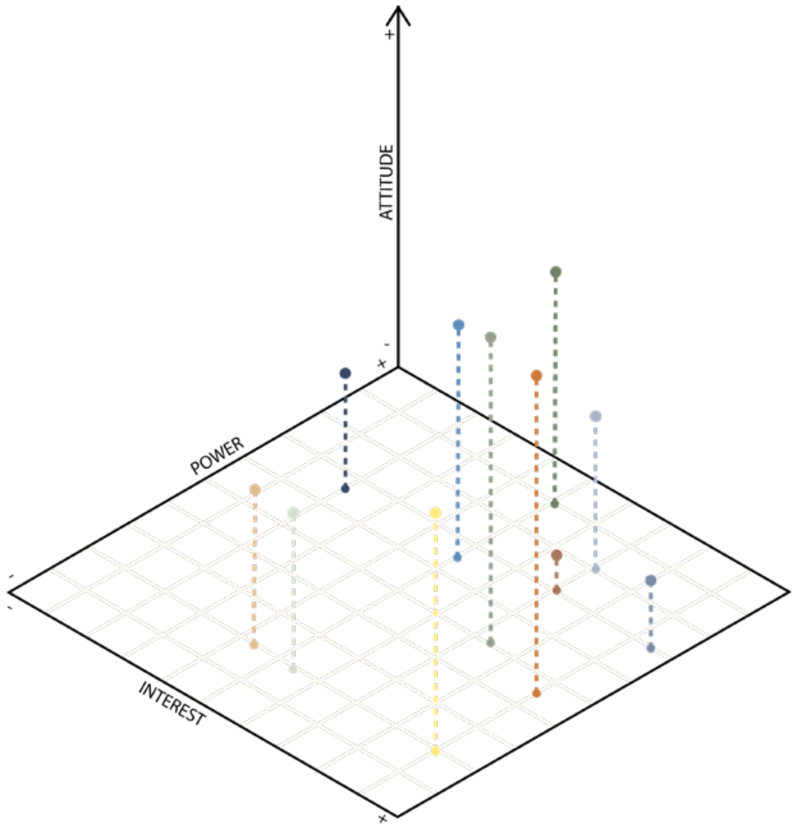
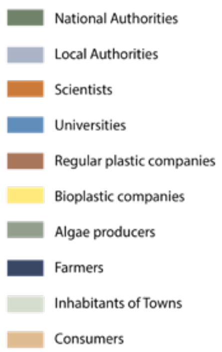


Fig. 42, Existing stakeholder position.



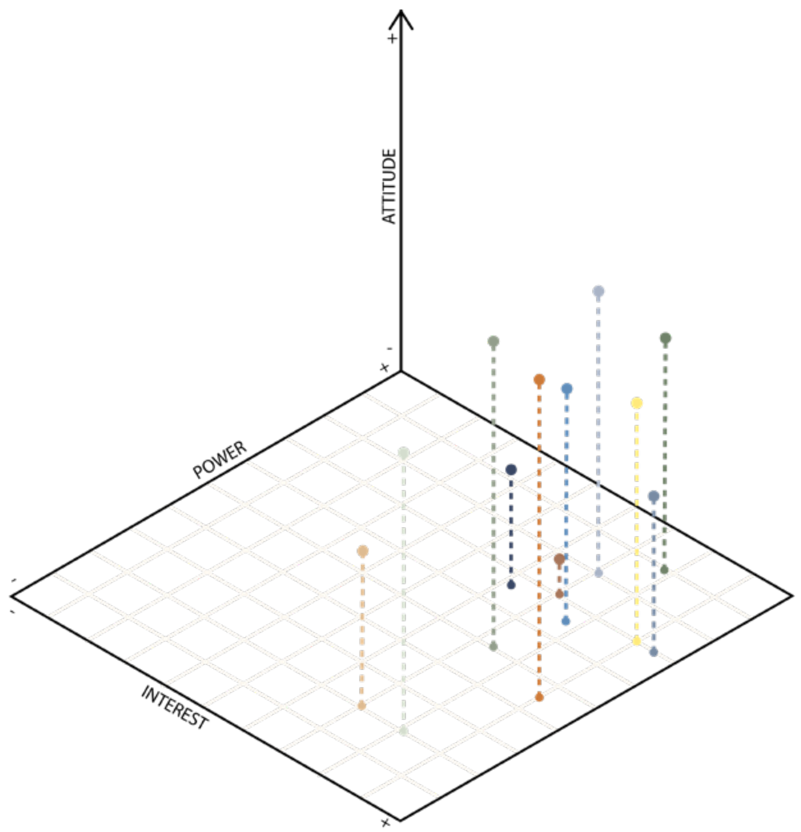


Fig. 44, Future stakeholder position.

Stakeholders analysis and timeline

Waste management
By 2030, increase substantially the share of renewable energy in the global energy mix (SDG 7.2)
By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse (SDG 12.5)
Limits the share of municipal waste landfilled to 10% (Landfill Directive)
Re-use & recycling of municipal waste to a minimum of 65% (Waste Framework Directive)
Reduction in fertiliser use of at least 20% (Farm to Fork Strategy)
Achieve high levels of separate collection of textile waste (Circular Economy Action Plan)
Carbon neutrality (Renewable Energy Directive)

Starting from 2025, a policy will be implemented to provide subsidies to farmers who choose to utilise algae compost in their farming operations, as a way to incentivize environmentally friendly and sustainable practices. The algae compost must meet certain quality and safety standards, and collaboration between government agencies, the algae industry, and farmers will be necessary. The goal of this policy is to promote soil health, reduce the use of chemical fertilisers, improve air and water quality, and create new jobs and economic opportunities. It is a step towards a more sustainable and resilient agricultural system that supports the health of the planet and communities.

By 2030, all transportation systems that fall under our vision will transition to using non-fossil fuels, including biofuels or electricity. This transition will be phased in over time to ensure a smooth and successful implementation. We recognize the importance of reducing our carbon footprint and are committed to supporting sustainable transportation solutions.

In 2035, a clothing deposit system will be established, akin to the plastic bottle deposit system. This policy will require consumers to pay a small fee when purchasing clothing items, which will be refunded when the item is returned. The aim is to incentivize the recycling and reuse of the bio-plastics in clothing items, reducing waste and promoting sustainability.

Algae production
Improve progressively, through 2030, global resource efficiency in consumption and production and endeavour to decouple economic growth from environmental degradation (SDG 8.4)
Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity (SDG 15.5)
Protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes (SDG 6.6)
Achieve good status in all bodies of surface water and groundwater (Water Framework Directive)
Establishing a larger EU-wide network of protected areas on land and at sea (Biodiversity strategy for 2030)
Use of renewable energy sources to a minimum of 45% (Renewable energy directive)
Study with better knowledge of seaweed climate change mitigation opportunities (Algae Initiative)
Promoting the use of blue biotechnology to develop new products (Sustainable blue economy)

Starting in 2025, a new algae credit policy will be introduced aimed at promoting sustainable agriculture and reducing harmful nitrogen emissions. The policy will reward farmers who take responsibility for maintaining a scrubber farm close to their farmland by granting them credits that can be exchanged for additional nitrogen emissions. The credits earned by farmers can be linked to the European Union Emissions Trading System, providing a wider market for trading and further incentivizing farmers to participate in the program. This new policy is part of a larger initiative to reduce carbon and nitrogen emissions and promote sustainable practices across industries, and it is hoped that it will contribute to the global effort to combat climate change.

Plastic Capturing
By 2030, enhance inclusive and sustainable urbanisation and capacity for participatory, integrated and sustainable human settlement planning and management in all countries (SDG 11.3)
By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution (SDG 14.1)
All plastic packaging is recyclable (Plastic Strategy)
A 77% separate collection target for plastic bottles (Single-use Plastics Directive)

Starting in 2025, all European coastal nations bordering the North Sea must establish and manage a minimum of two designated areas for capturing plastics. Additionally, they must deploy booms in tidal zones to prevent the influx of macro plastics into the North Sea. This policy aims to reduce plastic pollution in the ocean and protect marine life.

Textile Industry
Support positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning (SDG 11.a)
By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes (SDG 9.4)
Promote inclusive and sustainable industrialization and, by 2030, significantly raise industry's share of employment and gross domestic product, in line with national circumstances, and double its share in least developed countries (SDG 9.2)
EU Ecolabel for Textile Products
All textile products on the EU market are durable, repairable and recyclable (Strategy for Sustainable Textiles)

To support sustainable textile production, the following measures will be implemented in the European Union:
Starting from 2025, a subsidy program will be introduced to promote the development of the algae-based textile industry. The aim is to encourage the use of renewable materials in the textile production process.
By 2035, at least 50% of plastics used in the textile industry should be derived from biobased sources. This is to reduce the reliance on non-renewable fossil-based materials and encourage the use of sustainable alternatives.
By 2050, the use of fossil-based plastics in the textile industry will be banned in the European Union. This measure is intended to further promote the use of sustainable materials and support a transition to a circular economy.

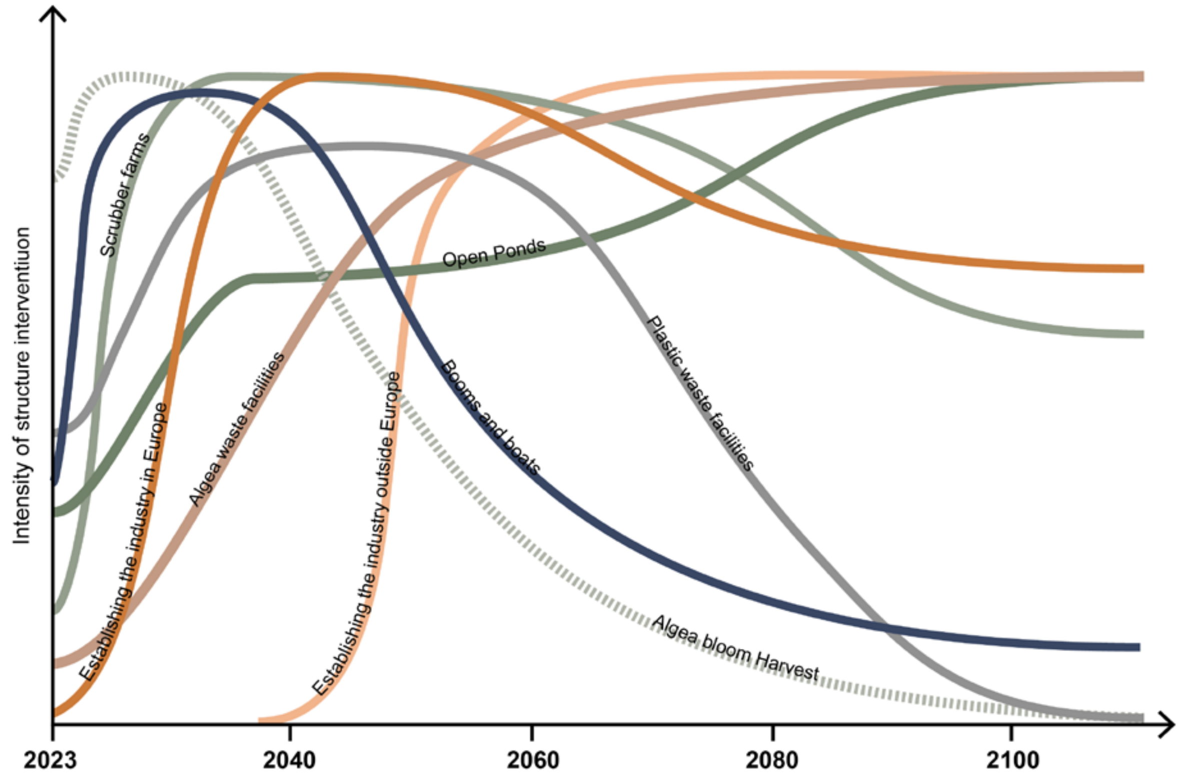


Fig. 45, Timeline.

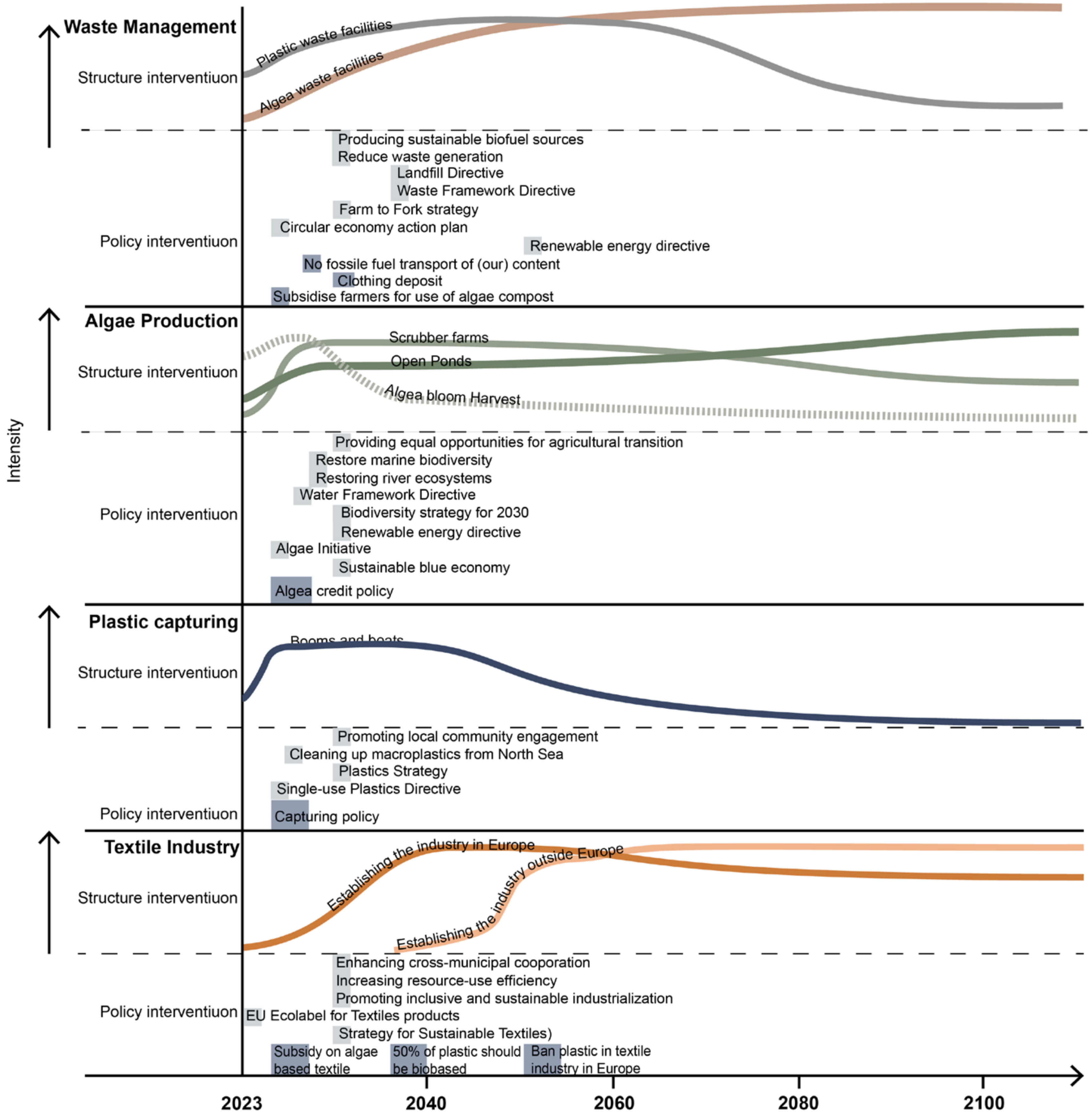


Fig. 46, Extensive timeline.

conclusion

This last section of the report will reflect upon the challenges faced in the design process of this project, and include an individual reflection.

Conclusion

The circular textile industry in South-Holland can be a catalyst for re-envisioning the use of plastic in North-West Europe by showing us one possible solution to decrease the amount of plastic used in the world. The large human problem of plastic pollution is not fully solved through this restructuring of 'just' the textile industry, but it shows how we can find unused potential to solve major environmental problems with elements we already have (or even struggle with) in our life currently. By looking at problems and seeing the potential instead of just the hurdles, we can aim to solve the larger societal problems that otherwise may seem daunting. This way of thinking, of using crises and turning them into opportunities, has the possibility to be key in the solution to many more societal problems.

What is also worthy to note is that the interventions in the landscape are distinctively small; most of the facilities and infrastructures are already present and can be easily transformed for us to use. This shows how we already accommodate a lot of the elements needed to transition, and it can be easily fitted into the life we live now. The word 'transition' can often sound daunting and drastic, but our project shows that this does not have to be the case. It may only take a couple of factories and some extra freight trains to constitute a full transition.

Lastly, we want to comment on the short-life span of our design. As we are using algae and plastic pollution while simultaneously preventing this pollution from existing, there will come a point where (parts of) our design stops working. As sad as that may be, this is something that we fully embrace, seeing as it will mean that our project has fulfilled its task. The aim of our project has been, and will always be, to eliminate plastic pollution. If that means that our design at one point will become absolute, this is something we accept. However, this does not mean our industry will fall apart; it means that the open ponds and scrubber farms will have to produce more algae in order to keep up with the algae demand to keep our industry running, unless a new and better industry will be created and can take over.

reflection

This last section of the report will reflect upon the challeng-es faced in the design process of this project, and include an individual reflection.

Maximum theorem

The main objective we started our project with was to create more space in the oceans for marine life. In this, we aimed to increase the spatial justice for stakeholders that could not argue for themselves (marine fauna and flora). By taking the steps we saw fit in order to achieve this, we have "accidentally" created public goods that benefit humans and land-based environments alike. By cleaning up the plastic from the sea (to prevent fish from dying), we also positively influence human health, and by cleaning out algae (to restore the biodiversity in natural waters), we also facilitate clean and healthy recreational areas. This therefore strengthens the spatial justice aspect of the project, seeing as we create a more balanced equilibrium, and no group is dealing with negative effects of our implementations. However, procedural justice is still imbalanced, seeing as we are still telling people what to do and where to implement certain things. This balance between procedural and distributive spatial justice comes to an impasse at the moment where we believe non-speaking actors should be accounted for in the distributive justice. Seeing as they are physically unable to speak for themselves, they need to be advocated for by other actors and this will mean some people will have more influence in the decision making process.

This brings us to a question of ethics. How ethical is it to make the decision to prioritise these non-speaking stakeholders over the human stakeholders? We argue that it is very ethical to do so, especially seeing that they have been underrepresented and overlooked for quite a long time and it may be their turn to be favoured. Even in this mindset, where underrepresented stakeholders are due for their 'time in the sun', our implementations have very limited negative implications for the other stakeholders, and therefore there are very little ethical implications connected to this decision.

As our project revolved around a highly global industry, it was first a challenge to imagine the industry as a local phenomenon. After localising the textile industry and promoting the use of existing materials, that are products of climate change, we realised that this industrial model could be upscaled. Upscaled in the sense that the model could be used elsewhere, as the same crisis of chemical pollution in water, algae bloom and a loss in biodiversity is seen in many places in the world.

Upscaling the model would mean promoting a local bio-based textile industry elsewhere. This could happen by looking at highly prominent areas for algae bloom and at countries with the existing textile background. Even though we need to take into account the efficiency of the Western world, and, in other places, this model would face more limitations and challenges than we came across in the test case of North West Europe.

If not to upscale, then we should reflect on the amount of algae actually 'produced' in our project. Looking at the systemic section we assume that we want to harvest as much as possible of the algae bloom, to help marine life and to improve the overall water quality. This leads to us having not only enough algae to make textiles but actually having an industry that could feed other industries, not related to textiles. Even though our project was highly focussed on plastic in textiles, we managed to make a model for an industry, where the main part is about realising how little infrastructure and facilities we need to implement to be able to harvest and have a lot of algae. This can be a huge potential in showcasing the government or municipal stakeholders, that with little investment they could turn a crisis into an opportunity with their own hands.

Individual reflection, Cecile

The design process during this third quarter has proven itself to be quite difficult. Besides having to quickly familiarise ourselves with new group mates and their way of working, we had to learn to think and envision on a very large scale. Both of these processes came with their bumps and jolts, and it was sometimes harder than anticipated.

As for the regional design process, what was often hard for us was that we had a very broad topic (water), and we were interested in a lot of things. This had the effect that for the first couple of weeks, we were kind of floating around within the topic and it was hard to find footing. Luckily, through the guidance of our mentors and the accompanying workshops of the SDS course, we were able to find a more specific topic to connect our vision to. Within this topic, we dove very deep into research, which then made it extremely hard to make the jump from large scale envisioning to small-scale design. I think that we made this extra difficult for ourselves by creating an industrial ecology which was connected to existing elements, resulting in a design which had little to no (new) spatial elements. Our project was very research-based, and seeing as the time we had to develop the project was very limited, this halted our design process.

Our main objective of the project was to make space for marine life, connecting to the spatial justice lectures and workshops we had had during the SDS lecture series. However, due to the project being very technically complex and sometimes a couple of steps removed from this goal, it was hard to directly connect the elements of spatial justice public goods to this objective.

In the end, I think we have been able to create quite a nice project, but maybe have struggled to connect it to the more spatial ethical implications due to us being very focused on the industrial ecology of the system we propose. But even so, I am quite happy with what we have produced, and it has inspired me to not only look differently at algae and polyester clothing, but also to adapt a more opportunistic way of thinking, trying to find more opportunities in crises in my daily life.

Individual reflection, Yuwei

Research and design have an interdependent relationship in regional context. Of course, doing a regional design has many ways (learned from Roberto's lecture on 7 types of designers), our group is most close to the strategic planner and the advocacy planner*. This is how we use research to overcome two main regional design difficulties under the strategic and advocacy planning values:

1) Regional design has intense interactions and negotiations among social, political, and economic actors, which are difficult to design.

In the beginning, we are aware that one regional design could not solve everything. So we start to research one aspect that has enough technology to fix - water pollution. After naturally spreading research scope to plastic pollution, algae and textile, we propose the two-sided strategy: retrieving & recycling plastic, and a sustainable textile industry. By far, research helps us to understand the industrial interactions between algae, bioplastic, textile and recycle stakeholders. Going into strategy, we expand the research on social and political relations among these stakeholders. Research about the SDGs is done to articulate the interventions and impact that we want in strategy. Then we design based on the research result, proposing facilities and material flows that connect stakeholders, not only spatially, but also with mutual economic profits and social & environmental impacts.

2) Unclear design boundary on multiple scales.

On the XL, L & M scale, we need to design across countries and cities. Pollution & algae blooms are not allocated by national borders (they are everywhere!) and it is impossible to plan the whole area. So what we did is to research these topics, and narrow down the most problematic areas and areas with most potential. In this way, we manage to solve the problem by focusing primarily on addressing the core areas. Then we start more specific research on the S scale, finding what kinds of physical interventions are proper for the two-sided strategy. Still, on the S scale, different steps in the industry are located in different areas. For example, we need to design three towns altogether in one zoom because open ponds, textile factories and waste management facilities are scattered in these three towns. To solve this issue, we turn to design based on the industry chain rather than fixed urban fabric borders. We research the transportation capacity of trucks, trains and bakfiets, and the average yield of algae and intermediate products. Then we add the new facilities and design the traffic flows. T

Design by research has some cons, or to say, it is easier to have some drawbacks when working in this method. For example, sometimes we get too deep into technology and information, lacking views on basic landuse, landscape, and daily lives of people in the area.

* Strategic planner means you develop strategies and interventions for all stakeholders to engage them to your design vision, and advocacy planner means you design for the interest of those who are rarely represented or considered, in our case, the nature, especially marine lives.

Individual reflection, Yoshi

During the third quarter of the MSc Urbanism curriculum, we focused on three themes: (1) developing a comprehensive understanding of regional spatial structures and development trends, (2) understanding the interrelations among design, planning, and politics, and (3) honing our communication skills for collaborative decision-making.
Our assignment centred on sustainability and the topics of circular economy, decentralisation, and sustainable land use.

Our group was assigned the topic of water, which initially proved challenging since it did not have a direct link to one type of pollution like the other topics. However, the SDS lectures helped us formulate specific questions and eventually led us to focus on plastic pollution, with algae as a substitute. As we researched further, we discovered that the textile industry was a significant contributor to pollution.

In terms of the three emphases of the quarter, I believe we did well in developing a comprehensive understanding of regional spatial structures and development trends through extensive research, although we had to ensure we didn't do too much research on algae. However, understanding the relations among design, planning, and politics was challenging, especially the connection between design and planning. The SDS lectures were instrumental in helping us understand the political aspect of our project. As for teamwork, we had no significant issues and made clear agreements, despite cultural differences.

So to conclude, research played a vital role in our process. Both as a tool to give guidance and as a tool to explore different paths.

Overall, I learned a lot during this quarter, including about northwest Europe, algae, plastic pollution, and group dynamics. Our project turned out well, and I am proud of what we accomplished.

Individual reflection, Yuzhou

During the course of our project, our team experienced a detour in our research direction. We initially focused on water-related issues, a topic that was too broad and difficult to narrow down. Our first proposal was centred on the fishing industry in the North Sea, but we discovered that it wouldn't play a significant role in our water vision for the future. However, through our research, we discovered the urgent issue of water pollution, particularly plastic pollution, and its devastating impacts on the marine ecosystem. From this, we found out the enormous potential of algae to mitigate plastic pollution and substitute traditional plastic products, leading to our final vision.
This detour, as we later realised, was not necessarily a negative thing. It eventually helped us to find a more intriguing and urgent topic, thanks to the feedback from our peers and tutors. It also taught us a valuable lesson about the importance of flexibility and openness in research projects. Even if we start with a specific goal in mind, we need to be ready to pivot in response to new information and emerging issues.
In addition, we learned the importance of considering social impacts in regional planning. At the beginning, we focused too much on the circular industrial model and spatial intervention, with little regard for the human factor. However, with the tutor's reminder, we rethought about the potential social impacts through collages and zoom-ins, making the project more vivid and tangible. This taught us that in large-scale projects, it's easy to lose resolution on social impacts. However, by paying attention to these impacts and representing them through collages and zoom-ins, we can make our projects more engaging and comprehensible to a wider audience.
In the meanwhile, our team encountered many opportunities and challenges in teamwork. We had to learn to work together, leveraging the unique skills and perspectives of each team member. Peer-review on group work was especially helpful, as it increased understanding and respect between us. We learned to understand and utilise the specialty of each teammate, which amplified our strengths and helped with each other's weaknesses. We also learned the importance of effective communication, especially when working on such a complex and interdisciplinary project. By communicating frequently and clearly, we were able to build trust and avoid misunderstandings and learned a lot from each other.
In conclusion, the detour we experienced led us to a more urgent and interesting topic, thanks to the feedback from our peers and tutors. We took advantage of a current crisis - algae blooms - and envisioned a novel circular industry model to tackle the urgent issue of plastic pollution spatially and politically. Our project shows that by leveraging the potential of algae to mitigate plastic pollution, we can create a more sustainable future for our planet. However, due to the limited time, local scale intervention and impact could be further improved and explored. We believe that our project provides a solid foundation for future research and development in this field.

Individual reflection, Greta

This project really tested the tension between research and design the most out of all the quarter projects I've participated in here at TU Delft. Due to a small amount of time and a very big scale the process was bumpy and at times unfeasible. The big scale was in itself a hurtle, not only because there was so much information to process, but also because the direction to tackle it was very unclear in the first few weeks.

The first few week we struggled finding a footing within a certain theme, which made a lot of the research unclear. It was research that broadened our knowledge about North West Europe and South Holland, and unravel many complex processes within our context today. At first, water was a main topic, and through swimming we eventually got to transportation, then marine life, then plastic and ended in a research project about plastics in the textile industry.

Later on, we got a grasp at the textile industry and this was where the synergy between research and design really became visible in our group work. To our sadness, the theme didn't have a big spatial impact. This showed another side of regional planning for us, the one that isn't all big impacts and beautifully transitioning landscapes. Our project tackles the edges of urban centers, and tries to push the strict boundaries towards a smoother transition. Allthough, this may sound like a shift in landscape, throughout different zooms we realised that it doesn't drastically change it. By analysing flows, and by implementing algae into the textile production cycle it unraveled a lot of interesting questions for us. Not only was it a nice challenge to understand the different stakeholders, with tools from the SDS and Capita lectures, and imagine what could help us shift their power into a certain direction. It was also really useful to get a grasp of how many initiatives, in our case related to plastic pollution, there was already existing. Many of these, initiated by the European Union were on-going but none of them tackled textiles in the way we wishes. It was a nice exercise to imagine how we could implement the bio-based textile industry into existing policies and inititatives and make it more visible for everyday people.

In the end, the project and process turned out to have a nice learning curve. It didn't include everything that we aimed for, due to timing, but it was a nice taste on what kind of complexity regional planning has, and how much potential there is to initiate change on this scale. Likewise, it was a process that was more research-based than design, which became very visible when we started sketching and designing, and started to have more valuable discussion in the group.

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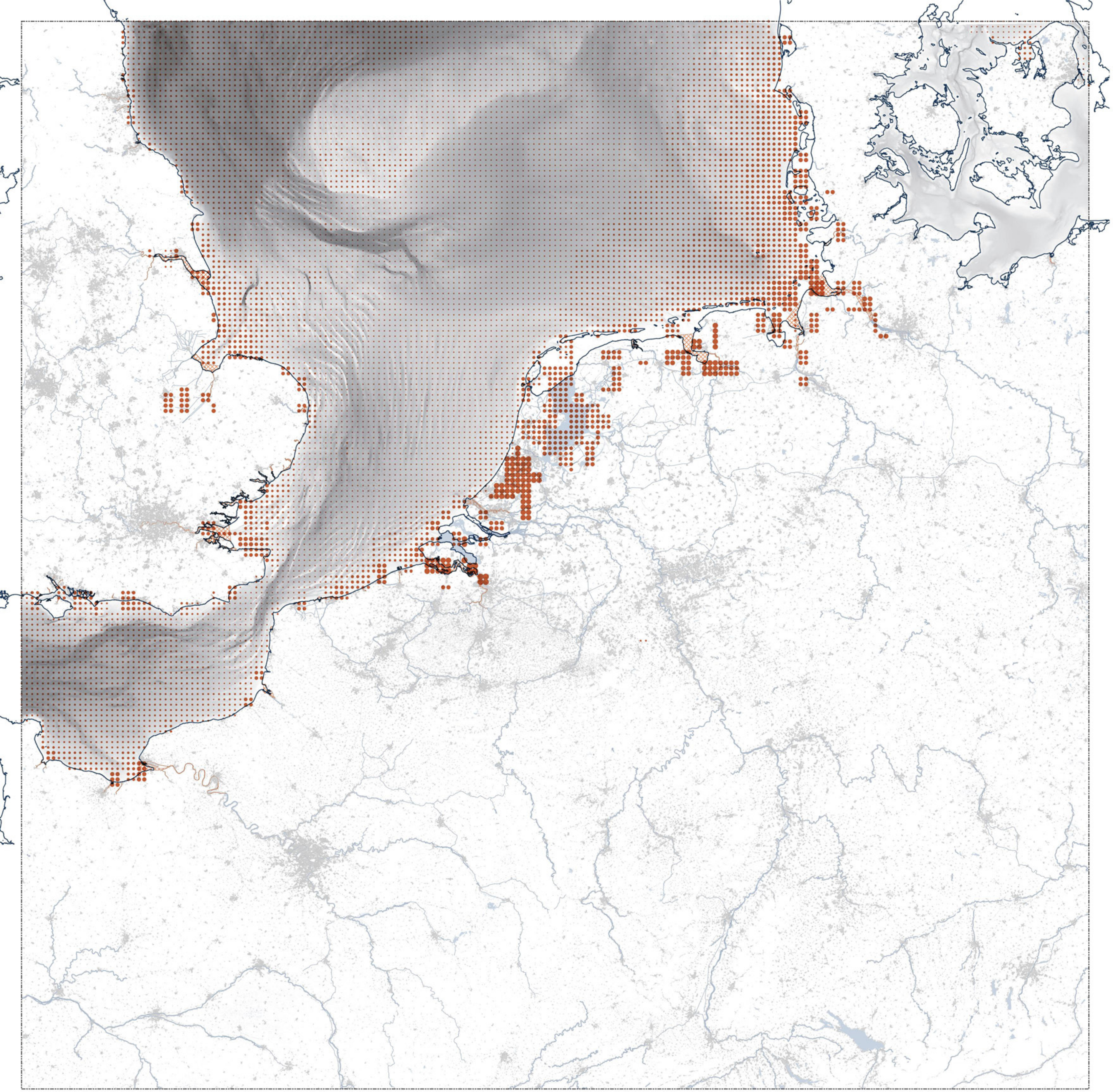
Figures

Except mentioned otherwise, all figures are made by authors.
Fig. 2, Nuns walking past garbage in Rome, Italy. Source: Getty Images.
Fig. 3, Global plastic pollution and accumulation (and future trends). Source: UNEP 2021, adapted from Jambeck et al. 2018; PlasticsEurope 2019; Geyer 2020.
Fig. 5, Plastic Pollution in the North Sea. Data from EMODnet, EUHydro dataset.
Fig. 6, Cumulative share of plastic inputs to the ocean. Source: Lourens Meijer et al. 2021. Retrieved on april 11, from https://ourworldindata.org/ocean-plastics.
Fig. 7, Primary plastics production (left) and generation (right) by industrial sector in 2015, measured in tonnes per year. Retrieved on april 12, from https://ourworldindata.org/plastic-pollution
Fig. 8, Tools and machines for plastic capturing used by Ocean Cleanup. Source: Ocean Cleanup. Retrieved on april 12, from https://theoceancleanup.com/about/
Fig. 9, North West Europe with borders and protected areas. Data from EMODnet, EUHydro dataset, Corine land cover, CDDA, Nature2000, WDPA.
Fig. 12: Figure made by author, based on Open Supply Hub. (n.d.). Open Supply Hub. https://opensupplyhub.org/facilities/?sectors=Apparel§ors=Textiles
Fig. 13, Historical textile towns. Data from EMODnet, EUHydro dataset, Corine land cover.
Fig. 16, Material coordinate system of bioplastics by European bioplastics. Source: What are bioplastics? Fact Sheet. 2016.
Fig. 18, Algae production. Data from EMODnet, EUHydro dataset, Corine land cover, OSM.
Fig. 19, Filamentous algae nutrient scrubbers (FANS). Source: Hariz, H. B., Lawton, R. J., & Craggs, R. J. (2023). Effects of operational parameters on the performance of unialgal Oedogonium sp. filamentous algae nutrient scrubbers under controlled environmental conditions. Journal of Environmental Management, 326, 116705. https://doi.org/10.1016/j.jenvman.2022.116705
Fig. 20, Algae bloom assessment map. Source: Rijksoverheid (2022). Biologishe waterkwaliteit KRW, 2021. Compendium voor de Leefomgeving. Retrieved on 3rd of March from https://www.clo.nl/indicatoren/nl1420-krw-biologische-kwaliteit-oppervlaktewater
Fig. 22, Nitrogen and phosphorus release in the water. Data from Corine land cover, EPRTR database.

appendix



Algae potential

Water body dissolved inorganic nitrogen (DIN)

Legend

Frame

Inland Waterbody

River, Canal - Large

Urbanized area

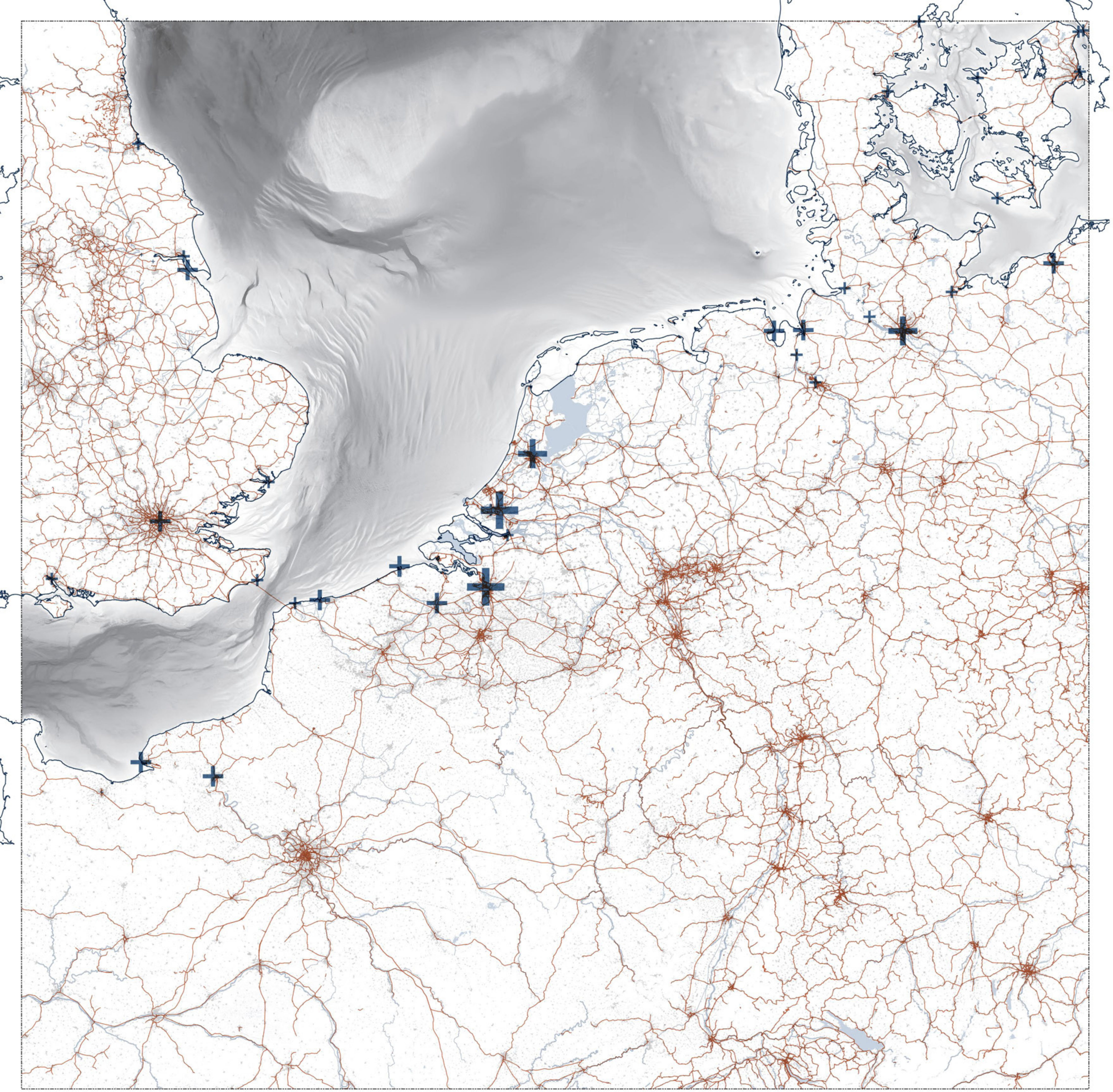
Tidal Transitional Area

Deepest values of DIN (umol/l)
Avg. 1977-2017, seasonal avg.

- 0 - 1,1
- 1,1 - 4,5
- 4,5 - 7,5
- 7,5 - 12,6
- 12,6 - 19,8
- 19,8 - 27,8
- 27,8 - 34,9
- 34,9 - 45,5
- 45,5 - 79,8
- 79,8 - 119,1

0 100 200 km

Algae potential
Transportation



Legend

Frame

Inland Waterbody

River, Canal - Large

Urbanized area

Main Port - Goods (1000 tonnes/year)

0 - 5000

5000 - 20000

20000 - 50000

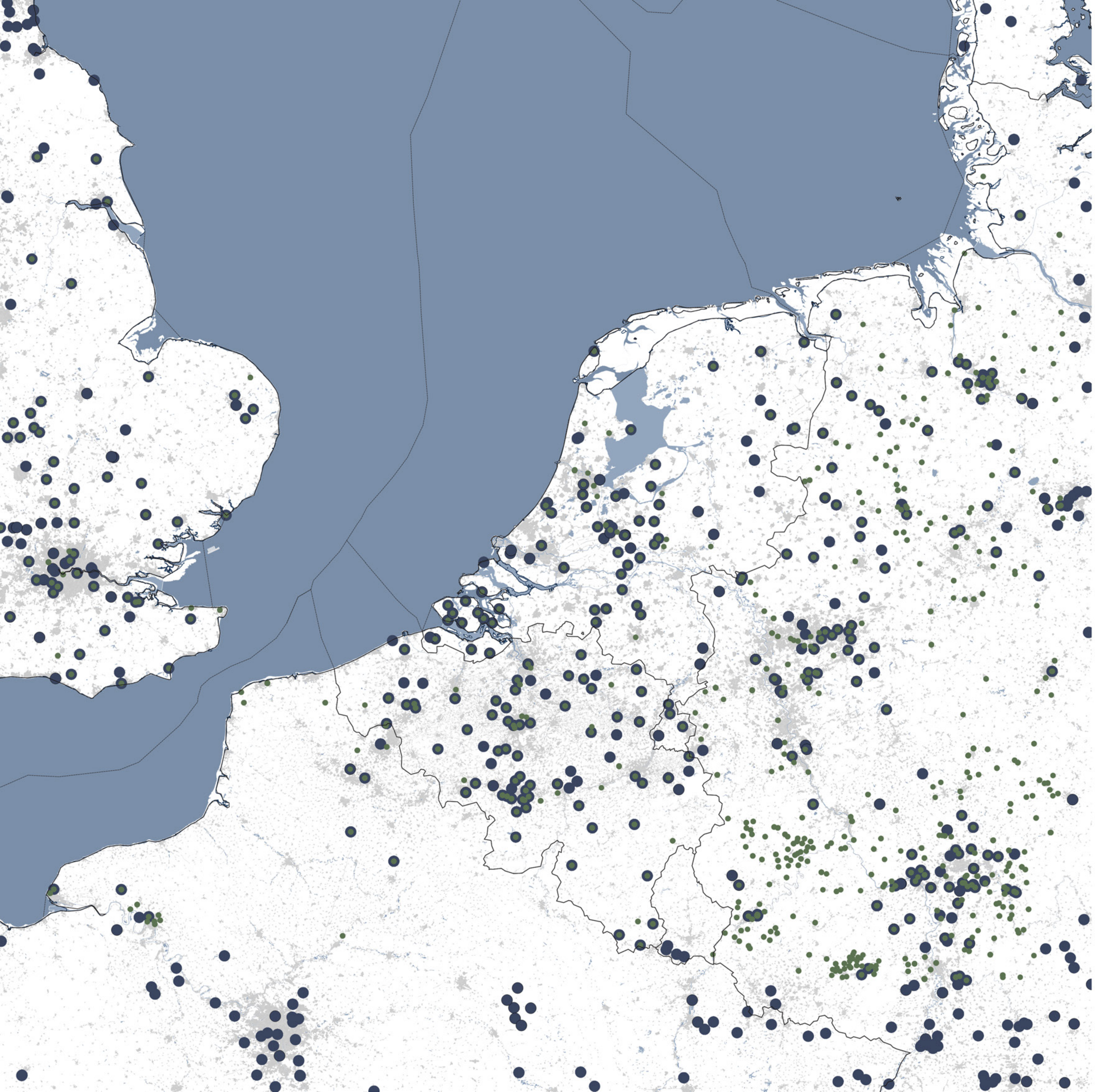
50000 - 200000

200000 - 450000

Railway

0 100 200 km

Existing recycling facility



Source: EMODnet, EUHydro dataset, Corine land cover, OSM

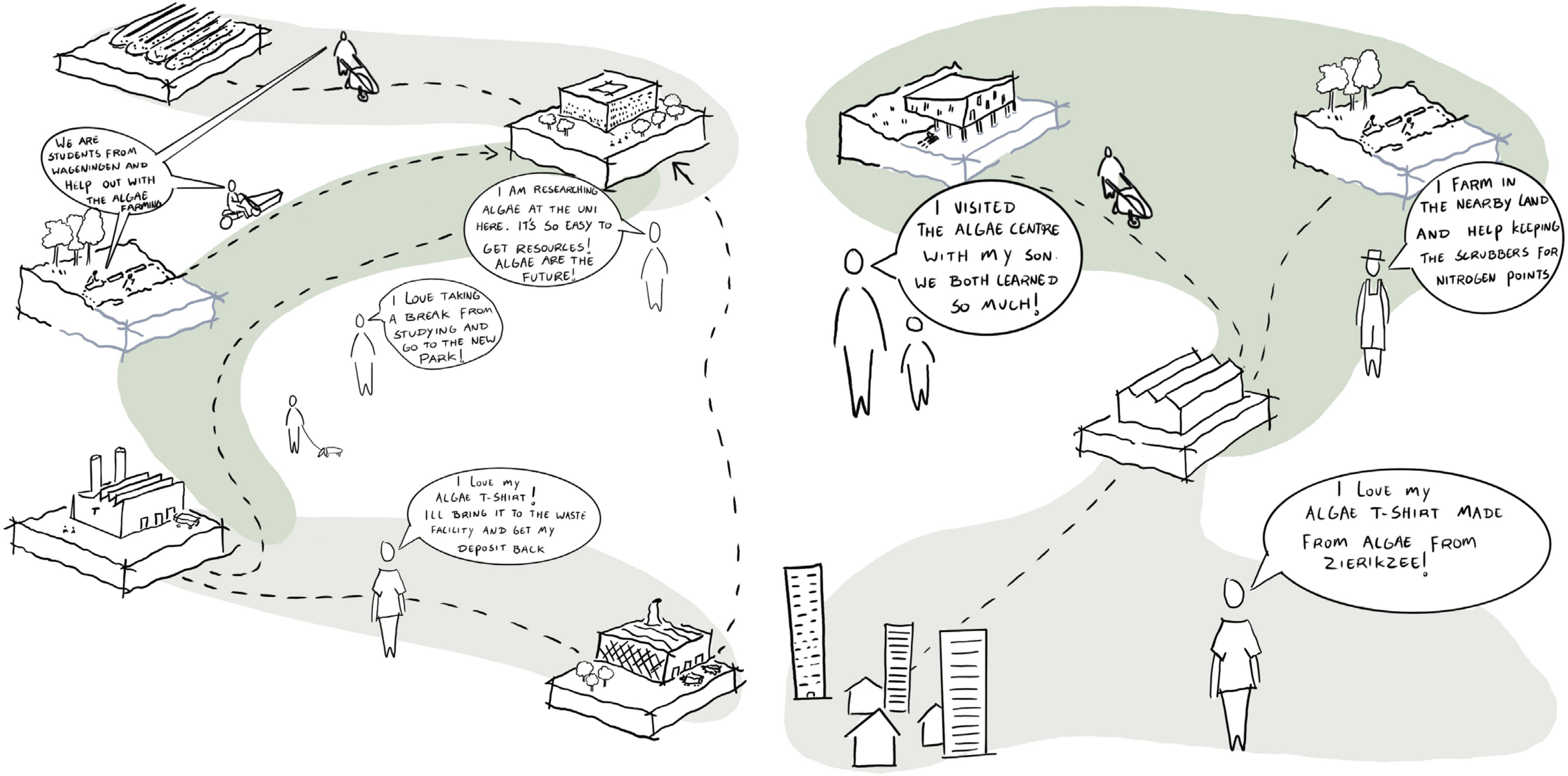
Wast Water

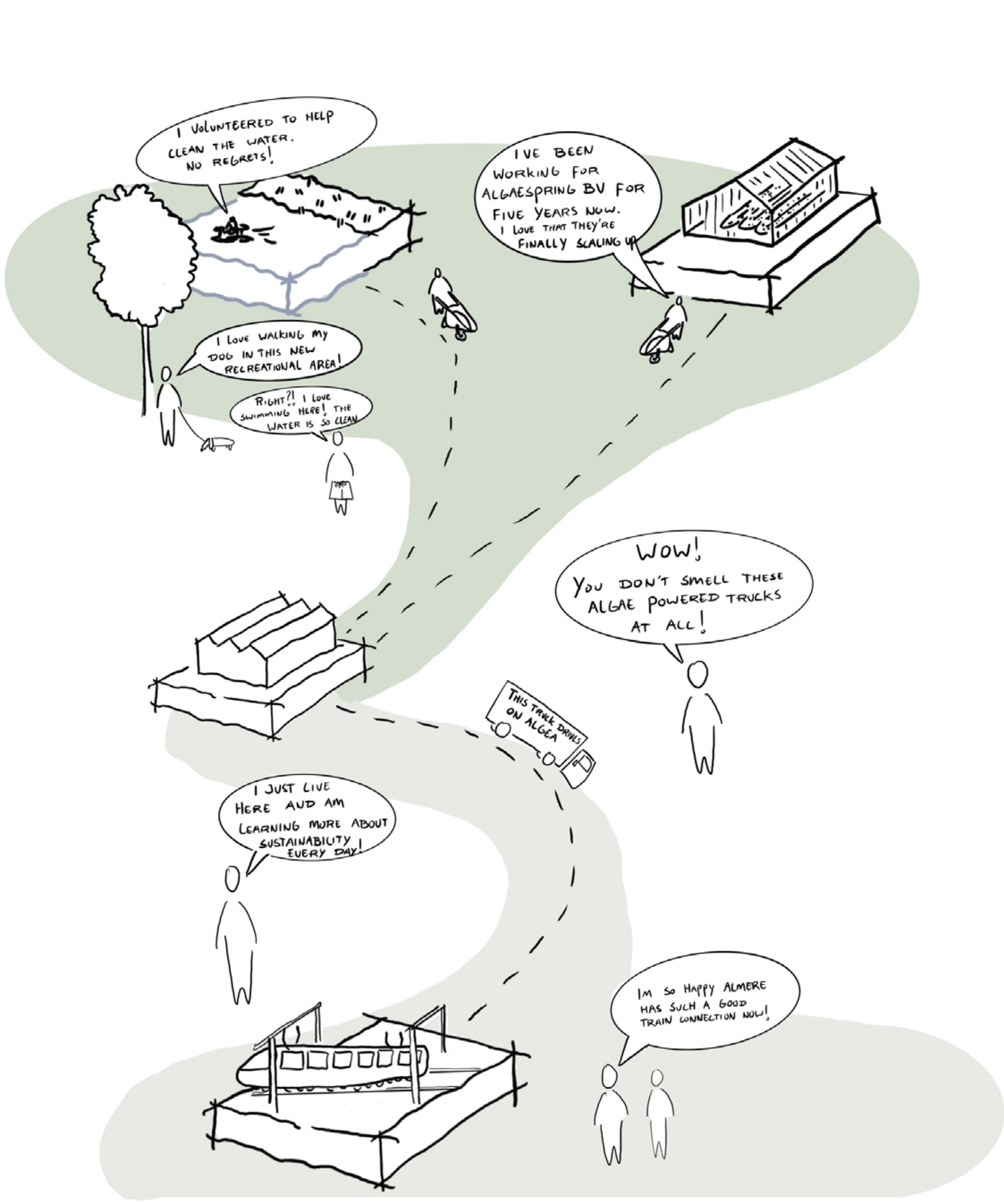
Legend

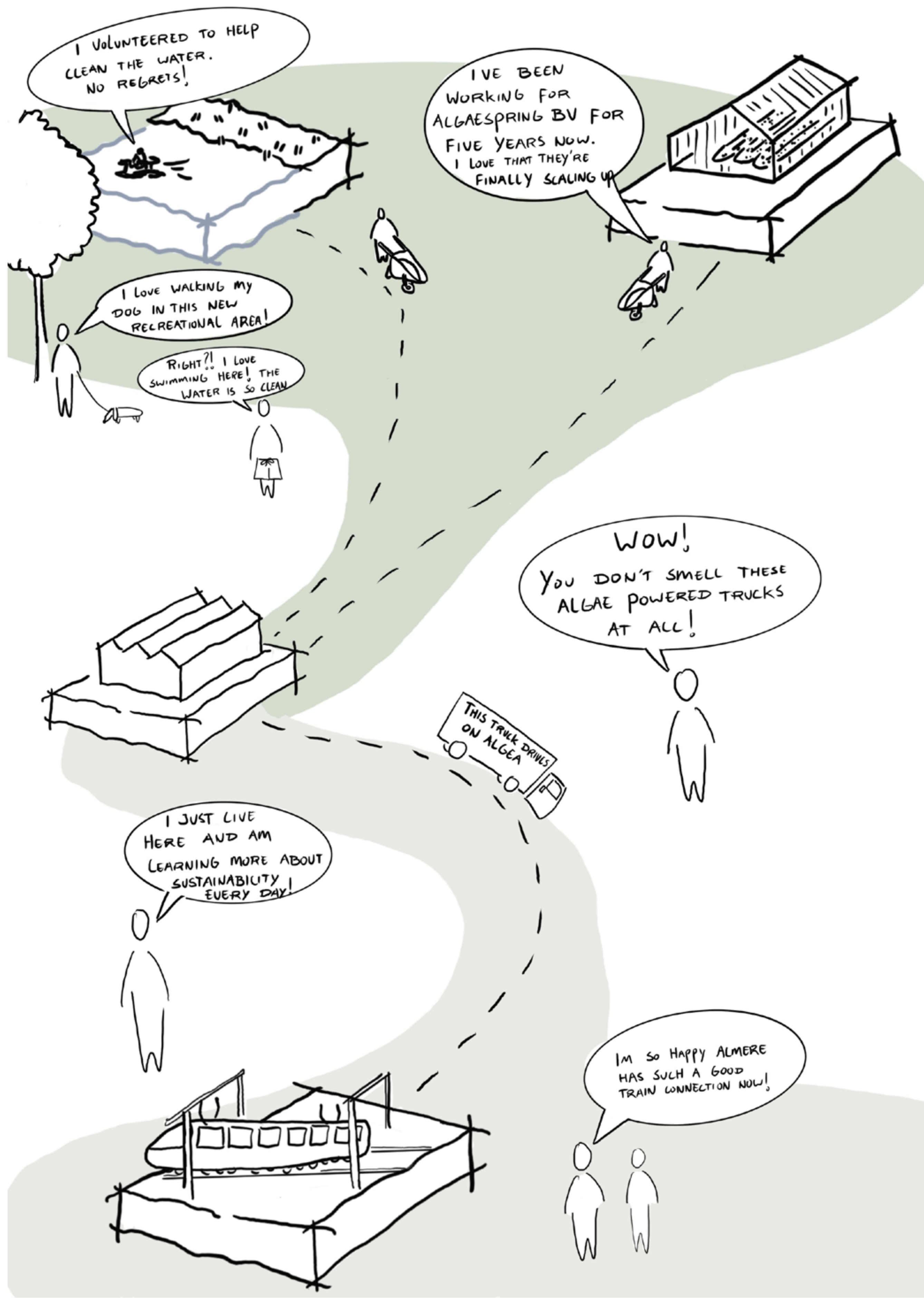
Source: Waterbase-UWWTD database, Corine land cover

Land use

Source: Corine land cover


We are students from Wageningen and help out with the algae farming
I am researching algae at the uni here. It's so easy to get resources! Algae are the future!
I love taking a break from studying and go to the new park!
I love my algae T-shirt! I'll bring it to the waste facility and get my deposit back
I visited the algae centre with my son. We both learned so much!
I farm in the nearby land and help keeping the scrubbers for nitrogen points
I love my algae T-shirt made from algae from Zierikzee!


I Volunteered to help clean the water. No regrets!
I've been working for AlgaeSpring BV for five years now. I love that they're finally scaling up
I love walking my dog in this new recreational area!
Right?! I love swimming here! The water is so clean
Wow! You don't smell these algae powered trucks at all!
This truck drives on algea
I just live here and am learning more about sustainability every day!
Im so happy Almere has such a good train connection now!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