HYDROGENERATION

NET-ZERO INFRASTRUCTURE FOR COMMUNITIES THROUGH MUTUALISM

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AR2U086 Research & Design
Spatial Strategies for the Global Metropolis

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April 2025

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“A hundred years ago, Rotterdam changed the world with industry.
Now hydrogen changes the industry for the world.”

- authors, 2025

ABSTRACT

The accelerating impacts of climate change and evolving geopolitical dynamics underscore the urgent need for the Netherlands to transition from fossil fuel dependency towards sustainable, renewable energy sources. Central to this challenge are the nation's industrial clusters, which not only contribute significantly to CO_2 emissions, but are also heavily reliant on fossil based fuels. Meeting the climate targets outlined in *The Klimaatakkoord (Climate Accord)*, especially the complete elimination of CO_2 emissions by 2050, necessitates not only a technological shift, but also a socially inclusive transition that accounts for the workers and communities embedded within these industrial regions.

This project proposes the large-scale implementation of green hydrogen as a key strategy in achieving social goals for the community. Hydrogen produced through electrolysis is presented as a viable alternative feedstock for decarbonizing industrial processes. The vision adopts a multi-scalar approach, combining a national perspective with targeted interventions at the regional clusters. For example Rotterdam being reimagined as the largest producer of green hydrogen in the Netherlands. Former fossil fuel-dominated zones are re-envisioned as spaces of green experimentation and innovation through the installation of mega-electrolysis plants and the transformation of post-industrial lands into green oases.

Crucially, the project emphasizes an equitable community transition. It introduces a multi-level governance mechanism in the form of a Hydrogen Council, aimed at empowering local communities to participate in the shaping of their post-fossil identities. Additionally, the integration of hydrogen credits is proposed as a tool to incentivize public adoption and normalize hydrogen use in everyday life. These spatial and social strategies are designed to improve environmental conditions, working environments, and the social fabric of transitioning industrial communities.

This approach aims to develop replicable models that can guide similar transitions across the Netherlands. Through the phased implementation of interventions over the next 25 years, the goal is to foster a beneficial relationship between industries and communities: mutualism. In the future, hydrogen is expected to stabilize as the predominant sustainable fuel source, securing its role in the future energy landscape.

keywords | hydrogen, industrial clusters, energy transition, community, governance

hydroGENeration: *hydrogen generation*

The generation of hydrogen refers to both *production of hydrogen* and *future generations* that live in a hydrogen-based world.

GLOSSARY

Assemblage
A flexible configuration of diverse elements (social, spatial, technological or ecological) that interact to form a dynamic, evolving whole.

Electrolysis (Electrolyser)
A process that uses electricity to split water (H_2O) into hydrogen (H_2) and oxygen (O_2). This method is key to producing green hydrogen and is carried out in an electrolyser.

Futuring
The practice of exploring, anticipating and shaping possible futures. It is not about predicting the future, but actively imagining multiple futures, especially to guide better decisions in the present.

Green hydrogen
Energy carrier that is produced using renewable energy (like solar or wind) to power electrolysis, which splits water into hydrogen and oxygen. It is a clean energy source with zero carbon emissions.

Hydrogen
Chemical element and a clean energy carrier that can be used in fuel cells to generate electricity or as heating gas, producing only water as a byproduct. It can be obtained from water through electrolysis.*

Mutualism
A type of symbiotic relationship between two different parties in which both of them benefit from the interaction.

**more information on the process of hydrogen production can be found in Chapter 4.*

Figure 1: ***Man walking his dog at the beach in the middle of renewable energy sources Maasvlakte, Rotterdam***
source: Maryna Poliakova, Unsplash

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A hundred years ago, Rotterdam changed the world with industry.
Now hydrogen changes the industry for the world.

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DEFINING THE BEAST

INTRODUCTION
Shifting away from fossil fuels: why is the transition necessary? What do we need to aim for and where can we make the largest impact?

1.1 INTRODUCTION: WHAT IS THE ENERGY TRANSITION?
THE NEED TO CHANGE

It is not just today's news, it is definitely tomorrow's news: global heating. Our own future is at stake because of our own actions. If we want to overturn this, large-scale action is needed. Not only globally but also nationally, warming can be seen: since 1901, the beginning of measurements, the average annual temperature has risen more than 3°C (KNMI, 2025).

The largest share of greenhouse gases in the Netherlands is due to the industrial sector. Yet we rely heavily on our industries: it provides our energy for mobility and households (CBS, 2023).

INDUSTRY IS THE LARGEST SECTOR EMITTING CO2

The question of whether industries are fueling growth and innovation or driving us toward an uncertain future is one that deserves careful consideration. This dual perspective is valid, as industrial growth has undeniably contributed to technological advancements and economic prosperity. However, the environmental toll of this progress cannot be overlooked. The need for innovation and growth must be critically examined in the context of its ecological consequences. The destruction of ecosystems, exacerbated by unsustainable industrial practices, raises serious concerns about the long-term viability of such growth.

The Netherlands, for example, is a significant contributor to global carbon emissions, accounting for 3.5% of total CO_2 emissions, despite representing only 0.41% of the world's land area (IEA, 2025). This disproportionate impact is largely due to the country's role as both an agricultural and industrial powerhouse, with a robust export and import economy. The electricity consumption in the Netherlands has risen by nearly 40% over the past 35 years (IEA, 2025), primarily driven by fossil fuel-based electricity generation. This upward trend in electricity demand underscores the continued reliance on non-renewable energy sources, which must be addressed if the country is to meet the climate goals outlined in the Klimaatakkord, aiming for zero CO_2 emissions by 2050.

Although the Netherlands has made notable progress in transitioning to renewable energy, particularly through the installation of wind turbines both onshore and offshore, and solar panels on residential buildings, significant challenges remain. The contribution of renewable energy to total electricity production has increased by 1,101%, a remarkable achievement. However, renewable sources still account for only 39.7% of the country's total electricity consumption (IEA, 2025). This indicates that fossil fuels continue to dominate the energy mix, highlighting the urgent need for a more rapid transition toward sustainable energy production in the coming years.

Moreover, the Netherlands' domestic energy production has decreased by 55.35%, yet this does not necessarily correlate with a reduction in overall CO_2 emissions. The country imports 40% of its total energy, effectively outsourcing the environmental costs of energy production (IEA, 2025). This shift in energy sourcing has only resulted in a modest decline of 8.84% in CO_2 emissions since 1990, further emphasizing the need to decouple economic growth from the fossil fuel industry and anchor future development to renewable energy sources.

The Netherlands' economy is heavily transport-oriented, with freight transport volumes reaching 581 million tonnes of imports and 501 million tonnes of exports (PBL, 2025). A significant portion of this freight consists of agricultural and oil products, whose transportation and refining contribute substantially to the country's carbon footprint. This trend has increased by 72% since 1990, underscoring the need for a transformative shift in industrial processes and societal practices.
To achieve meaningful change, a fundamental transformation is required, not only in terms of technological advancements but also in societal mindset. The transition toward a sustainable future requires systemic shifts that challenge existing industrial and economic models, moving away from fossil fuel dependence and toward renewable, low-carbon alternatives. Without such a shift, the Netherlands, and indeed the world, will continue to face the dual threat of environmental degradation and economic stagnation in the face of climate change (PBL, 2025).

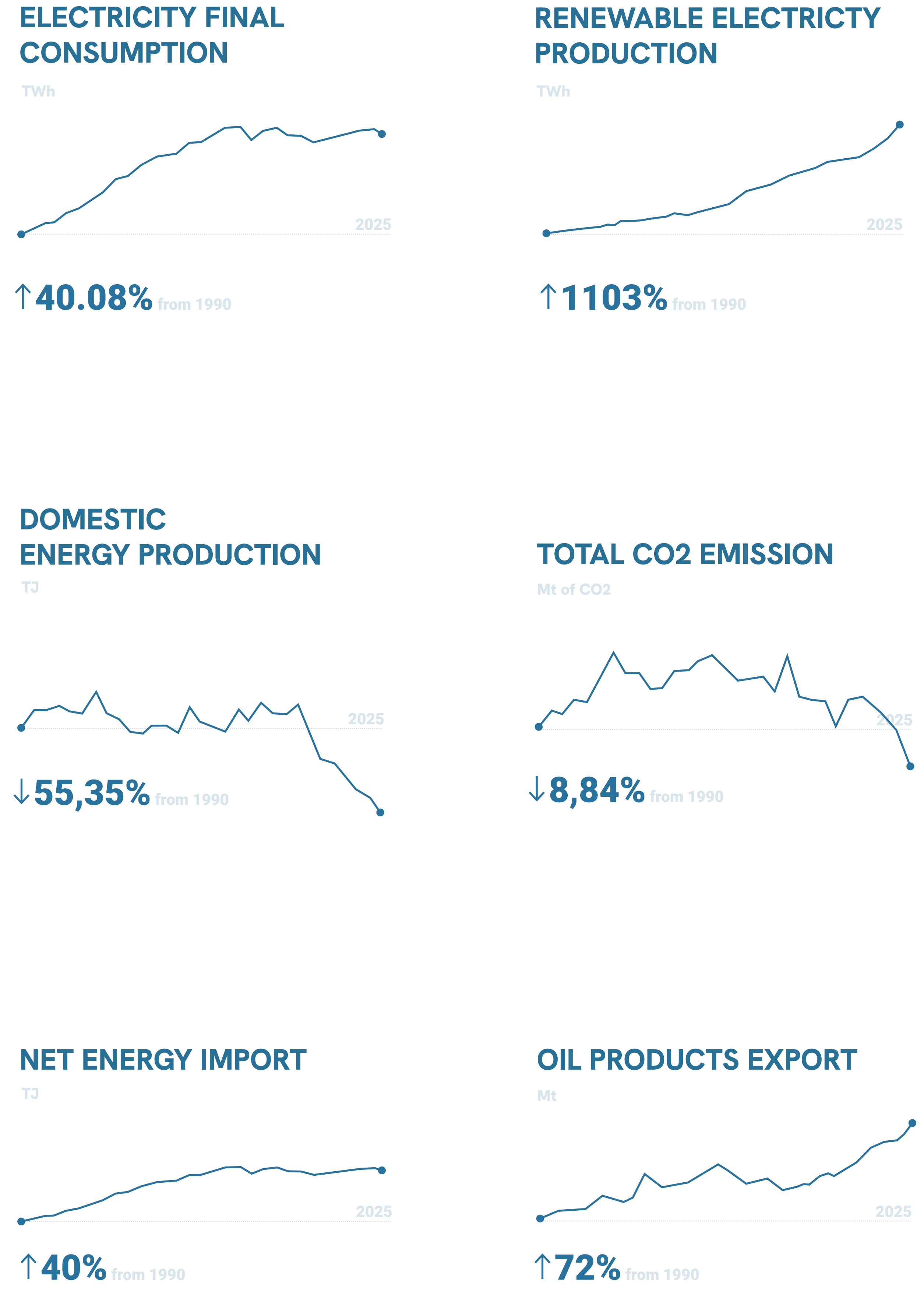


Figure 2: ***graphs showing increase or decrease of energy topics***
source: IEA (n.d.)

1.2 PROBLEM STATEMENT
THE URGENCY OF CHANGE

Balancing energy independence and urban livability in The Netherlands

The discovery of extensive natural gas reserves in the Netherlands has historically played a vital role in reshaping the nation's energy infrastructure, catalyzing economic development, and enabling the growth of energy intensive sectors. These domestic energy resources significantly reduced the country's reliance on foreign energy imports and contributed to industrial expansion. Key industries such as petrochemicals, steel production, aviation, and particularly the Port of Rotterdam, Europe's largest seaport, flourished under conditions of reliable and relatively affordable energy. These developments positioned the Netherlands as a strategic player in the European energy market and laid the foundation for a robust, export-oriented economy.

The availability of natural gas not only fostered national energy security, but also served as a magnet for industrial investment, encouraging regional economic development and urban growth. Industrial agglomeration around strategic clusters, such as ports and transportation corridors, has been instrumental in creating employment opportunities, advancing infrastructure, and enhancing the Netherlands' international competitiveness.

However, these economic advantages are increasingly accompanied by social and environmental trade-offs, particularly due to the country's high population density and the increasing pressure on urban environments due to climate change.

The continued reliance on fossil fuels, has led to significant environmental externalities. These include the emission of greenhouse gases and air pollutants detrimental to both ecological systems and public health. In highly urbanized and densely populated areas, these environmental impacts are especially pronounced. impacts of emissions, noise pollution, increased traffic volumes and reduced access to green and open spaces converge to diminish overall urban livability.

As the Netherlands faces climate obligations and a growing awareness of the social costs of industrial externalities, the need to reconcile energy independence with sustainable urban living has become more urgent.

The complexity of this challenge lies in managing a strategic transition from fossil fuel-based energy systems toward renewable alternatives, for example green hydrogen, without compromising economic resilience or energy reliability. An evidence-based approach is essential to navigate this transition, one that considers spatial planning, environmental justice and the broader environmental outcomes that shape urban resilience.

Communities situated in and around existing industrial clusters often bear the brunt of environmental degradation while simultaneously relying on these industries for employment and economic stability. These populations are disproportionately exposed to the negative externalities of industrial activity, including reduced environmental quality and spatial inequality. As such, the energy transition must not only address technological and infrastructural shifts, but also ensure a socially just transformation, one in which the distribution of environmental benefits and burdens is equitable.

This calls for inclusive planning strategies that prioritize vulnerable communities, safeguard livelihoods, and promote shared responsibility in shaping a sustainable urban future.

COMMUNITIES NEAR INDUSTRIAL AREAS MUST BE EMPOWERED AS KEY STAKEHOLDERS IN GRASSROOTS PLANNING, SHAPING DECISIONS AND UNDERSTANDING THE SYSTEMIC CHANGES NEEDED FOR A JUST, SUSTAINABLE FUTURE.

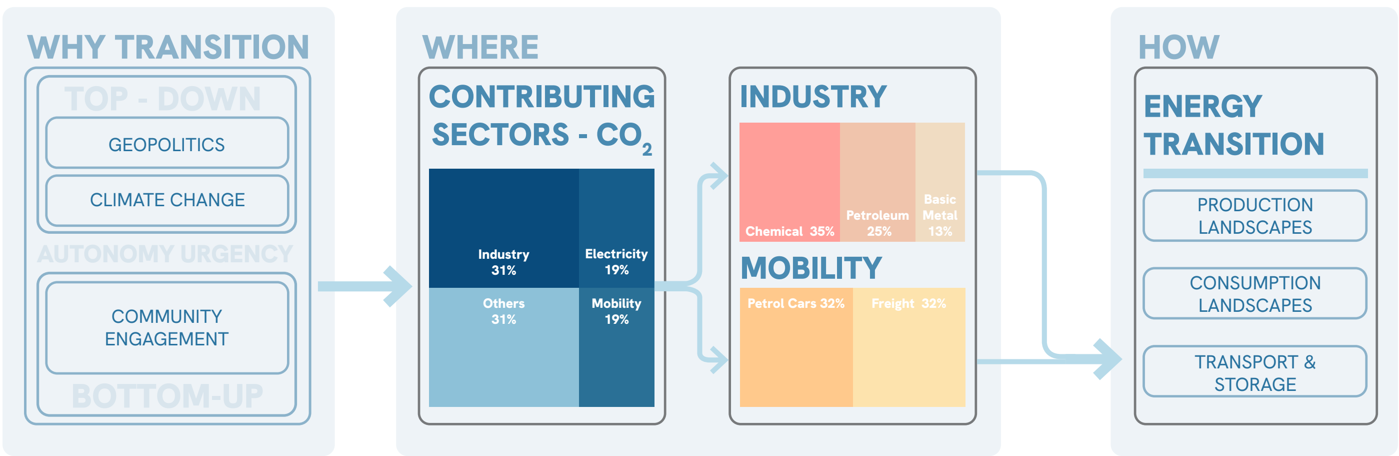


Figure 3: ***energy transition: why, where and how?***
source: CBS (2023)

1.3 RESEARCH QUESTION
AND SUB-QUESTIONS

HOW CAN FUTURE SPATIAL STRATEGIES ENABLE THE INTEGRATION OF HYDROGEN AS AN ENERGY SOURCE TO IMPROVE SOCIO-ECONOMIC CONDITIONS OF THE COMMUNITIES ALONG THE EXISTING INDUSTRIAL CLUSTERS?

1. What are the key characteristics of the affected communities, including their concerns?

It is important to understand the community and their characteristics. Who are the affected communities, where do they live, what are their occupations, how are they impacted by the current energy system, and what are their aspirations for post-fossil fuel identities?

These inquiries will be central to understanding the social dynamics of the energy transition and ensuring its inclusivity.

2. What is the spatial configuration of the existing industrial landscape around the most polluting clusters and how does it affect the surrounding neighbourhoods?

The concept of spatial justice is a critical consideration in the context of the energy transition, particularly with regard to the socio-environmental impacts of industrial infrastructure. This issue underscores the importance of carefully studying the existing industrial landscape before initiating any changes associated with a sustainable energy transition.

A comprehensive understanding of the location and impact of current industrial clusters is essential to inform future planning decisions. It is necessary to assess the spatial configuration of these clusters and their effects on surrounding neighborhoods. Specifically, the question arises: Where are the current industrial clusters located, and how do they influence the adjacent communities, particularly in terms of environmental health and livability?

3. In what key ways does the hydrogen supply chain significantly influence the development of the built environment?

The successful execution of the energy transition necessitates substantial investments, particularly in the (re) development of existing infrastructure. The widespread adoption of renewable energy faces significant barriers, particularly with regard to the overload of existing energy grids. For example, in the Netherlands, some municipalities face restrictions on the installation of new photovoltaic panels due to the inability of the energy grid to accommodate additional energy input.

In light of these challenges, this sub-research question examines the viability of green hydrogen as a potential solution to decarbonize heavy industry, mobility, and energy storage. It is crucial to understand the fundamentals of hydrogen, including its types, production methods, and possible applications.

More information on the sub-questions is accessible in Appendix A.

1.4 AIMS OF THE PROJECT

BASED ON THE SUSTAINABLE DEVELOPMENT GOALS

Figure 4: ***relevant Sustainable Development Goals***
source: United Nations (2015)

This research was initiated in response to the energy transition, approached from the perspective of the local community in relation to industrial transformation. Several key objectives support this research, each of which aligns with the United Nations Sustainable Development Goals (SDGs) for the period 2015 to 2030 (Ministry of General Affairs, 2024). The overarching aims of the SDGs are to reduce poverty, inequality, injustice and climate change. In Figure 4, these goals are ranked in descending order of significance, reflecting their relative priority within the context of this research.

The central objective of this project is to explore the potential for a bottom-up energy transition from fossil fuels to hydrogen in and around industrial zones in the Netherlands. A bottom-up approach emphasizes inclusivity, safety and societal resilience, aligning particularly with SDG 11 (Sustainable Cities and Communities) and SDG 16 (Peace, Justice and Strong Institutions) (United Nations, 2015).

Successful implementation of such a transition necessitates the active participation of various stakeholders, including communities, the government and business. This collaborative model resonates with SDG 10 (Reduced Inequalities) and SDG 17 (Partnerships for the Goals). Within this project, such collaboration is conceptualized as mutualism, a symbiotic relationship wherein both industry and the local community benefit. In the current context, the energy transition serves as an opportunity to establish a more equitable balance between industrial development and societal wellbeing.

Beyond the primary aims of a just transition and mutualism between industry and community, this project also seeks to contribute to the creation of a clean and affordable living environment. These ambitions correspond with SDG 3 (Good Health and Well-being) and SDG 7 (Affordable and Clean Energy). The transformation of the industrial landscape will provide opportunities for a stronger focus on knowledge generation and long-term property. Through increased emphasis on education and research, the industrial sector can become a hub of innovation, fostering economic growth and sustainable livelihoods. This aligns with SDGs 4 (Quality Education), 9 (Industry, Innovation and Infrastructure), and 12 (Responsible Consumption and Production) (United Nations, 2015).

In conclusion, this research seeks for a bottom-up hydrogen transition as an example for inclusive, sustainable industrial development. By aiming at collaboration between stakeholders, the goal is to create ***mutualism****.*

The transition offers more than environmental benefits, it promotes social equity, economic opportunity, and innovation. It envisions a future where industrial innovation and community needs are in balance, ensuring a just and resilient energy transition for generations to come.

1.5 METHODOLOGY

HOW ARE WE CONDUCTING RESEARCH?

This project envisions the integration of the energy transition with the emergence of a hydrogen economy by addressing its spatial, policy and governance dimensions. The methodology is structured to follow a systematic and multi-scalar approach, beginning with an in-depth investigation of the regional contexts of fossil fuel dependency, transition communities and the spatial configuration of energy-intensive industrial clusters. The research process is organized into four key phases.

Research and critical analysis

Step one of the methodology, research and critical analysis, begins with a comprehensive literature and media review on community development and the energy transition. Fieldwork complements this, focusing on spatial typologies and industrial landscapes. Findings from secondary and primary research inform a problem statement and central research question, which are further refined into sub-questions. These address community concerns, spatial implications of existing landscapes and the technical transition to hydrogen, analyzed through environmental, ecological and economic lenses, with particular focus on spatial typology, systemic design and hydrogen infrastructure.

Implementing frameworks

Upon answering the research questions, the process advances to the next step, which involves implementing a conceptual framework by synthesizing the research findings into a coherent set of tangible values and objectives. This phase bridges the gap between analysis and design by translating findings into strategic directions that inform future-oriented planning. These frameworks serve as guiding principles for shaping a vision of a post-fossil society. By integrating spatial, social, and technical dimensions in a structured and goal-oriented manner, the framework lays the foundation for multi-scalar interventions and enables the formulation of practical strategies for implementation.

Sythesis and visioning

Futuring post fossil identities involves translating the vision into a multi-scalar framework that addresses the energy transition across different levels of governance and spatial planning. At the European scale, the focus lies on aligning with the broader ambition for the Netherlands to become a leading hydrogen hub within the EU. At the national scale, this vision materializes through the design and implementation of a robust hydrogen backbone infrastructure that supports widespread decarbonization. Finally, at the regional scale of Rotterdam, the emphasis shifts toward establishing governance structures and spatial identities that facilitate equitable industrial transformation and empower local communities.

Assembling the strategy

The report then progresses to the assembling the strategy phase, which outlines the pathway for the Netherlands to achieve its energy transition goals. This phase explores various potential scenarios and selects one plausible trajectory to guide the future vision. Subsequently, key governance, policy, and spatial interventions are proposed through an implementation framework, which is organized in phases to ensure a smooth and adaptive transition. The ultimate aim is to foster mutualism between industries and communities, ensuring that the benefits of the energy transition are shared equitably across all stakeholders.

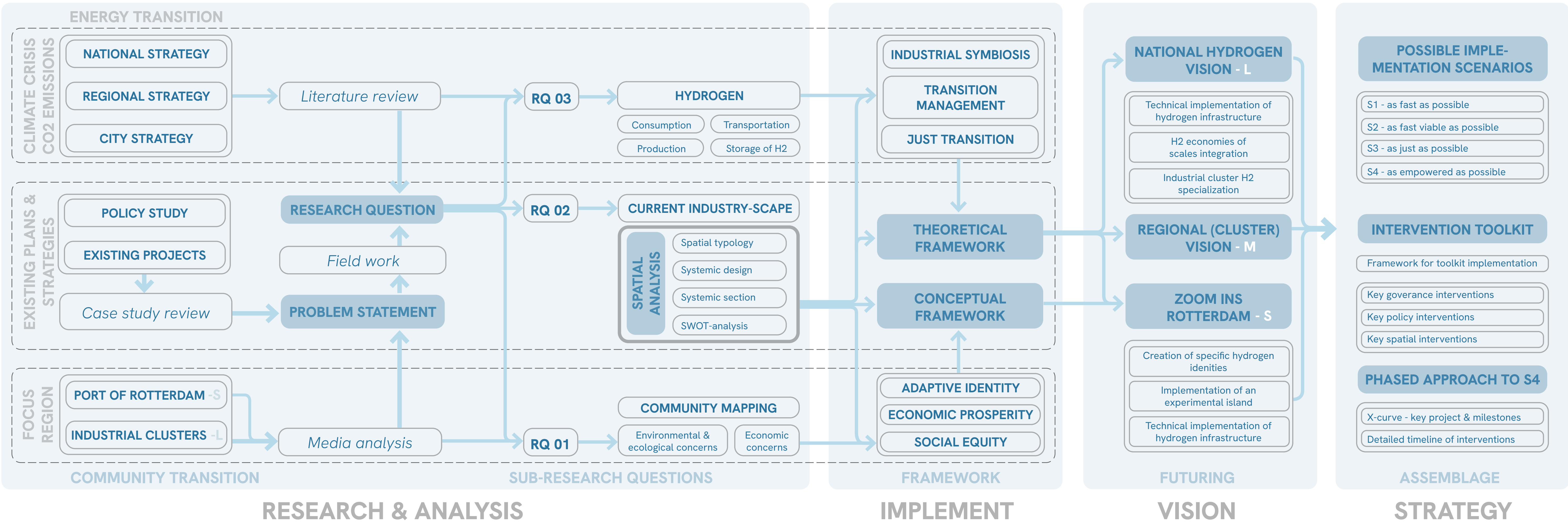


Figure 5: ***methodology scheme showing the research approach***

INDUSTRY: INDUSTRIAL SYMBIOSIS

Industrial symbiosis is an increasingly important concept within the realm of sustainable industrial development (Chertow, 2000). It involves the collaboration of different industries to exchange resources, such as energy, materials and waste, in a way that creates mutual benefits. This approach not only reduces environmental impact, but also enhances the efficiency and economic resilience of the industries involved. The integration of green hydrogen into industrial symbiosis systems is an emerging opportunity to further enhance sustainability, offering significant potential to decarbonize sectors that are difficult to electrify, such as heavy industry and transportation.

Green hydrogen, produced through the electrolysis of water using renewable energy sources, holds a key position in the transition towards a sustainable energy future. Its potential to decarbonize industries reliant on fossil fuels has made it a central focus of many national and international sustainability strategies (European Commission, 2020). In the context of industrial symbiosis, green hydrogen can play a crucial role by providing a clean and versatile energy source for industries that require high-temperature heat or other forms of industrial energy that are currently difficult to produce with renewable sources alone.

Integrating green hydrogen into industrial symbiosis systems creates significant economic and environmental benefits. It increases energy security, and stimulates the growth of new, green industries. By enabling industries to share resources and technologies, industrial symbiosis creates opportunities for collaboration that would not be possible in traditional, linear industrial systems.

When hydrogen is used in conjunction with industrial symbiosis, the reduction of carbon emissions becomes even more pronounced, as industries are able to not only decarbonize their own processes, but also reduce the environmental impact of their waste and by-products. This holistic approach helps industries collectively reduce their carbon footprint, contributing to the broader goal of sustainable industrial transformation.

In conclusion, industrial symbiosis offers a framework for ***the integration of green hydrogen into industrial systems****. By fostering collaboration between industries, this approach enhances resource efficiency and sustainability, helping to decarbonize sectors that are traditionally hard to address with renewable energy alone.*

INDUSTRY

ENERGY TRANSITION: TRANSITION MANAGEMENT

Transition management is a critical framework for managing complex, long-term sustainability transitions, especially in the context of the energy sector. It focuses on guiding societal transformations through structured processes, engaging multiple stakeholders, and balancing various interests to achieve long-term goals (Loorbach, 2007). The energy transition, which involves shifting from fossil fuel-based systems to renewable energy sources, is one of the most challenging and urgent transitions of our time. Transition management provides a strategic approach to navigating the uncertainties and complexities inherent in this process.

At its core, transition management emphasizes the need for adaptive governance. The energy transition cannot be managed with a one-size-fits-all solution due to its complexity and the various levels of decision-making involved, ranging from local governments to international policy frameworks. Instead, it promotes a flexible, multi-level approach where stakeholders at different scales collaborate to co-create solutions (Rotmans et al., 2001). This collaborative approach is essential, as the energy transition requires input from a broad range of actors, including governments, businesses, civil society and individuals.

The concept of "transition arenas" is central to transition management. These are platforms where diverse stakeholders come together to explore and co-design solutions for the energy transition. Such platforms facilitate the exchange of knowledge and ideas, fostering innovation while ensuring that the needs and concerns of all relevant parties are considered. In practice, transition arenas allow for the alignment of long-term vision with short-term actions, helping to create coherent policies and strategies for energy system transformation *(Loorbach, 2007).*

Moreover, transition management promotes an iterative approach. Given the uncertainty surrounding new technologies, policy frameworks and societal preferences, transition management encourages continuous learning and adjustment. As such, the energy transition is not viewed as a linear process but rather as an evolving one, where goals are continuously reassessed in response to emerging challenges and opportunities.

In conclusion, transition management is a vital tool for ***steering the energy transition****. By fostering collaboration, engaging multiple stakeholders and encouraging adaptive governance, it ensures that the transition to renewable energy is not only feasible but also socially and economically inclusive. (Rotmans et al., 2000) (Loorbach, 2007)*

ENERGY TRANSITION

COMMUNITY: SOCIALLY JUST TRANSITION

Just Transition is a widely recognized concept in sustainable development (Sabato & Fronteddu, 2020). It ensures that the process of addressing climate change is equitable, aiming to ensure that "no one is left behind" (European Commission, n.d.). As industries and communities shift towards greener practices, it is essential to support those most affected by these changes. Just Transition emphasizes fairness, ensuring the economic and social consequences of this transformation are shared equitably.

At its essence, Just Transition seeks to balance environmental goals with social equity. The adoption of sustainable practices, particularly renewable energy, will inevitably disrupt industries built around fossil fuels, such as coal, oil and gas. Communities that depend on these sectors are at risk of economic instability, job loss and social dislocation. Here, the principle of Just Transition becomes crucial, addressing environmental issues must go hand in hand with protecting the livelihoods of those most vulnerable to these changes.

This approach stresses the importance of providing adequate support to regions and sectors experiencing the greatest disruption. Social justice is a key consideration and policies must be designed to prevent exacerbating inequalities. Practical measures, such as retraining programs, new job opportunities in emerging green sectors and investments in local economies, are essential to ensure that these communities can adapt and thrive in the new economy.

The concept is particularly relevant to this project, as transitioning to sustainable energy sources will have significant socio-economic effects. The communities most reliant on traditional energy industries will face disruptions that need to be managed carefully. To minimize these impacts, it is essential to offer alternative employment and training opportunities, as well as support for economic diversification, ensuring a smooth and equitable transition for workers in affected industries.

In conclusion, Just Transition is central to ensuring that the shift towards a sustainable future is both ***inclusive and fair****. As we advocate for renewable energy adoption, it is critical to consider the social and economic impacts on those most affected. By integrating social justice into sustainability efforts, a future where everyone benefits, and no one is left behind, can be created.*

COMMUNITY

2

ENERGY TRANSITION COMMUNITY

FOCUS ON THE PEOPLE
A look into the transition community, their wishes and their concerns, trough media analysis and fieldwork.

INDUSTRIAL CO2 EMISSIONS

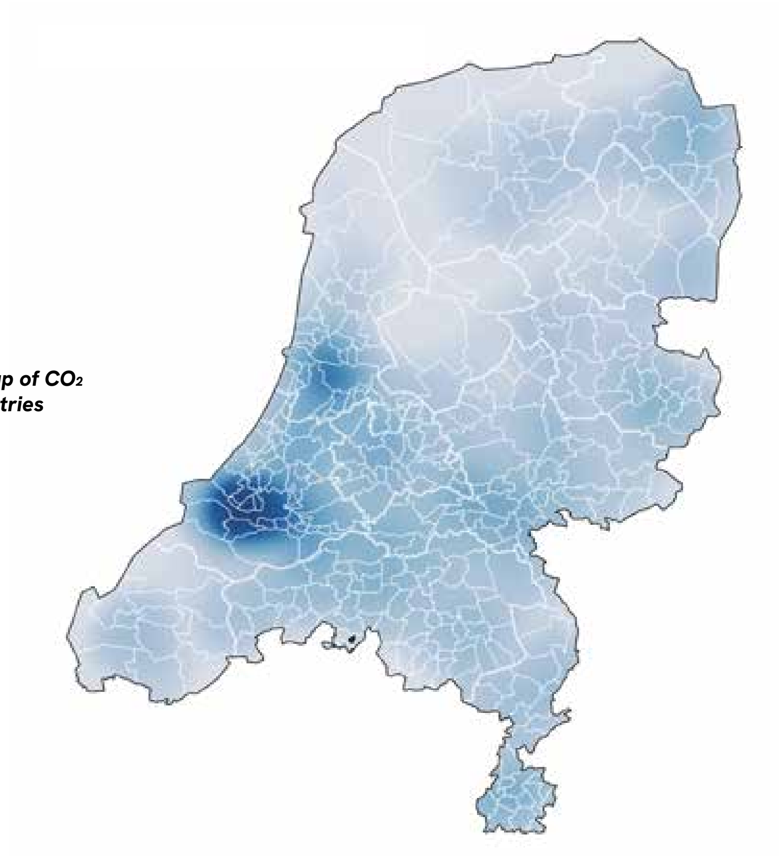


Figure 6: ***heatmap of CO_2 emitted by industries***
source: CBS (2023)

SOLAR POWER POTENTIAL

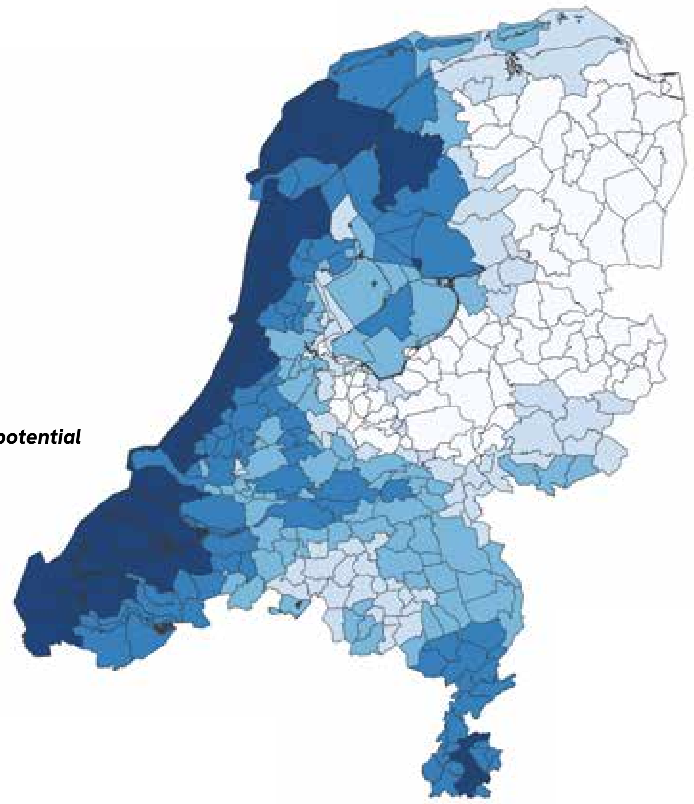


Figure 7: ***solar power potential***
source: Solargis (2021)

POPULATION DENSITY

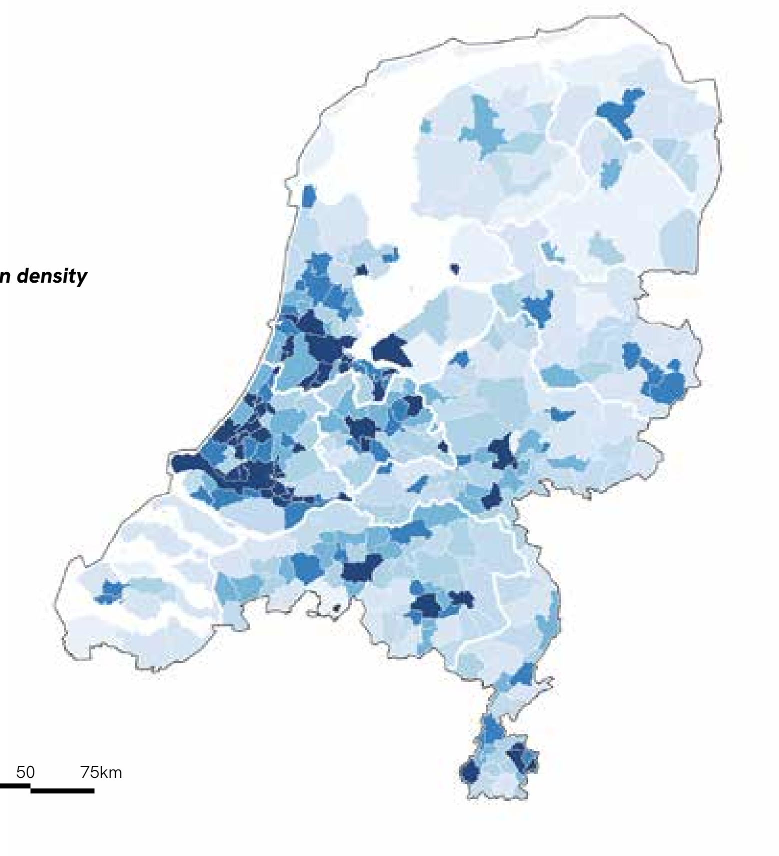


Figure 8: ***population density per municipality***
source: CBS (2023)

FOCUS REGIONS

Figure 9: ***four chosen clusters based on high CO_2 emissions, high population density and largest solar potential. The four clusters along the coast are the focus regions from Chapter 3 onwards.***

2.1 FOCUS REGION

WHERE CAN WE MAKE AN IMPACT?

2.1.1 Where are we focussing and why?

The industrial sector is a major contributor to CO_2 emissions. Figure 6 shows a heatmap of emissions from the industrial sector. It reveals that there are various clusters of high CO_2-emitting industries spread across the country. This project focuses on a national scale, specifically on the four major clusters located along the coast: Zeeland, Rotterdam, Amsterdam and Groningen.

Later in the project, the focus will shift to a more detailed analysis of the cluster surrounding the Port of Rotterdam. This area is the largest CO_2 emitter in the country.

Moreover, it becomes particularly interesting when looking at the population density map (figure 8). The port area is located in one of the most densely populated regions of the Netherlands. This makes it a complex and compelling area, where the interests of heavy industry and the residents of surrounding towns and cities closely interact, and at times conflict.

2.1.2 How are we going to tackle the focus region?

In order to make a meaningful contribution to the energy transition, it is important to gain a better understanding of these industrial clusters. All four focus clusters emit high amounts of CO_2 (Figure 6), but the way they function and their identities differ significantly. This identity is partly shaped by the types of companies located there and the products or services they focus on. Later in this report, each cluster will be analyzed and defined in more detail.

The identity of a cluster is also influenced by how it is perceived and experienced by the people who live, work, or are otherwise connected to the surrounding area. It is therefore essential to understand how these communities engage with and relate to these large industrial zones. By doing so, we can help ensure that the energy transition in these major industrial areas, within our densely populated country, proceeds in a fairer, smoother and more efficient way.

The four chosen clusters are based on high CO_2 emissions, high population density and largest solar potential. The four clusters along the coast are the focus regions from Chapter 3 onwards.

“IJmond without furnaces is as Paris without the Eiffeltower.”

Protest at TATA Steel site: machinists want attention to their concerns for the future, including identity loss and redundancies, 2020.

Figure 10: ***protests at TATA Steel, IJmuiden***
source: United Photos, Toussaint Kluiters, published in Noord-Hollands Dagblad (June 19th, 2020)

2.2.1 Community personification

In the media, these industrial clusters are not always portrayed in a positive light. For example, residents living near TATA Steel demanded compensation for the nuisance caused by the company (Opheikens, 2023) and a Rotterdam neighbourhood association has been searching for years for a solution to the ongoing noise pollution, which continues day and night (KRO-NCRV, 2017).

During fieldwork discoveries have been made about the community. There is a group of people who generally hold a more positive view of the industry. This community is spread throughout the country but is largely concentrated around industrial areas. They are proud of the industry, seeing it as an integral part of their city's history and their own identity. They take pride in the opportunities the industry has created in their region, and in the economic growth it brought during the past century. This community also includes people who currently work in the industrial sector and rely on it for their livelihood. Many of them hope to continue working in these sectors in the future.

This report presents a vision and strategy for the energy transition of the industrial clusters, with this community as a central starting point. What they all have in common is a **strong desire for the industry to remain in the future.** However, they also share concerns about how the energy transition will impact these industrial areas, their living environment and their everyday lives.

Figure 11: ***Fictional personas, based on media analyses and conversations held with residents of Wijk aan Zee.***

Figure 12: ***main concerns of the community***

2.2.2 Community concerns

The community first and foremost shares concerns about the energy transition in general.

One major concern is that the **identity** of their town, city, or living environment will be affected if industry is forced to shut down as a result of the energy transition. They see industry as an essential part of their history and heritage (Berghuis, 2021). Besides that, they also worry that the energy transition might further impact their surroundings, for example, through the placement of new wind turbines near the dunes or in green spaces (NOS, 2021; Onnink, 2023).

A second concern is the fear that the community will not be included in important **decisions** regarding the energy transition, energy supply and other matters that directly affect their environment. They believe it is essential that the concerns and interests of local residents and other stakeholders are taken seriously and truly listened to (Coöperatie ZeelandBruist, 2023; Rietveld, 2024).

This is not just a bottom-up concern. In a report by the Netherlands Institute for Social Research (SCP), researchers warn that public trust in government may be damaged if people are not included in the development of major plans. They also emphasize that this participatory process must be fair and just (Sociaal Cultureel Planbureau, 2023).

A third concern within the community is the fear of losing their **jobs**. Firstly, because many people are employed in the fossil fuel sector. As the energy transition progresses, these jobs are expected to disappear in the future (NOS, 2023).

Secondly, because the energy transition will require major investments from companies. Workers fear that in order to cover these costs, companies may start cutting jobs. For instance, employees of TATA Steel have already protested in Brussels, demanding subsidies to support the transition toward green steel production (Jak, 2025).

Lastly, there are concerns that companies located in the Dutch industrial clusters might relocate abroad if stricter regulations, such as tighter emission standards, are introduced as part of the energy transition. In such cases, it might be more attractive for companies to operate in countries with more lenient policies. A political party in the Rotterdam City Council has already raised concerns about this possibility (Holleman, 2025).

H2

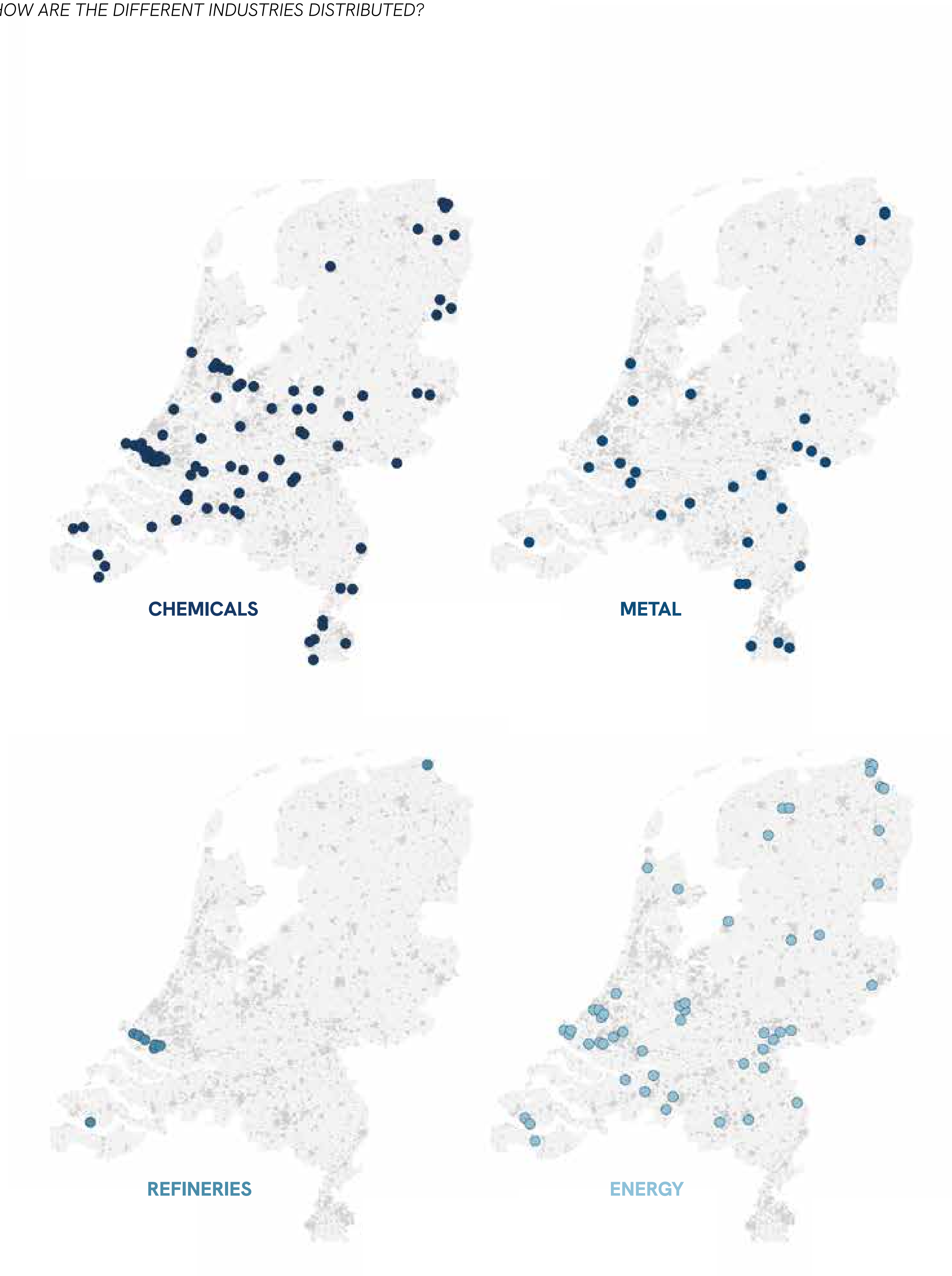
TOWARDS CLEAN ENERGY
A hundred years ago, Rotterdam changed the world with industry.
Now hydrogen changes the industry for the world.

3

CURRENT INDUSTRY-SCAPE

INDUSTRIAL CLUSTERING
Zooming into the main coastal clusters.
What typologies and spatial characteristics define these spaces and need to be taken into account for future (re)designs?

3.1 INDUSTRY CLUSTERS
HOW ARE THE DIFFERENT INDUSTRIES DISTRIBUTED?



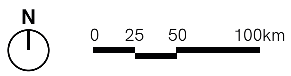


Figure 13: ***locations of different sectors of industry***
source: PDOK Inspire - Location of industry (2022)

3.1.1 Energy consumption and emission of industries

The industrial sector is the largest emitter of CO_2 and is responsible for almost half of all CO_2 emissions in the Netherlands (CBS, 2023) Within this sector, chemical companies, oil companies and metal industries make up a large part of these emissions (Figure 14).

The maps in Figure 13 show how these different types of industries are spread across the country. It becomes clear that many of the most polluting companies are located in the four main industrial clusters around the ports of Rotterdam, Amsterdam, Zeeland and Groningen (Ritchie et al., 2022). In addition, there are two more noticeable clusters in Limburg and near Nijmegen.

Figure 15 shows the energy consumption of the industrial sector and the sources that are used. At the end of the last century, almost all energy consumption came from polluting sources. In recent years, there has been a huge increase in renewable energy sources, with wind, solar and bioenergy playing a big role. However, we are not there yet, as the majority of energy use still comes from gas. Many heavy industries are currently still difficult to electrify (COB, 2023). In the future, hydrogen could offer a solution for this.

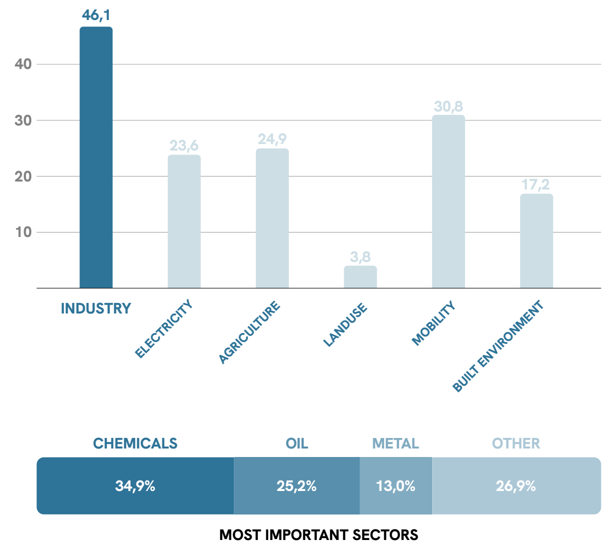


Figure 14: ***the most emitting sectors in The Netherlands in megaton***
source: CBS (2023)

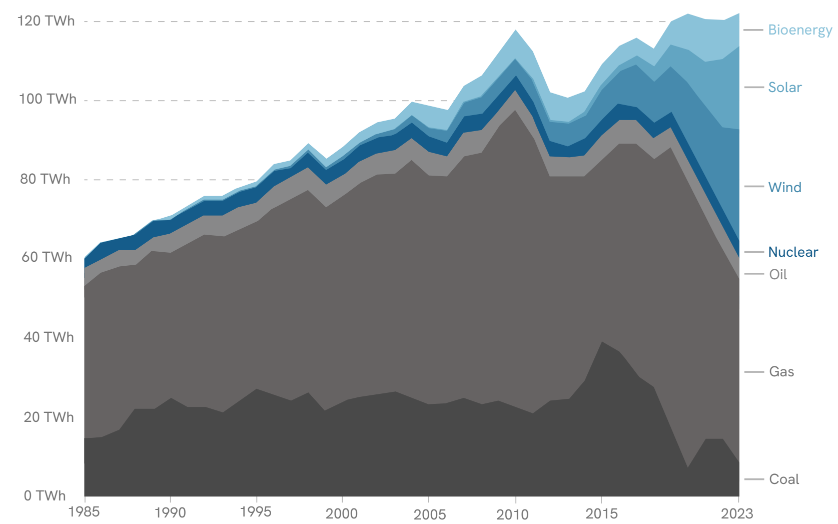


Figure 15: ***energy consumption sectors in The Netherlands***
source: Ritchie et al. (2022)

AMSTERDAM CLUSTER

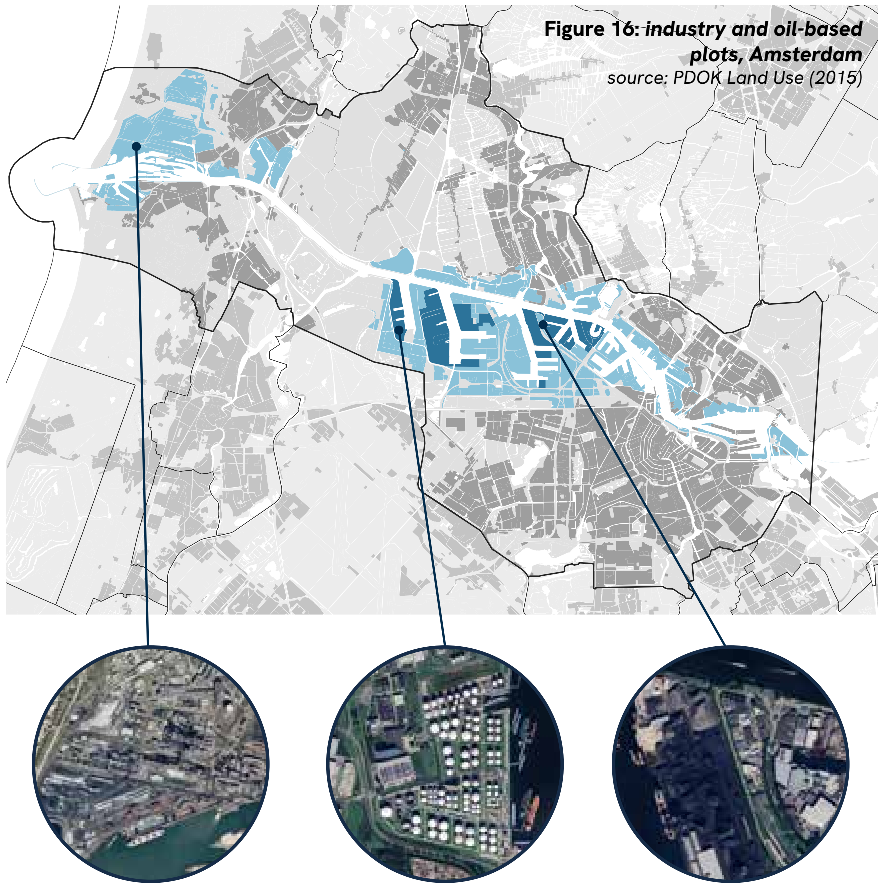


Figure 16: ***industry and oil-based plots, Amsterdam***
source: PDOK Land Use (2015)

ROTTERDAM CLUSTER

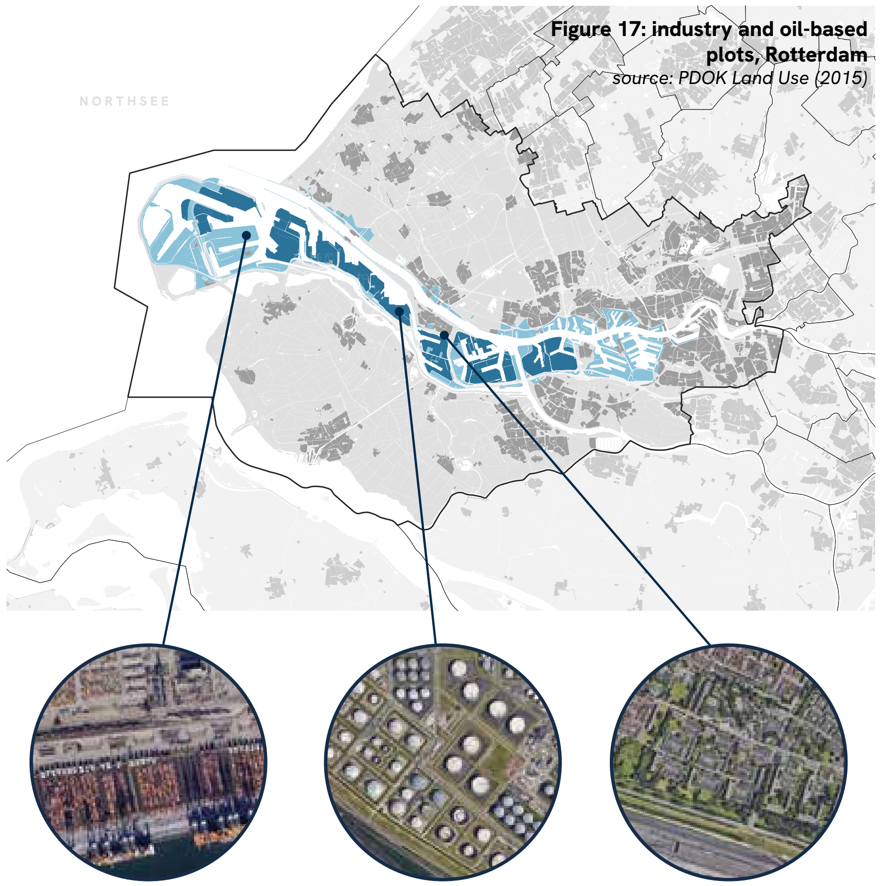


Figure 17: **industry and oil-based plots, Rotterdam**
source: PDOK Land Use (2015)

3.1.2 Oil-based land-use in clusters

A large share of CO_2 emissions comes from the chemical and oil sectors (CBS, 2023) Many of these companies are located within the focus clusters. In the future, a significant part of this space will become available, creating opportunities to redesign these areas.

However, the typologies and identities of each cluster differ considerably. It is therefore important to thoroughly understand and research these differences before making top-down decisions and determining which choices can be made from a bottom-up perspective. The maps on the side provide an overview of the typologies of all clusters. Later in this chapter, the focus will shift to a more in-depth look at the Rotterdam cluster.

N

buildings
harbour area
oil related industry
focus/cluster area

GRONINGEN CLUSTER

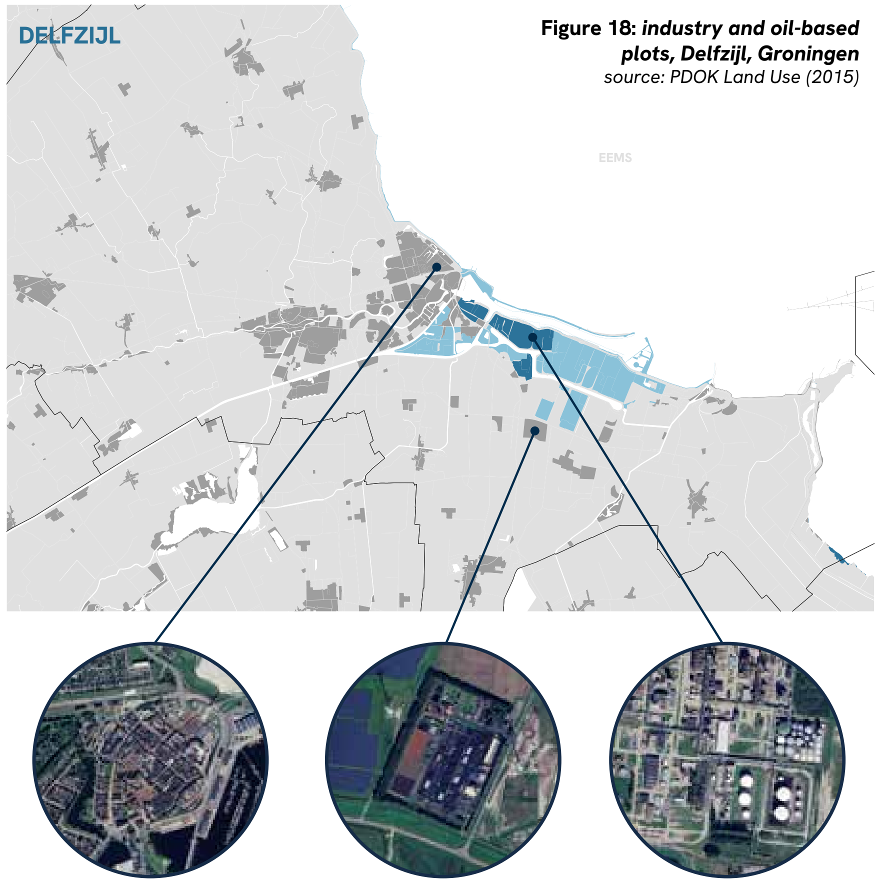


Figure 18: ***industry and oil-based plots, Delfzijl, Groningen***
source: PDOK Land Use (2015)

ZEELAND CLUSTER

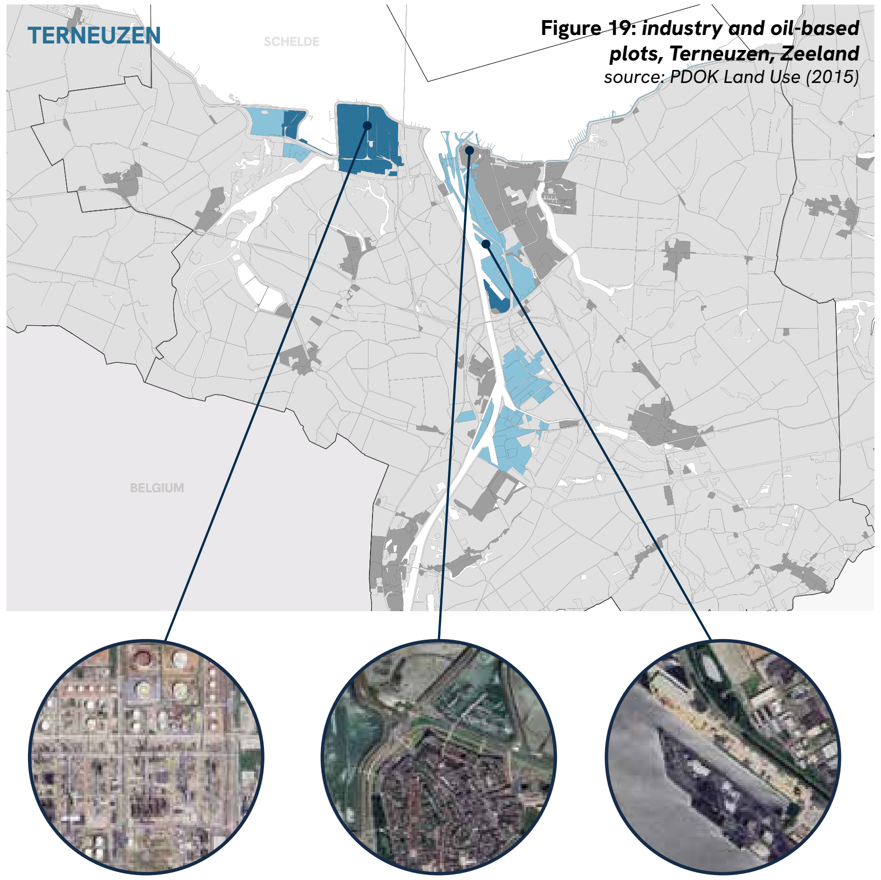


Figure 19: ***industry and oil-based plots, Terneuzen, Zeeland***
source: PDOK Land Use (2015)

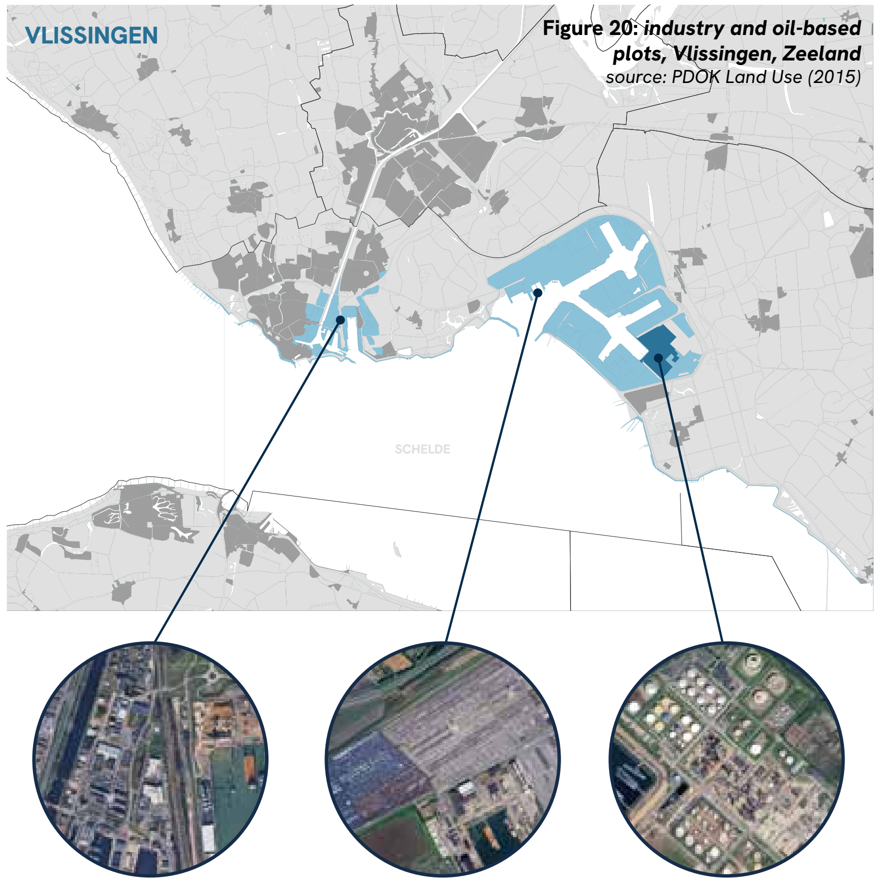


Figure 20: ***industry and oil-based plots, Vlissingen, Zeeland***
source: PDOK Land Use (2015)

3.2 SYSTEMIC ANALYSIS OF FOCUS CLUSTERS

WHAT DOES THE FLOW OF ENERGY LOOK LIKE?

3.2.1 Current flow of energy in the clusters

The current energy flows within industrial clusters around the world are predominantly reliant on fossil fuels such as coal, oil and natural gas. At each stage of the extraction, refining, utilization and consumption of these non-renewable resources, CO_2 is emitted into the atmosphere, contributing significantly to climate change (Calvin et al., 2023). Fossil fuels are not only used for energy production, but also serve as key inputs in various industrial processes, such as steelmaking, chemical refining and oil refining. These industries have historically followed a linear model of resource use, where raw materials are extracted, processed, consumed and discarded, often with little regard for sustainability or waste minimization.

In recent years, however, there has been a shift toward more energy-efficient systems, particularly through the adoption of cogeneration (combined heat and power, or CHP) systems. These systems, which generate both electricity and useful heat from the same energy source, have become more common in energy-intensive sectors. By making better use of the energy produced, cogeneration significantly improves efficiency compared to traditional power plants, which typically have large carbon footprints. Despite this, cogeneration alone does not achieve a substantial reduction in carbon emissions, as it still relies on fossil fuels as the primary energy source.

As industrial sectors increasingly adopt a symbiosis approach to improve resource efficiency, the overall environmental impact is mitigated to some extent, but it does not fully address the pressing need to reduce carbon footprints on a large scale (Chertow, 2000) Industrial symbiosis involves the exchange of by-products, waste and energy between different industries, creating a more circular system. However, the integration of such practices, while beneficial, cannot significantly reduce carbon emissions unless a fundamental change is made in the energy sources fueling these industries.

This brings us to the growing potential of renewable energy production methods, specifically solar and wind power. These technologies offer a cleaner, more sustainable alternative to fossil fuels for electricity generation. The feasibility of implementing renewable energy at a large scale within industrial clusters is made possible by the extensive infrastructure already in place such as electrical grids, pipelines and energy storage systems alongside the introduction of Carbon Capture and Storage (CCS) technologies. CCS allows for the capture and storage of CO_2 emissions from industrial processes, helping to reduce the carbon footprint of fossil fuel use. However, while CCS can be an important tool in mitigating emissions, it is not a complete solution and does not eliminate the underlying reliance on fossil fuels.

To truly achieve a significant reduction in the carbon footprint of heavy industrial processes, we need to consider a completely new alternative fuel source. Unlike electricity, which is highly inefficient for many heavy industries due to the high energy demand and specific temperature requirements, hydrogen can provide a cleaner and more effective energy carrier for industries like steel production, chemicals and heavy manufacturing (Bataille, 2020) Shifting to hydrogen as a primary fuel source would require an overhaul of existing infrastructure and significant investment in new technology, but it holds the promise of enabling the decarbonization of sectors that are currently difficult to electrify.

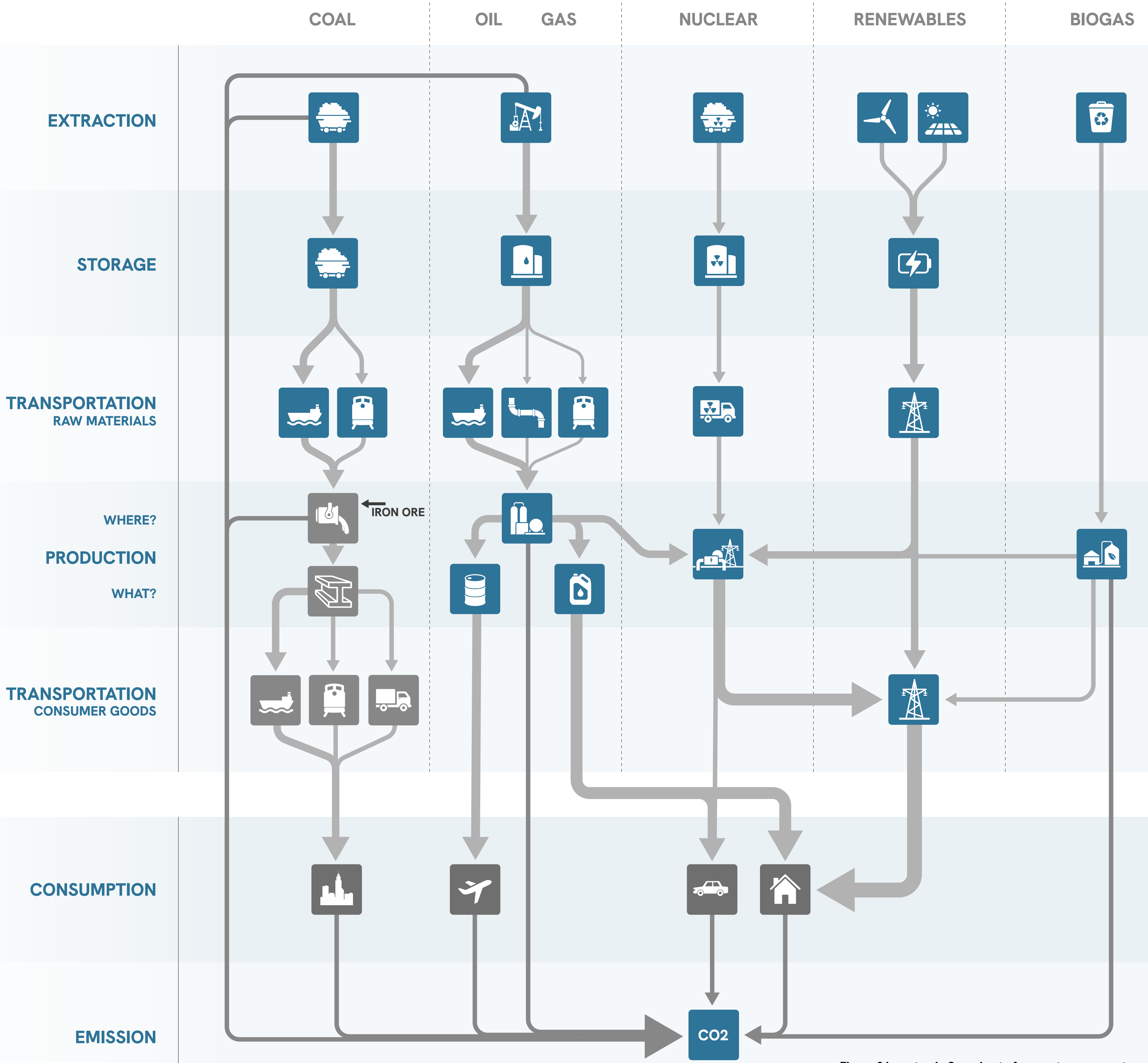


Figure 21: ***systemic flow chart of current energy system***
(arrows are indicative size but not to true scale)

3.2.2 Land footprint of the current flow

Currently, the ports of Rotterdam and Amsterdam, as well as the industrial areas in Zeeland and Groningen, mainly work with gas, oil and coal. The processing, storage and use of these energy sources produce a large amount of greenhouse gas emissions. However, compared to renewable sources, they require relatively little space. This is an advantage for industrial clusters located in densely populated areas where space is limited.

In the future, if there is a gradual shift toward renewable energy sources, greenhouse gas emissions will be significantly reduced. However, renewable sources generally require more space, especially wind energy. This means the transition to renewables will have a positive effect on the climate, but it will also create more pressure on land use and spatial planning.

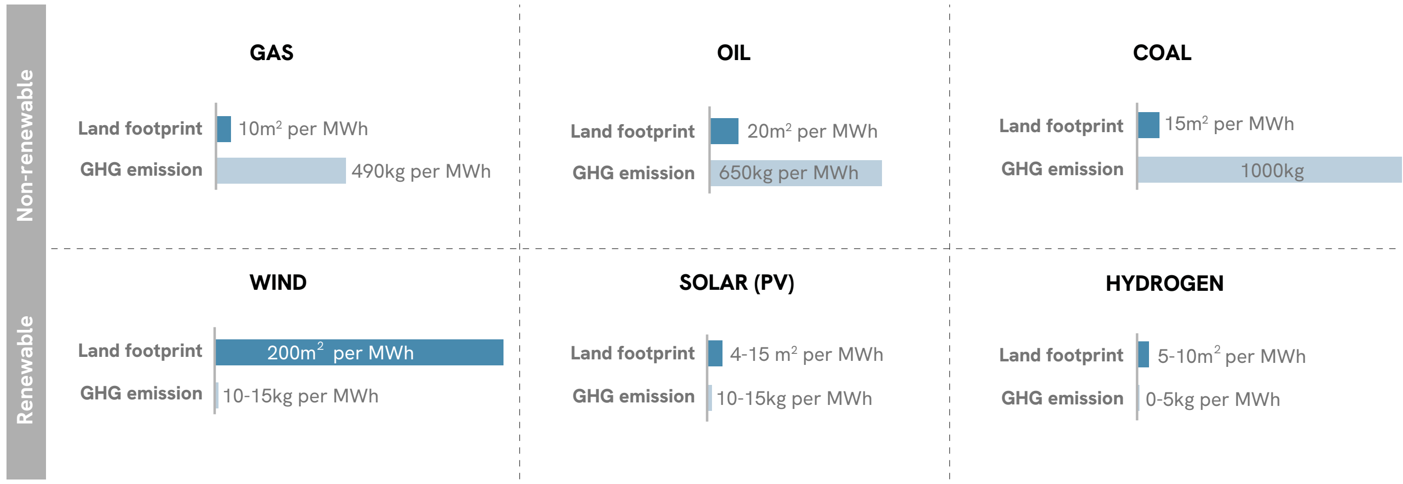


Figure 22: ***land footprints and greenhouse gas emissions of sectors***
source: Ritchie (2022)

3.2.3 Systemic section of the energy flow

The section below illustrates the current energy flows in and around a port area in the Netherlands. It presents a schematic representation of port clusters in the Netherlands.

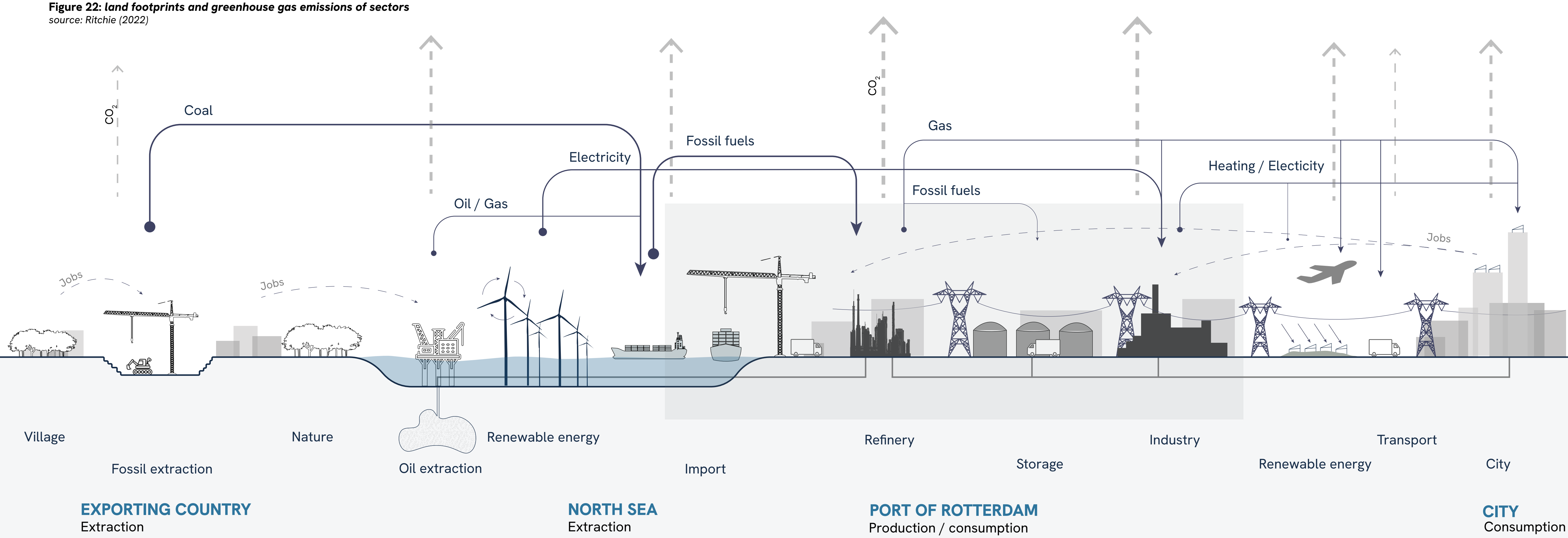
On the left side, it is shown that fossil materials are extracted from the ground in countries such as Poland, China, Australia, and Canada (Mohr et al., 2015). The Netherlands holds a strategically advantageous position due to its maritime connectivity, making it a key gateway for large-scale import and transit of energy and raw material flows, such as oil and petroleum products, into Europe (Weterings et al., 2013).

The diagram indicates that oil and gas enter the country through the port. Additionally, electricity is primarily generated offshore via wind turbines. Throughout 2024, 54% of all electricity generated in the Netherlands came from renewable sources (Oerlemans, 2025).

The port itself is represented by the grey area in the section. Fossil fuels enter through the “import” phase, are processed in the “refinery,” and subsequently stored in designated “storage” facilities. The industrial sector utilizes and processes these fossil resources, while the city makes use of residual industrial heat for heating and electricity.

The thick dashed arrows signify the degree of CO_2 emissions, highlighting the industrial sector as the principal polluter in comparison to urban areas (CBS, 2023). The thin dashed curved lines represent the employment impact, illustrating, for instance, how the port generates substantial employment opportunities for urban residents.

↓ **Figure 23:** ***systemic section of oil- & gas-based energy flows***



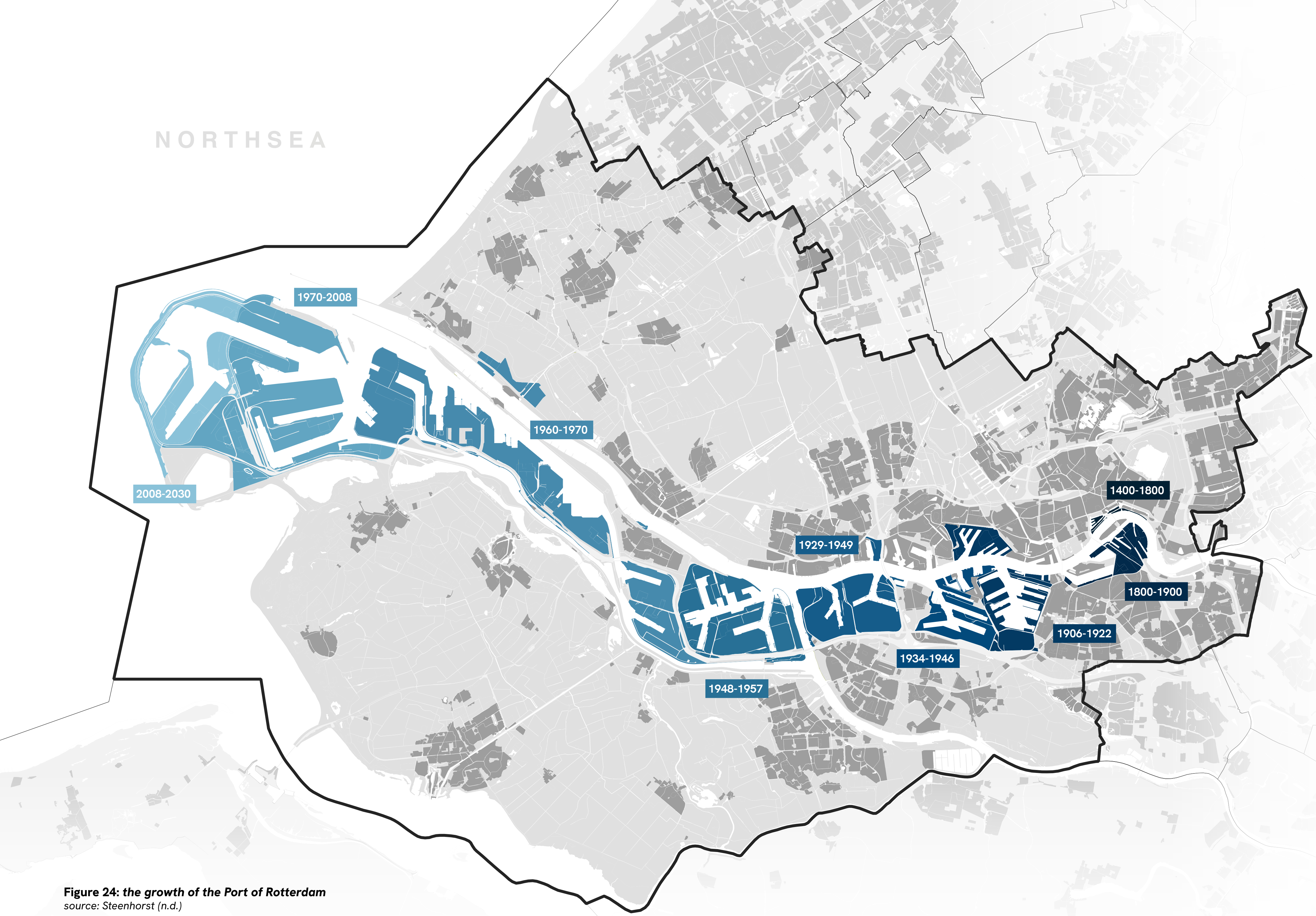


Figure 24: ***the growth of the Port of Rotterdam***
source: Steenhorst (n.d.)

LEGEND

- built-up area
- 2008-2030
- 1970-2008
- 1960-1970
- 1948-1957
- 1929-1949
- 1934-1946
- 1906-1922
- 1800-1900
- 1400-1800
- focus area

N

0 1 2 4 6km

Figure 25: ***start of the construction of the Europoort in 1958***
source: Port of Rotterdam (n.d.-c)

Figure 26: ***first container ship is unloaded in 1966***
source: Port of Rotterdam (n.d.-c)

Figure 27: ***start of the construction of the Maasvlakte in 1969***
source: Port of Rotterdam (n.d.-c)

3.3 FOCUS CLUSTER - ROTTERDAM

ABOUT HISTORY, TYPOLOGY AND EMPLOYMENT

This chapter zooms in on the Port of Rotterdam to provide a more detailed and nuanced understanding of one of the industrial clusters.

3.3.1 History of the largest port in Europe

The Port of Rotterdam originated around 1250, at a dam built in the mouth of the river Rotte (Canon van Nederland, n.d.). Although the port has existed for centuries, it was not until the nineteenth century that it began to develop into the most important harbour city of the Netherlands. From that moment on, the port was continuously expanded, primarily to benefit from the growing industrial activity in the German Ruhr area. Due to silting, access to the port from the sea had become increasingly difficult, so a new waterway was dug during this period: the Nieuwe Waterweg. New harbour basins were constructed and machines such as steam cranes were introduced to make loading and unloading more efficient.

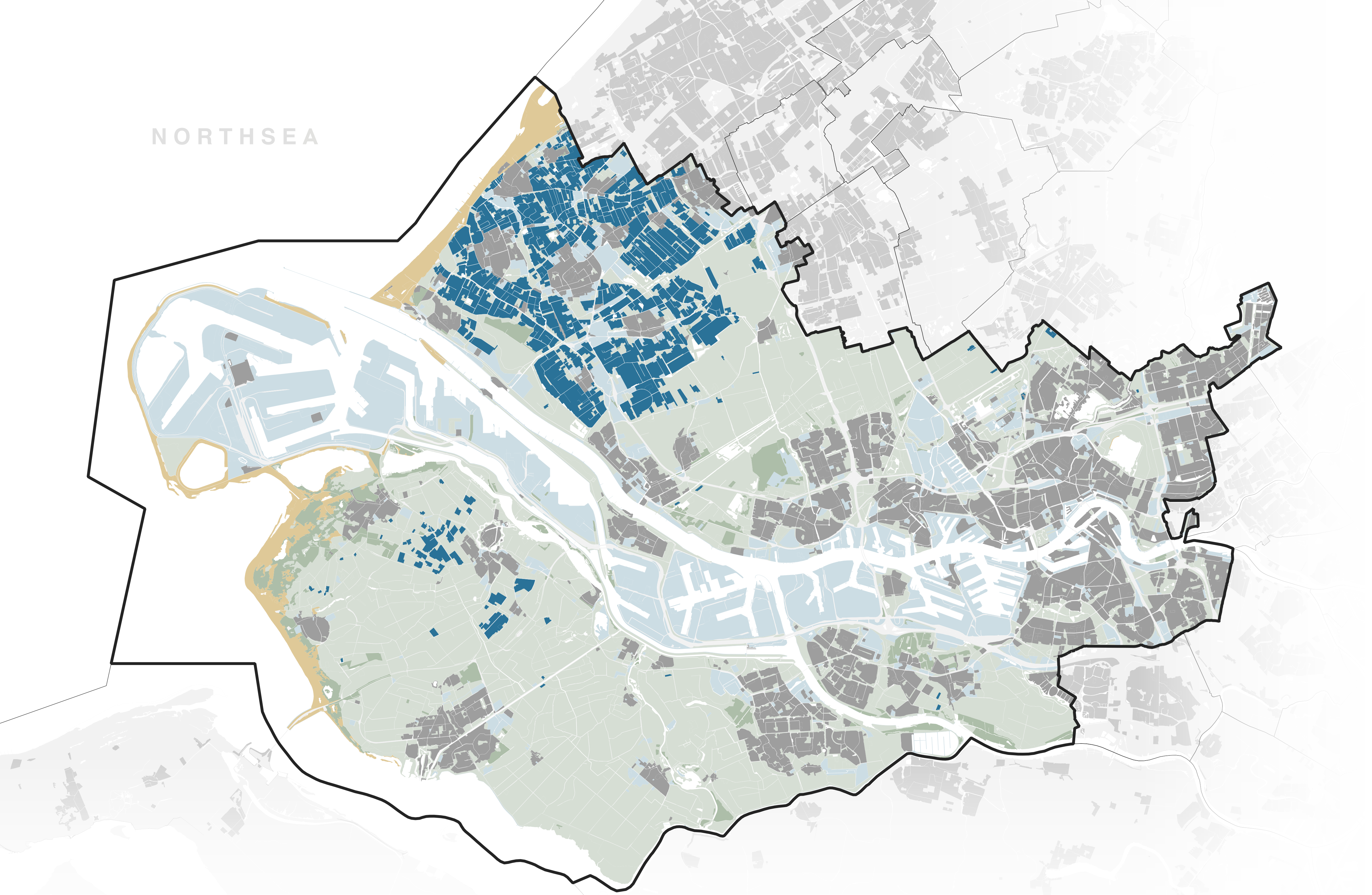
During the Second World War, nearly half of the port was damaged by bombings. However, during the post-war reconstruction, restoring the port of Rotterdam was a top priority. The port expanded rapidly and, by 1962, had become the largest port in the world. A few years later, Rotterdam was one of the first ports to adopt the use of sea containers, which enabled large-scale shipping and handling. Continuous growth led to the construction of both the First and Second Maasvlakte, reclaiming land from the sea to accommodate even more port activity.

As globalisation increased the volume of international trade, competition between ports intensified. Since 2004, Rotterdam has no longer been the largest port in the world. Still, the Dutch government considers it essential to maintain Rotterdam's competitiveness. As a 'mainport', it is a key node in global trade networks and plays a major role in the national economy (Port of Rotterdam, n.d.-b).

However, this unrestrained growth has also sparked concerns and opposition (Canon van Nederland, n.d.). People are increasingly worried about safety risks in the port and the environmental impact of the vast industrial area. The conversation is no longer just about economic benefits, but also about how to make the port future-proof; both ecologically and socially, for the surrounding communities and the natural landscape.

3.3 FOCUS CLUSTER - ROTTERDAM

ABOUT HISTORY, TYPOLOGY AND EMPLOYMENT



3.3.2 Spatial typology analysis

The Port of Rotterdam stretches over 40 kilometers from the city center all the way to the North Sea. With an annual cargo output of 466 million tons, it is the largest port in Europe (Port of Rotterdam, n.d.-d).

The area can be seen as a vast paved island in the landscape, separating the villages north and south of the Maas. For most people, large parts of the port are either inaccessible or irrelevant to their daily lives. Surrounding the port are several small villages, which, due to the massive expansion of the port in recent decades, have become almost entirely engulfed by industrial activity.

Rotterdam is the undisputed leader in the import of crude oil. As a result, the central part of the port area is almost completely focused on the oil industry (Port of Rotterdam, n.d.-d). The next two paragraphs take a closer look at the affected villages and the oil-based industry.

Figure 28: ***land-use of the Rotterdam cluster***
source: PDOK Land Cover

LEGEND

- built-up area
- agricultural land
- forest
- dunes
- industry
- oil-based industry
- greenhouse horticulture
- affected villages
- focus area

N

0 1 2 4 6km

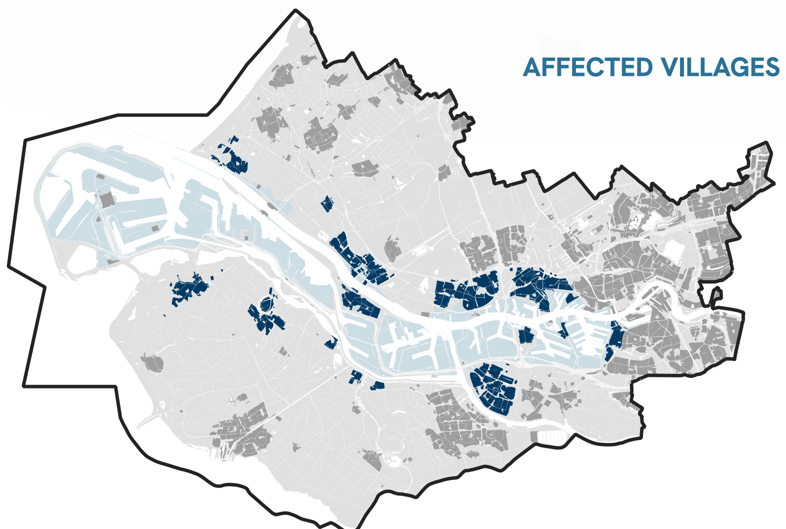


Figure 29: ***affected villages***
source: PDOK Land Cover

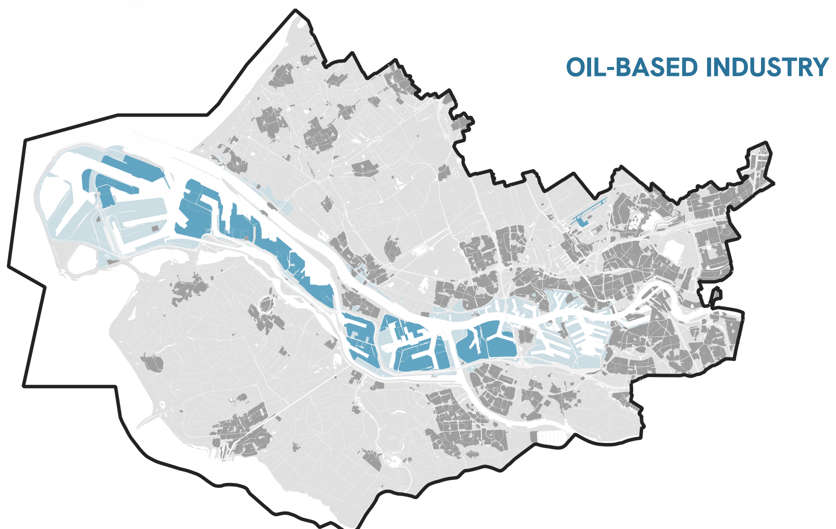


Figure 30: ***oil-based industry***
source: PDOK Land Cover

3.3 FOCUS CLUSTER - ROTTERDAM
ABOUT HISTORY, TYPOLOGY AND EMPLOYMENT

3.3.3 Affected villages around harbour

The port area is surrounded by a mix of both smaller and larger settlements. On the eastern side, the port borders the city centre, where several Rotterdam neighbourhoods as well as satellite cities like Vlaardingen and Schiedam are located. Thanks to their proximity, these areas are well-connected and easily accessible via Rotterdam's public transport network.

Moving further west, the port becomes increasingly surrounded by open polder landscapes and greenhouse clusters. The villages on this side can be described more as rural settlements within a more open and dispersed environment. Due to their greater distance from the urban core, these places tend to be less accessible by public transport.

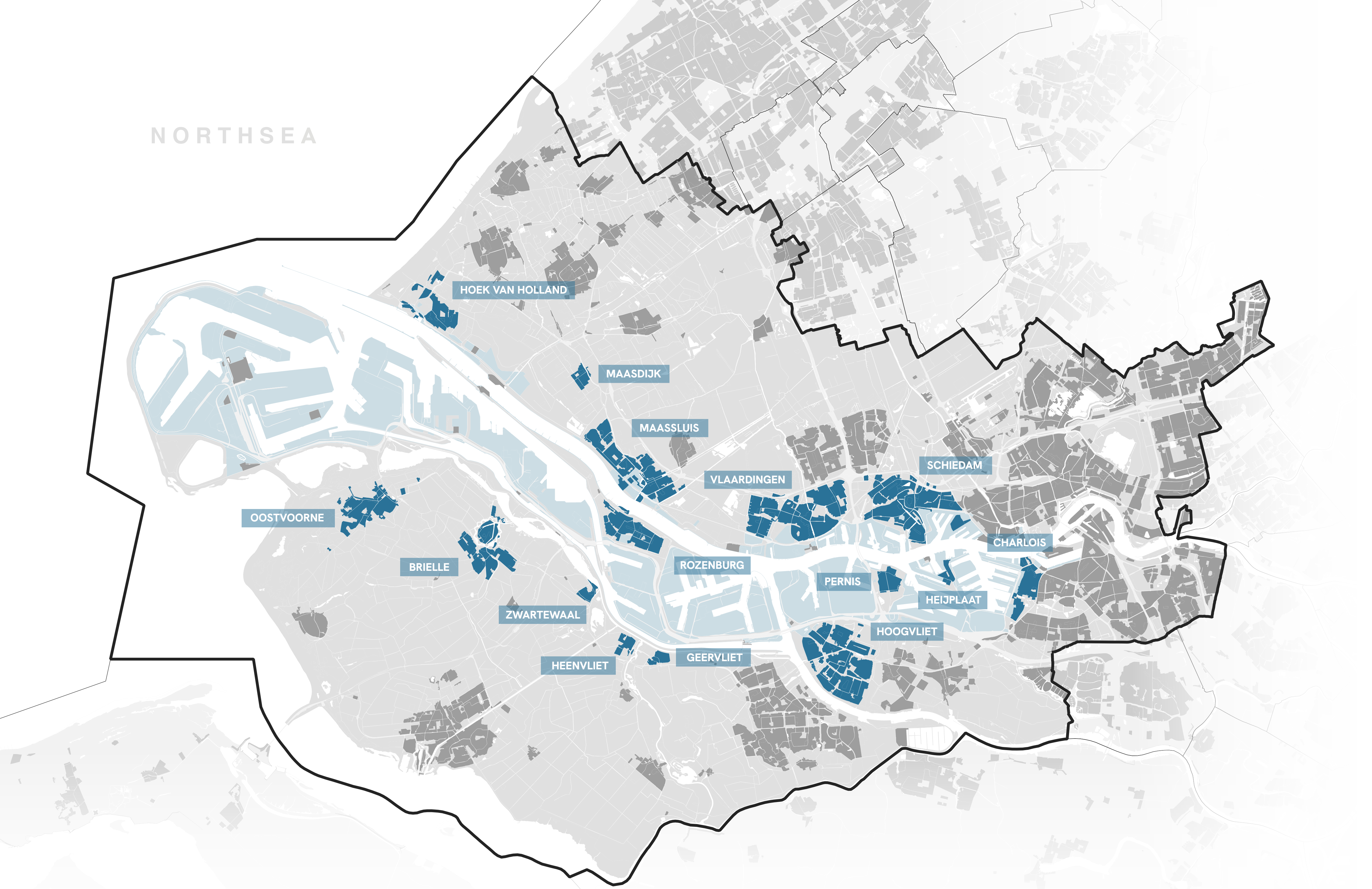


Figure 31: ***villages around the industrial harbour of Rotterdam***
source: PDOK Land Cover

LEGEND
- built-up area
- water
- industrial cluster Rotterdam
- affected villages
- focus area

N
0 1 2 4 6km

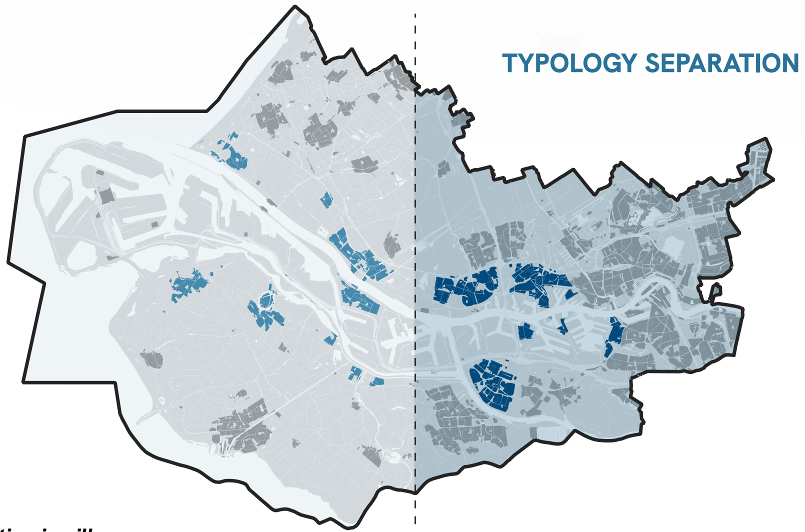


Figure 32: ***typology separation in villages***
source: PDOK Land Cover

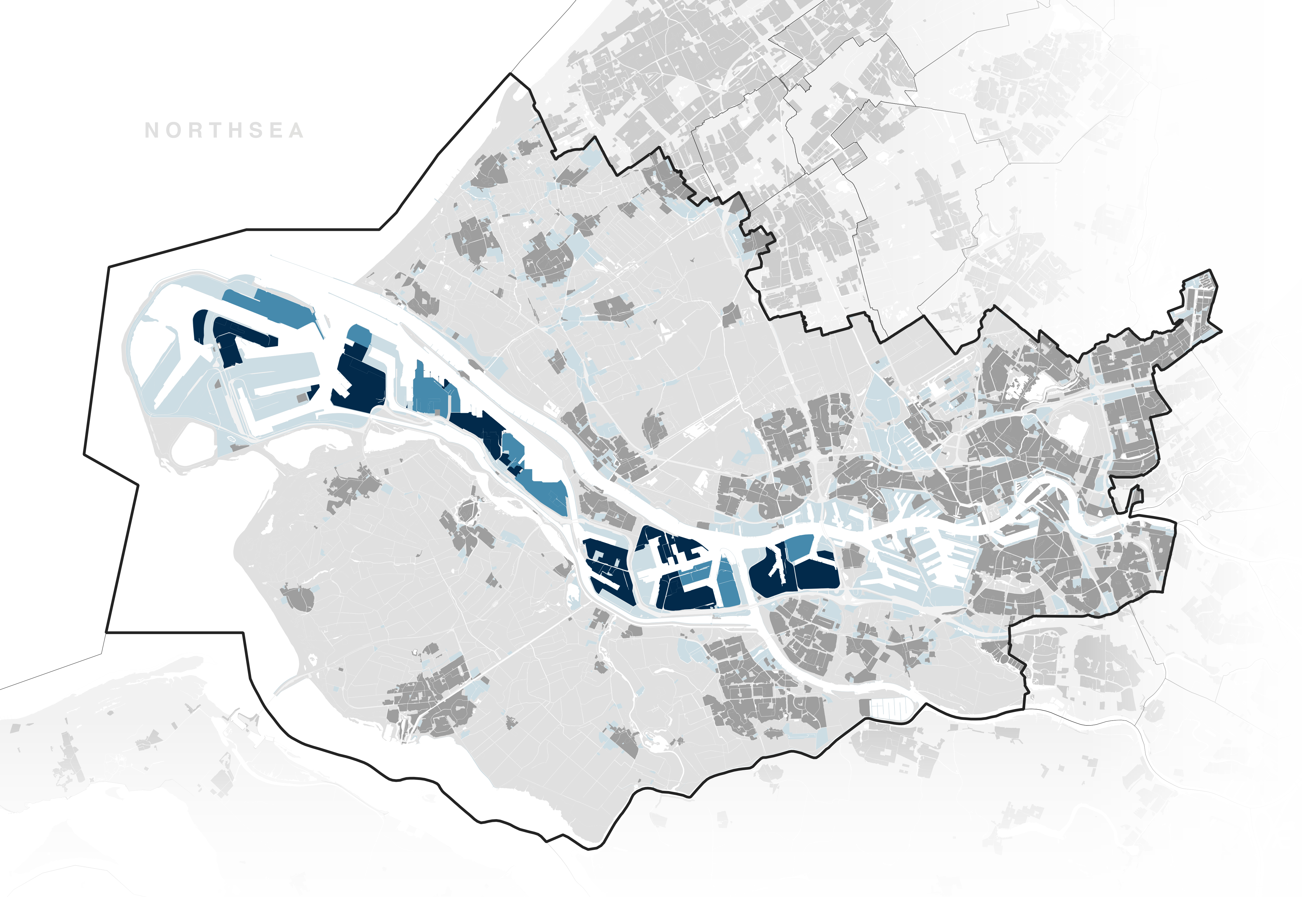


Figure 33: ***liquid storage and oil refineries in the Port of Rotterdam***
source: PDOK Land Cover

LEGEND

- industrial cluster
- built-up area
- liquid storage
- oil refineries
- focus area

N

0 1 2 4 6km

3.3 FOCUS CLUSTER - ROTTERDAM

ABOUT HISTORY, TYPOLOGY AND EMPLOYMENT

3.3.4 Oil-based industries

In the port area, many cargo-related companies are located on both the east and west sides of the Maasvlakte. The central part is mainly dedicated to the oil and chemical industries.

Thanks to its ideal location, large tank storage capacity and significant own production, the Port of Rotterdam is currently an attractive place for the trade and transfer of oil products (Port of Rotterdam, n.d.-a). Every year, oil tankers unload between 95 and 100 million tons of oil, mainly from the Middle East, at the oil terminals in the Europoort and on the Maasvlakte (Port of Rotterdam, n.d.-b). Here, the oil is properly blended, and a large part of it is pumped through various pipeline systems to refineries in the port area. The rest is transported to places like Vlissingen, Antwerp and Germany. This is possible due to the strong connections via pipelines, inland shipping and rail, which make further distribution across Europe efficient.

These tank terminals are the beating heart of oil trade in Rotterdam (Port of Rotterdam, n.d.-a). For example, several airports are directly connected to the fuel storage locations. In total, tank terminal operators in Rotterdam offer around 7.5 million cubic meters of storage capacity spread over more than twenty locations in the port.

To conclude, the oil industry is a crucial part of the Port of Rotterdam, not only in terms of space but also in terms of identity. The oil sector is strongly connected to many other industries across Europe. Transforming the port area and phasing out the oil-related businesses will therefore have a major impact on the entire economy. It is important to create a clear vision, both nationally and internationally, to ensure that this transition happens smoothly.

This transformation will also mean a loss of a large part of the port's identity. That is why it is essential to develop a bold and local vision for this industrial cluster, so that the port area can be reshaped and redefined in a more sustainable way.

3.3.5 Jobs in the harbour region

The Port of Rotterdam is an important part of the Dutch economy and provides many jobs, both directly and indirectly. Across the Netherlands, the port supports more than 500,000 jobs and generates over 60 billion euros in added value (Port of Rotterdam, n.d.-b).

In 2020, 88,018 employees were directly involved in port-related activities in Rotterdam. Of these, about 65% worked in the transport sector related to port activities, while 35% were employed in fixed locations within the port area.

Due to the energy transition and the shift toward hydrogen, there will be changes in employment within the transport sector. In the future, fewer oil-based products will be produced, and new companies may enter the port that manufacture different kinds of goods which may require different transport methods.

In addition, some jobs in fixed companies, such as in the chemical industry, will disappear, while new jobs will be created in cleaner, more sustainable sectors.

It is important to recognize that many people depend on their port-related jobs and income. During the transition to new energy sources, it is crucial to ensure that large groups of workers are not left unemployed for long periods. Retraining programs must also be carefully managed so that employees from outdated and polluting companies can find new jobs that suit them in future-proof sectors.

88,018 employees in de harbour of Rotterdam (2020)

57,418 employees in transport sector

30,600 employees work in fixed positions

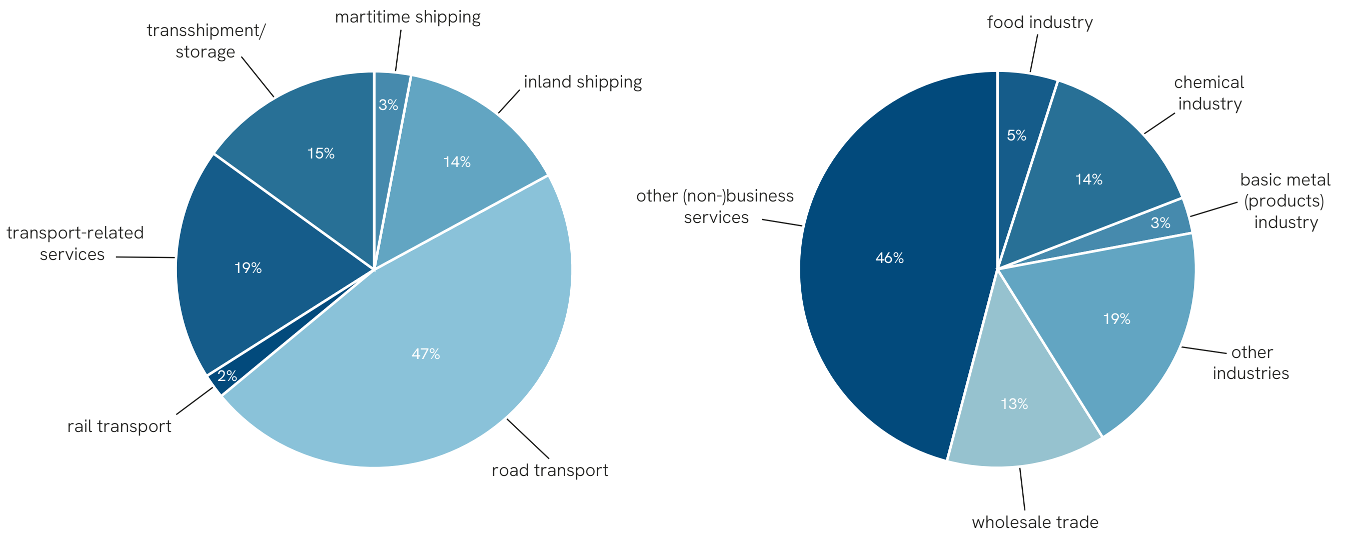


Figure 34: ***direct employment in the harbour of Rotterdam***
source: Streng et al. (2021)

H2

TOWARDS CLEAN ENERGY
A hundred years ago, Rotterdam changed the world with industry.
Now hydrogen changes the industry for the world.

4

WHAT THE HYDROGEN?

SOME TECHNICAL BACKGROUND
What is hydrogen used for, how is it made, what infrastructure is needed, what are the current plans and how will it help in the energy transition?

4.1 WHAT IS HYDROGEN?

THE RAINBOW OF ENERGY EXPLAINED

4.1.1 An introduction to H2

Hydrogen is increasingly recognized as a key element in the global energy transition, due to its high energy content and potential for zero carbon emissions. As the most basic element in the universe, hydrogen exists primarily in compound forms such as water (H_2O) (Glasstone, 2013).

Historically, hydrogen has played significant roles across different sectors, ranging from early aviation and ballooning to space exploration. Notably, NASA became the world's largest consumer of hydrogen by the early 1960s, utilizing it for propulsion in manned and unmanned spaceflight (NASA, 2021). However, public perception of hydrogen has often been overshadowed by safety concerns, particularly following high-profile incidents such as the Hindenburg disaster in 1937 (Dawood, Anda & Shafiullah, 2020). Modern safety assessments reveal that hydrogen is non-toxic and disperses rapidly, due to its low molecular weight. Although its low ignition temperature (approximately 400°C) makes it highly flammable (Dawood, Anda & Shafiullah, 2020), proper ventilation and leak detection systems significantly mitigate the associated risks, especially in confined environments.

In contemporary industrial systems, hydrogen is primarily utilized in ammonia production, petroleum refining, and chemical manufacturing (Rostrup-Nielsen, 2017). Its application is now expanding into hard to decarbonize sectors such as steelmaking, long-haul transport, and aviation areas where direct electrification remains technically and economically inefficient (Bataille, 2020). When used in fuel cells or combustion, hydrogen emits only water vapor, reinforcing its role as a clean energy carrier.

The environmental impact of hydrogen largely depends on its production pathway. Conventional methods of producing with fossil fuel are carbon-intensive unless coupled with carbon capture and storage (CCS) technologies, while producing using renewable energy sources results in near-zero emissions. The variability in lifecycle emissions underscores the importance of investing in low-carbon hydrogen production technologies.

Despite its promise, hydrogen adoption faces structural barriers. These include high production costs, limited infrastructure for distribution and storage, and underdeveloped regulatory frameworks. However, increasing political will and investment especially within European and global decarbonization agendas are accelerating research, infrastructure development, and market integration. In the context of industrial decarbonization, hydrogen is increasingly regarded not only as a technological solution but as a systemic enabler of climate neutrality (Green Hydrogen, 2023)

4.1.2 What is the rainbow of H2?

As hydrogen re-emerges as a key element in the global energy transition, significant attention needs to be placed on the environmental impact of its production methods. While molecular hydrogen itself is a clean energy carrier, the processes involved in its extraction vary widely in terms of carbon emissions. To differentiate the various production methods, a color-based classification system often referred to as the "hydrogen rainbow" has been adopted to distinguish between these methods based on their feedstocks and associated greenhouse gas outputs (Arcos & Santos, 2023)

Black Hydrogen
Black hydrogen is produced through the gasification of coal or lignite, making it one of the most carbon-intensive methods of hydrogen production. This process involves converting solid fossil fuels into hydrogen and other gases under high temperatures.

Grey Hydrogen
Grey hydrogen is the most commonly produced form of hydrogen today, derived via steam methane reforming (SMR) using natural gas. This method emits significant amounts of CO_2 into the atmosphere. While cost-effective, grey hydrogen lacks compatibility with climate goals.

Blue Hydrogen
Blue hydrogen also utilizes SMR, but incorporates carbon capture and storage (CCS) to reduce its greenhouse gas emissions. The overall sustainability of blue hydrogen depends heavily on the efficiency of the CCS system. It is often positioned as a transitional solution in the shift toward cleaner energy systems.

Turquoise Hydrogen
Turquoise hydrogen is produced through methane pyrolysis, a process that thermally decomposes methane into hydrogen gas and solid carbon. If powered by renewable energy, this method can offer a lower-emission alternative without producing CO_2 as a direct byproduct.

Green Hydrogen
Green hydrogen is generated via electrolysis powered by renewable energy sources such as wind, solar, or hydropower. This process splits water into hydrogen and oxygen, emitting no greenhouse gases. As the only truly zero-carbon form of hydrogen, green hydrogen is central to climate-neutral strategies, particularly in hard-to-abate sectors like steelmaking and heavy transport.

Pink Hydrogen
Pink hydrogen is produced via electrolysis powered by nuclear energy. While this method avoids CO_2 emissions, its sustainability is subject to debates around nuclear energy's lifecycle.

White Hydrogen
White hydrogen refers to naturally occurring geological hydrogen found in subterranean deposits. white hydrogen is currently at the exploratory stage, with limited commercial viability.

This classification system underscores the need for transparency and precision when discussing hydrogen strategies within the broader decarbonization agenda. As nations and industries formulate roadmaps for hydrogen integration, the environmental integrity of hydrogen must be evaluated not solely by its end use, but by its entire production lifecycle. Understanding the "rainbow" enables stakeholders to make informed decisions that align with both climate goals and regional energy contexts.

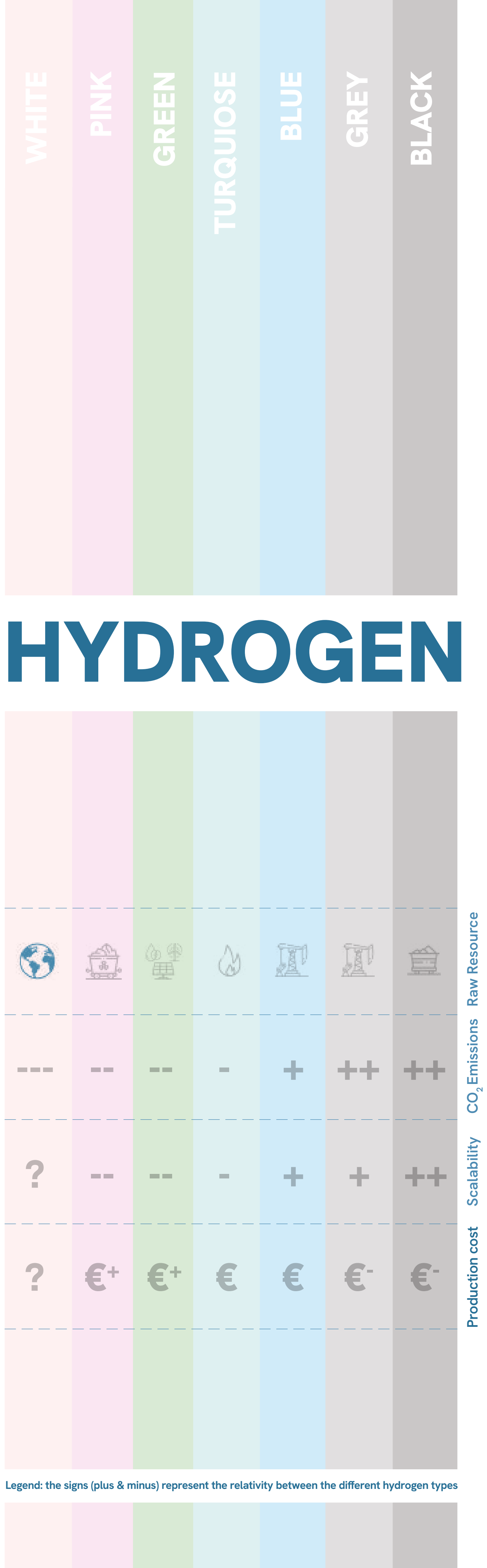


Figure 35: ***types of hydrogen***

4.1.3 Where is H2 utilized now?

Transportation

Hydrogen can be transported through retrofitted pipeline infrastructure. Many existing natural gas networks are technically capable of being adapted for hydrogen transport, either through dedicated pipelines or by gas blends. Blending hydrogen into existing gas grids allows for incremental adoption while minimizing upfront capital costs.

In addition to pipelines, hydrogen can be transported via compressed gas tankers over land and liquefied hydrogen carriers over longer distances, such as across seas. Compressed hydrogen is typically stored at high pressures (up to 700 bar) in specialized tanks, suitable for short to medium-range distribution. For international or intercontinental trade, liquefaction involving cooling hydrogen to -253°C is a more space efficient but energy intensive method, enabling bulk transport via cryogenic tankers (Demaco, 2022).

Further alternatives include chemical carriers, such as ammonia or liquid organic hydrogen carriers. These carriers can be transported using conventional fuel logistics and later decomposed to release hydrogen at the point of use, although this introduces conversion losses and increases the system's overall complexity.

The adaptability in the ways hydrogen can be integrated into existing energy and industrial systems reflects not only its commercial viability but also its potential to support a socially just transition. By leveraging existing infrastructure and enabling sectoral coupling, hydrogen facilitates a gradual yet transformative shift towards cleaner energy.

Multi-functionality

Green hydrogen exhibits a high degree of multi-functionality, making it a cornerstone for the decarbonization of a broad range of sectors. Due to its ability to be stored and transported in various forms including as a gas, liquid, or even converted into carriers such as ammonia it can be flexibly integrated across different scales and applications.

In heavy industries such as steel and chemical production, hydrogen can serve as a clean feedstock, replacing fossil-based inputs. In heavy mobility sectors such as freight transport, aviation, and maritime shipping it functions as a low emission fuel alternative, offering a viable solution where electrification is inefficient or impractical.

Furthermore, when produced through electrolysis powered by renewable energy, green hydrogen significantly reduces lifecycle carbon emissions, reinforcing its role in achieving long term climate targets. Its capacity to adapt to multiple energy and industrial systems simultaneously enhances systemic resilience and accelerates the energy transition in a holistic manner.

Low-carbon strategy

Green hydrogen offers a fully zero-emission solution as its production relies solely on renewable electricity and water through the process of electrolysis, making it a vital component in achieving global decarbonization targets. By utilizing renewable energy sources like wind or solar for electrolysis, green hydrogen can serve as an ideal energy carrier with minimal environmental impact. Furthermore, hydrogen's versatility extends to its role as a substitute for various synthetic fuels, such as ammonia or synthetic natural gas, which can be produced using hydrogen as a feedstock. This capability reduces reliance on traditional carbon-intensive fuels. (Bockris, 2002)

Figure 36: ***overview of the H2-system***

Energy storage

Green hydrogen offers a strategic solution for long-duration energy storage, effectively addressing the intermittent nature of renewable energy sources such as solar and wind. When excess renewable electricity is available, it can be used to power electrolysis, a process that splits water into hydrogen and oxygen.

The hydrogen produced can then be stored in various forms compressed gas, cryogenic liquid, or as hydrogen carriers like ammonia depending on the storage scale and temporal demand.

Additionally, large scale underground storage in salt caverns and depleted gas fields presents a viable option for seasonal or high-volume hydrogen storage, enhancing the flexibility and resilience of energy systems. Although energy is lost during conversion and reconversion, the value of hydrogen lies in its ability to decouple energy production from consumption.

When solar or wind generation is low and energy demand peaks, stored hydrogen can be utilized as a fuel in power plants to generate electricity and stabilize the grid. Importantly, the byproduct oxygen from electrolysis also plays a role in the hydrogen cycle: it is later used in fuel cells, where hydrogen recombines with oxygen to generate electricity and water completing a closed loop, circular energy system (Breeze, 2018). This cyclical capability reinforces hydrogen's role in ensuring energy reliability, grid flexibility, and seasonal storage in a decarbonized energy future.

Power capacity

The storage of hydrogen presents challenges due to its physical properties under ambient conditions. The volumetric energy density of hydrogen in its gaseous state, after electrolysis, is only 0.09 kg/m^3 at atmospheric pressure, requiring enormous storage tanks to accommodate large quantities of hydrogen.

However, hydrogen can also be stored as a liquid. When kept at temperatures below its boiling point of -252.9 °C and under a pressure between 350 – 700 bar, the volumetric energy density increases significantly to approximately 71.48 kg/m^3. This is nearly 800 times higher than in its gaseous form, drastically reducing the space needed for storage.

Such high-density storage methods allow for more efficient energy storage, enabling easier integration into existing energy systems and reducing storage infrastructure requirements (Demaco, 2021). This makes liquid hydrogen a promising option for large scale energy storage and transport.

4.1.4 Which sectors can use green H2?

Green hydrogen, due to its capacity as a zero-emission energy carrier, plays a crucial role in the decarbonization of hard to abate sectors. Its versatility and adaptability allow integration across a spectrum of end-use applications, each contributing differently to the broader sustainability transition. Prioritizing sectors based on impact and feasibility, the following overview outlines the key sectors where green hydrogen can make a systemic change.

Heavy industry
Among the most critical applications is the decarbonization of energy-intensive industries, particularly steel, cement, and chemical production. These sectors currently rely heavily on fossil-based fuels not only for energy but also as feedstock. Green hydrogen offers a direct replacement, particularly in steelmaking via hydrogen-based direct reduction processes. Its use reduces CO_2 emissions significantly, supporting climate targets while maintaining industrial productivity.

Heavy mobility
The transport sector, particularly heavy duty freight, shipping, and aviation, faces limitations in adopting battery electric solutions due to range, weight, and refueling constraints.

Here, hydrogen fuel cells provide a high energy density alternative, enabling longer operation cycles and faster refueling times. Green hydrogen's role is especially promising in long-haul trucking and maritime transport, where electrification is less practical.

Built environment heating
While electrification remains the dominant strategy for decarbonizing heating in buildings, hydrogen presents an alternative in specific contexts, such as retrofitting existing gas infrastructure in densely built environments.

Blending hydrogen into natural gas grids or utilizing 100% hydrogen networks can support a gradual shift toward cleaner residential and commercial heating.

Power-to-X (P2X) solutions
Green hydrogen also enables Power-to-X technologies, where renewable electricity is converted into hydrogen and subsequently transformed into synthetic fuels (e-fuels), ammonia, or methanol. These products can serve as energy vectors, industrial inputs, or export commodities, offering flexibility in managing renewable energy overproduction and contributing to global decarbonization pathways.

The sustainable implementation of green hydrogen across sectors not only advances environmental goals but also delivers wide-ranging socio-economic and spatial benefits.

Firstly, by integrating hydrogen into existing and emerging infrastructures, regions undergoing industrial transition can experience equitable spatial transformation, ensuring that communities are not displaced but instead repositioned as active agents within the energy shift.

Secondly, green hydrogen strengthens the reliability and resilience of the energy grid. By serving as a flexible, long-duration storage medium and backup power source, it buffers the intermittency of renewables and supports grid stability during peak demand.

Thirdly, at scale, green hydrogen production presents a pathway to affordability. While initial costs are high due to electrolyser deployment and renewable input dependency, economies of scale, technological advancements, and policy incentives are expected to drive down production costs.

Furthermore, the development of a hydrogen economy contributes to the creation of quality employment, particularly for workers transitioning from traditional energy sectors. Jobs in electrolyser manufacturing, pipeline retrofitting, storage system management, and fuel cell innovation offer opportunities for reskilling and long-term economic inclusion. As innovation accelerates and global investment continues to rise, green hydrogen is projected to become increasingly cost-competitive, positioning it as a viable cornerstone in the global clean energy landscape (Bockris, 2002).

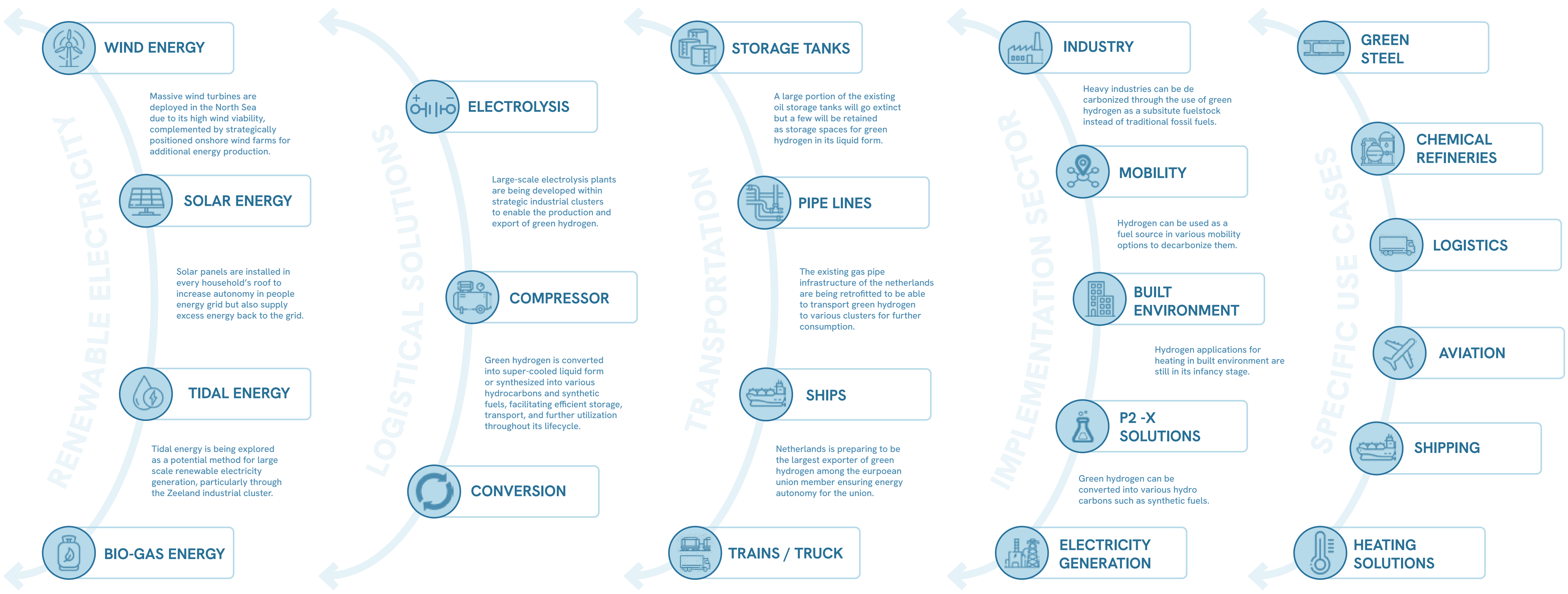


Figure 37: ***hydrogen: from renewable energy to consumers***

4.2 WHAT CHANGES WITH GREEN HYDROGEN?

DOES H2 SOLVE EVERYTHING?

4.2.1 How does H2 change the energy flow in Rotterdam?

As the world shifts away from oil, gas, coal, and biogas, a new energy system is emerging. This transition not only eliminates CO_2 emissions but also reshapes how energy flows across sectors and industries.

At the heart of this transformation is hydrogen, especially green hydrogen, produced using renewable electricity. Unlike fossil fuels, hydrogen produces only water vapor when used. This makes it a key player in decarbonizing hard-to-electrify sectors such as heavy industry and aviation. Besides that it also could be used as a fuel in vehicles or for heating. For the production of green steel, hydrogen replaces carbon in removing oxygen from iron ore.

The production of hydrogen can be done more locally on smaller scales. The energy flow will therefore increasingly move from centralized to decentralized. Nuclear and renewables will provide stable and abundant electricity. Some of this electricity will go directly to power homes, transport, and factories. The rest will be used to produce green hydrogen through electrolysis.

By removing fossil fuels from the system, CO_2 emissions will be effectively eliminated (IEA, 2021).

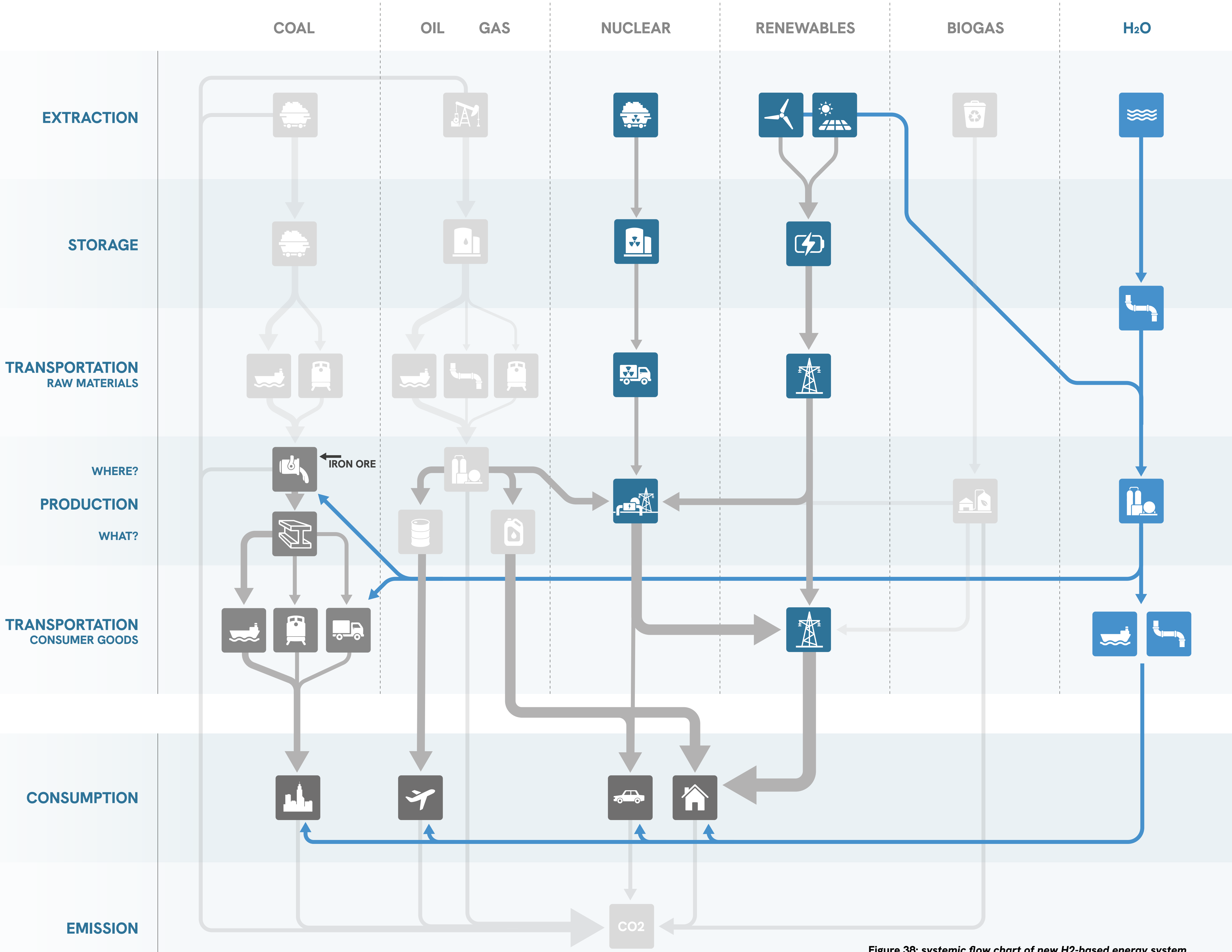


***Figure 38:** systemic flow chart of new H2-based energy system*
(arrows are indicative size but not to true scale)

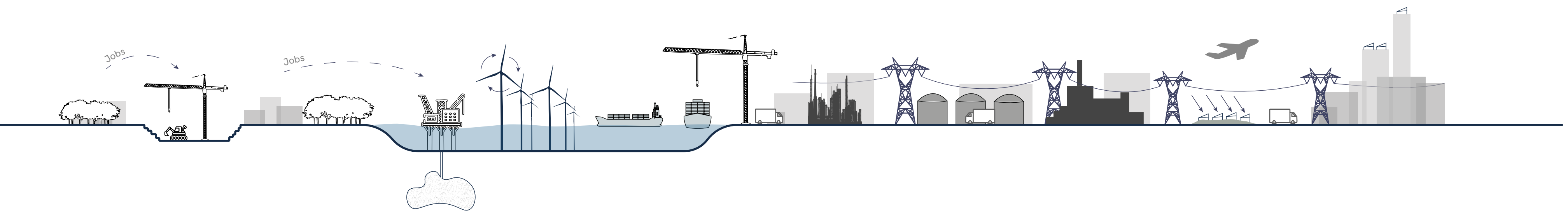
4.2.2 What are the largest differences in the energy flow?

As outlined in Chapter 3.2.3, the current energy flow is primarily centred around oil and gas, supplemented by renewable energy sources. In a scenario where hydrogen becomes the central energy carrier, this flow is expected to change significantly (Bergqvist et al., 2019). Several key transformations are anticipated:

Countries from which the Netherlands currently imports fossil-based products may, following the hydrogen transition, become importers of hydrogen produced in the Netherlands. In this shift, the Netherlands would evolve from an energy-importing to an energy-exporting country. Offshore wind farms are expected to be expanded substantially in order to generate sufficient renewable electricity to power industrial processes in the port area. Electrolysers will extract water from the North Sea to produce hydrogen via electrolysis. Existing oil storage infrastructure will be repurposed for hydrogen storage. This transition requires the use of more robust materials, stricter safety standards, and operational modifications (Emmel et al., 2023), implying that storage tanks must be either replaced or thoroughly retrofitted.

The industrial sector will need to adopt hydrogen as a new energy vector in its production processes. Waste heat from industrial activity can continue to be used for residential heating purposes.

The most significant impact of this transition will be seen in emissions: from predominantly CO_2 to primarily H_2O. Although CO_2 emissions will not be eliminated entirely, given that some processes will still involve combustion of alternative materials, a substantial reduction is expected. Furthermore, the transition will also affect the local community surrounding the industrial area. Improvements in air and water quality are expected, which will benefit public health (de Ruiter et al., 2018). The shift to hydrogen may also create opportunities for new industries to establish themselves in and around the port, potentially leading to increased employment.



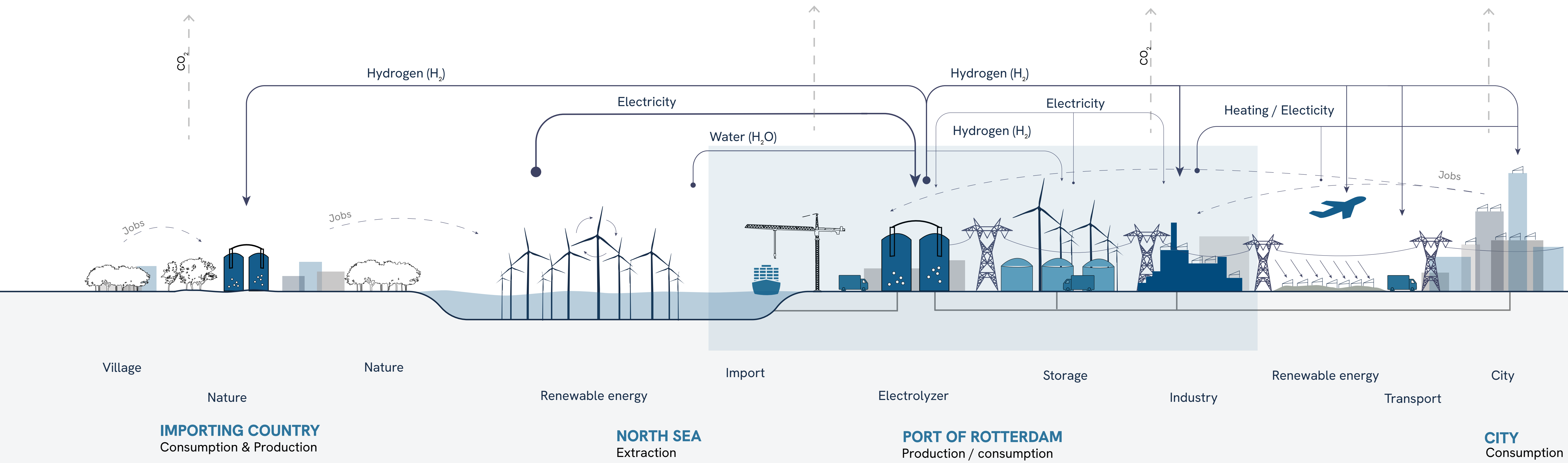


Figure 39: ***systemic section showing flow of energy in a hydrogen economy***

4.3 FACING THE REALITY

CURRENT PROJECTS IN EUROPE

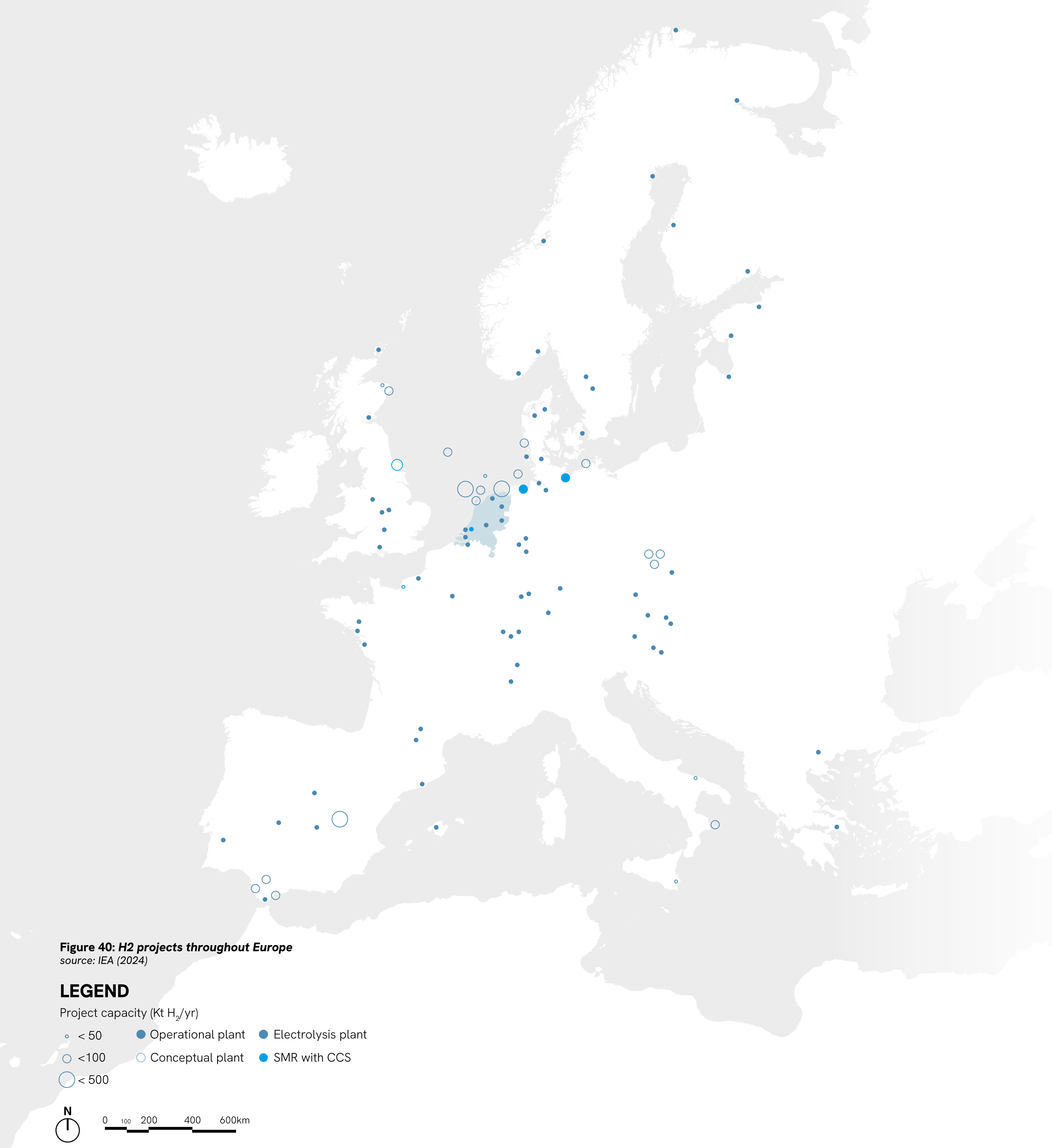


Figure 40: *H2 projects throughout Europe*
source: IEA (2024)

4.3.1 What is happening right now with green H2?

Green hydrogen production in Europe has entered a phase of rapid acceleration, driven by ambitious climate targets outlined in agreements (Paris Climate Accords and the Dutch Klimaat Akkoord), alongside robust policy frameworks (European Green Deal, the Fit for 55 package). As of 2025, Europe accounts for approximately 25% of all announced low-emission hydrogen projects globally, according to the International Energy Agency's Hydrogen Production Projects Database (IEA, 2025).

This substantial share underscores Europe's leadership in establishing a green hydrogen economy, with the Netherlands positioned as a central actor poised to play a crucial role in the global hydrogen transition.

A defining feature of Europe's current hydrogen landscape is the diversity of its projects, which range from small-scale operational pilot plants to concept-stage gigawatt-scale industrial hubs. These initiatives are heavily concentrated in industrial regions such as the Netherlands, Germany, and Spain, but are also emerging in newer geographies, reflecting a collective continental ambition to decentralize and democratize energy systems.

In Spain, the Puertollano plant, operated by Iberdrola, stands as the largest facility in Europe dedicated to producing green hydrogen for industrial use. It integrates a 100-megawatt solar photovoltaic plant with a 20-megawatt electrolysis system and a lithium-ion battery storage system with a capacity of 20 MWh. The operation of this facility is expected to prevent the emission of approximately 48,000 tonnes of CO_2 annually (CSR Europe, 2025).

In the Netherlands, the NorthH2 project, a collaboration between Shell, Gasunie, and Groningen Seaports, aims to develop a comprehensive green hydrogen infrastructure powered by a dedicated offshore wind farm. The project envisions the deployment of large-scale electrolysis capacity to produce hydrogen, which will be distributed using repurposed natural gas infrastructure, showcasing the adaptive reuse of existing assets (Parnell, 2020).

Meanwhile, in Belgium, the HYPORT Oostende initiative focuses on installing electrolysis capacity near the Port of Oostende to harness surplus offshore wind energy for hydrogen production. The hydrogen generated through this project will serve multiple sectors, including electricity, transport, and industry. The pilot electrolysis plant was targeted for completion by 2022, with the full-scale facility expected to be operational by 2025 (HYPORT, 2020).

4.3.2 Which stakeholders are involved?

Ensuring that the energy transition is executed in a just and equitable manner requires the careful identification and analysis of stakeholders. One of the most critical tasks in strategic planning is the management of the interface between numerous and often competing stakeholders in relation to the strategic goals of a given project or plan (Ackermann & Eden, 2011). In the context of the energy transition, particularly concerning green hydrogen as a means of future-proofing economies and societies, thus the complexity of stakeholders is mapped through a sectoral lens.

Governmental stakeholders play a foundational role in enabling and directing the hydrogen transition. These actors operate across multiple levels: from European institutions that define overarching climate and energy frameworks, to national governments responsible for implementing regulatory mechanisms and financial incentives, to provincial administrations and municipal authorities. Notably, entities such as the Port of Rotterdam, which have their own long-term sustainability visions, are actively shaping regional hydrogen strategies and infrastructure.

The primary sector of the hydrogen transition consists of actors directly involved in hydrogen production. Within this category, a clear distinction emerges. First, there are the hydrogen pioneers organizations engaged in research and development, continuously innovating and publishing findings on new hydrogen technologies. Second, there are industrial stakeholders capable of transitioning from fossil fuels to large scale green hydrogen production, thereby achieving economic viability. Third, infrastructure oriented companies are actively transforming existing systems and establishing the necessary hydrogen supply chains to support the growing demand.

The secondary sector comprises stakeholders involved in renewable electricity generation, which is indispensable for green hydrogen production. Both onshore and offshore renewable energy companies play a pivotal role in supplying the vast amounts of electricity required for electrolysis. However, production alone is insufficient; the electricity must also be reliably transported to hydrogen clusters. This underscores the importance of grid operators, who are tasked with strengthening and upgrading national electricity grids to prevent overloads and ensure consistent energy flow to hydrogen facilities.

The demand side of green hydrogen is equally critical to its economic viability. Emerging consumer sectors are increasingly adopting hydrogen based technologies for low carbon or carbon-free production processes. The steel industry is at the forefront, exploring the use of hydrogen in direct iron reduction. Similarly, chemical refineries, many of which currently use grey hydrogen, are positioned to transition to green hydrogen, using it as a feedstock or fuel substitute. The mobility sector also presents opportunities, including the use of hydrogen in public transportation, such as regional trains, and in heavy duty vehicles developed by companies like Hyzon. Furthermore, hydrogen holds potential in the aviation industry, due to its favorable energy to weight ratio, and in maritime shipping, particularly for long range, cross continental routes.

The research and development sector is integral to the growth of the hydrogen economy. This includes private consultancy firms publishing roadmaps for hydrogen adoption, as well as expert organizations such as the International Energy Agency (IEA) and TNO, which advise governments on transition strategies. Academic institutions and universities also contribute significantly through experimental research and innovation in hydrogen technologies aimed at improving efficiency and scalability.

Financing mechanisms are crucial across all sectors. Economic viability is often contingent upon support through various funding instruments, such as European partnerships (e.g., the European Hydrogen Bank), national growth funds, and investments from private equity firms and banks, which provide loans and financial backing for infrastructure and innovation.

Finally, at the heart of the hydrogen transition are the communities and individuals who live in proximity to production sites, work in hydrogen related industries, and will ultimately utilize hydrogen in their daily lives. Their engagement is essential in shaping a transition that is not only technologically feasible but also socially just. Public discourse must include concerns regarding livelihoods, post fossil fuel identities, and the broader implications of the transition. The Dutch people, with its strong commitment to climate goals, have a vested interest in achieving carbon neutrality. Moreover, there is a moral imperative to safeguard the interests of future generations by ensuring that they inherit a planet that remains within ecological limits.

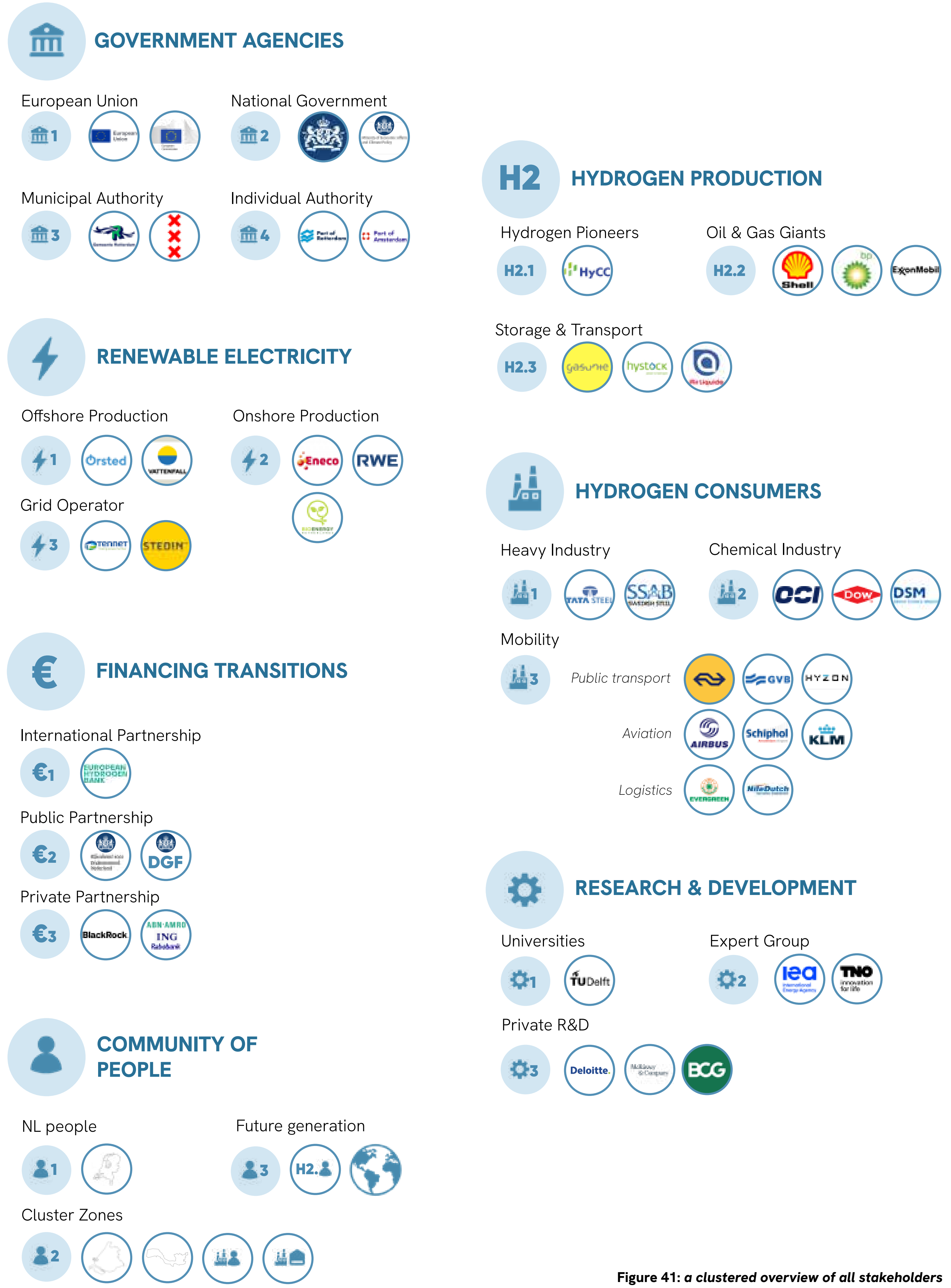


Figure 41: ***a clustered overview of all stakeholders***
The images are copyrighted trademarks of the respective rights-holding companies.

4.3 FACING THE REALITY

WHO IS INVOLVED IN THE HYDROGEN TRANSITION?

High Interest – High Power
Stakeholders in this quadrant are key players with substantial influence over decision-making processes and a vested interest in the success of the energy transition. In the public sector, this group includes national government ministries. These institutions possess both regulatory power and planning authority, shaping the socio-technical transition through legislation, funding, and strategic vision. Their interest is aligned with long term sustainability goals outlined in frameworks such as the European Green Deal and the Dutch Climate Act.

In the private sector, stakeholders such as green energy companies, climate advocacy groups, and urban planning and design consultancies also fall into this category. These actors are deeply invested in the transition for both environmental and economic reasons.

High Interest – Low Power
This group comprises actors who are highly invested in the hydrogen transition but have limited formal influence over decision-making processes. Academic and research institutions. Their interest lies in contributing scientific evidence, although their practical influence remains constrained. It is essential that these institutions receive financial support to amplify their contributions.

Urban residents and local communities, though significantly affected by the outcomes of hydrogen-related developments, are frequently marginalized in decision-making. Effective community engagement mechanisms must be established to incorporate their voices, build public trust, and ensure that their lived experiences are reflected in the planning and implementation phases.

Low Interest – High Power
This group consists of stakeholders who wield considerable influence over the energy sector but demonstrate limited interest in supporting sustainability transitions, particularly when these challenge their existing business models. Major fossil fuel companies maintain a dominant position in the current energy system. While they hold the potential to obstruct or delay the hydrogen transition, strategic engagement with these actors is necessary. Persuading them to reorient their business models toward green hydrogen can support long-term industry sustainability.

Financial investors and institutional funders also fall within this quadrant. While they may not oppose green hydrogen initiatives, their involvement is often driven by economic metrics rather than environmental or social considerations. Their stance remains relatively neutral, but they can be pivotal enablers.

Low Interest – Low Power
Stakeholders in this category have limited influence over the hydrogen transition and currently demonstrate low levels of engagement or awareness. This group largely includes residents living near project sites who, despite being directly impacted, often lack formal channels for participation or influence. Proactive community engagement is essential to enhance their understanding of the project's implications and foster interest in shaping their own environmental futures.

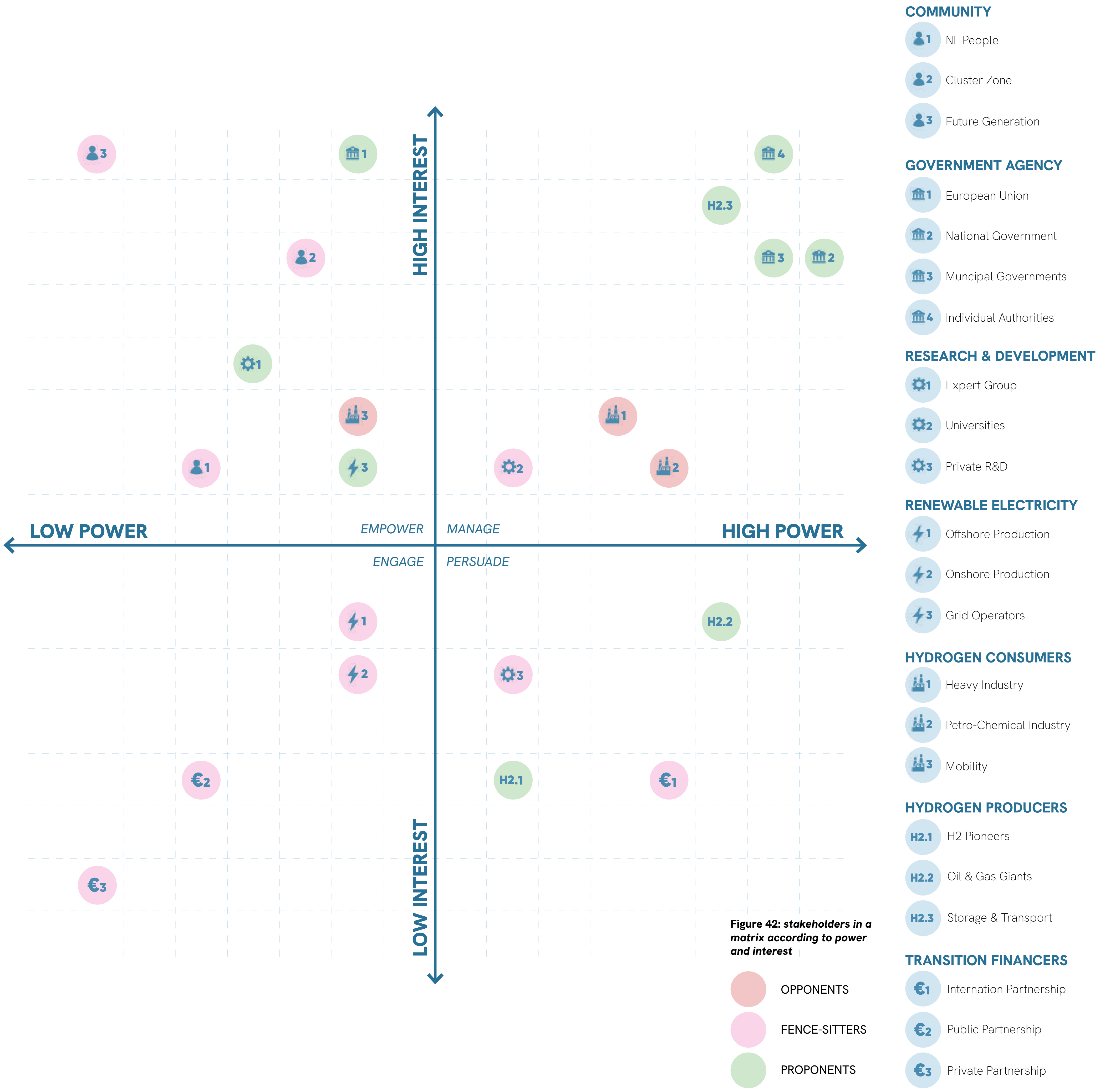


Figure 42: stakeholders in a matrix according to power and interest

4.3.3 What are the existing policies & visions for H2?

European level
At the European level, goals have already been set for the transition to hydrogen, especially in the production of chemical products (European Commission, n.d.). In 2022, less than 2% of total energy use in the EU came from hydrogen. However, 96% of this hydrogen was still produced using natural gas, which led to high CO_2 emissions.

That is why the EU is now prioritising the development of renewable hydrogen. The aim is that by 2050, about 10% of the EU's energy demand will be covered by renewable hydrogen. This will help decarbonise energy-intensive industries and the transport sector. Hydrogen plays an important role in the EU's broader strategy for the energy transition.

To support this development, the European Commission announced nearly €720 million in funding for seven renewable hydrogen projects in Finland, Spain, Portugal, and Norway (Vlieger, 2024). In addition, the European Commission approved over €1 billion in state aid for Dutch companies to invest in green hydrogen production (Boersma, 2024).

There is also a collaborative initiative launched by gas network operators from 21 European countries: the European Hydrogen Backbone initiative (EHB) (Geurts, 2021). This plan outlines a vision for a dedicated hydrogen transport network across Europe. The goal is to expand the backbone to 40,000 km by 2040. Around 69% of this network will consist of repurposed existing gas pipelines. While the EHB aligns closely with EU energy and climate goals, it is an independent collaboration between network operators. Still, it clearly shows that cooperation is already happening to make the hydrogen transition possible and that the European Union is willing to invest money.

National level
The Dutch government also seems to have a positive attitude towards hydrogen and is already providing subsidies for hydrogen projects (Ministry of Economic Affairs and Climate Policy, 2025). One of the national goals is to have a hydrogen refuelling station in every major city and every 200 kilometers by 2030. The government also aims to reach an electrolysis capacity of 3 to 4 gigawatts by 2030, supported by enough storage locations and infrastructure.

To stimulate hydrogen production, the government is giving financial support to develop a national hydrogen transport network. The plan is to connect five major industrial clusters with each other, with neighbouring countries, and with import and transfer locations for hydrogen (Gasunie, 2025). One of these clusters is located in Rotterdam.

The national hydrogen network is being developed by Gasunie, which is mainly using existing natural gas pipelines, since the need for gas transport will decline in the coming years. In places where the current infrastructure is not suitable or available in time, new pipelines will be built. In this way, Gasunie is making a significant contribution to keeping the energy transition affordable.

Province level
A report by the province of South Holland (2024) states that hydrogen will play a crucial role in the future energy system in 2050. It is even seen as the most important link in the transition towards a sustainable energy system, especially in sectors that are hard to electrify, such as heavy industry and transport.

South Holland aims to become a key hub for hydrogen import and distribution, partly thanks to the Port of Rotterdam. A plan has already been developed to connect the province to other regions in the Netherlands, as well as to international hydrogen networks. The ambition is to produce green hydrogen locally as much as possible.

There is an awareness that this transition will have a major impact on the spatial planning of the province. The province focuses on collaboration between governments, grid operators, industry, and knowledge institutions. However, the report does not mention how, or if, residents and other stakeholders will be involved in the process.

City level (Rotterdam)
The Port of Rotterdam is also fully committing to hydrogen, which they see as a key element in making industrial processes more sustainable, supporting clean transport, and serving as a building block for green chemistry (Port of Rotterdam, n.d.-a).

Just like the national government, the Port of Rotterdam Authority is already working with Gasunie on a major hydrogen pipeline between the Tweede Maasvlakte and Pernis, which is planned to be ready by 2025 (COB, 2023). Two years later, a connection is expected between the port, Moerdijk, Chemelot in South Limburg, and the Ruhr area in Germany. Finding space for this pipeline in the already crowded underground of the port was a big challenge, but eventually, a route of over 30 kilometers was designed.

According to the Director of Commercial Delivery at the Port Authority, this pipeline is seen as an important starting point for the Dutch hydrogen network, which already had a national vision. He states that the ambition is to make the Port of Rotterdam the most sustainable port in the world. At the same time, there is also a strong need to invest in hydrogen infrastructure to keep up with the port's role. Currently, the Port of Rotterdam is the energy hub for Northwest Europe. They want to maintain that position in the future, which means the port must be able to offer alternatives to today's fossil fuels.

In addition to the hydrogen pipeline, there are also plans for a second pipeline to transport CO_2 from inland industrial areas to Rotterdam. This would allow captured CO_2 from Dutch and German industries to be transported and stored in empty gas fields. The idea is that many industrial processes cannot yet be made fully CO_2-free in the short term. Once those complex processes are also converted, the CO_2 pipeline could later be used for hydrogen transport as well.

4.3 FACING THE REALITY

CURRENT PLANS ON H2 BACKBONE

Below the planning map from Gasunie is showing how the current gas pipelines (Figure 44) will be reused to create the hydrogen backbone (Figure 43), connecting all industrial clusters with each other and with foreign countries.

In this report, this backbone is used as a starting point for developing the vision.

THE SWITCH FROM FOSSIL TO RENEWABLE

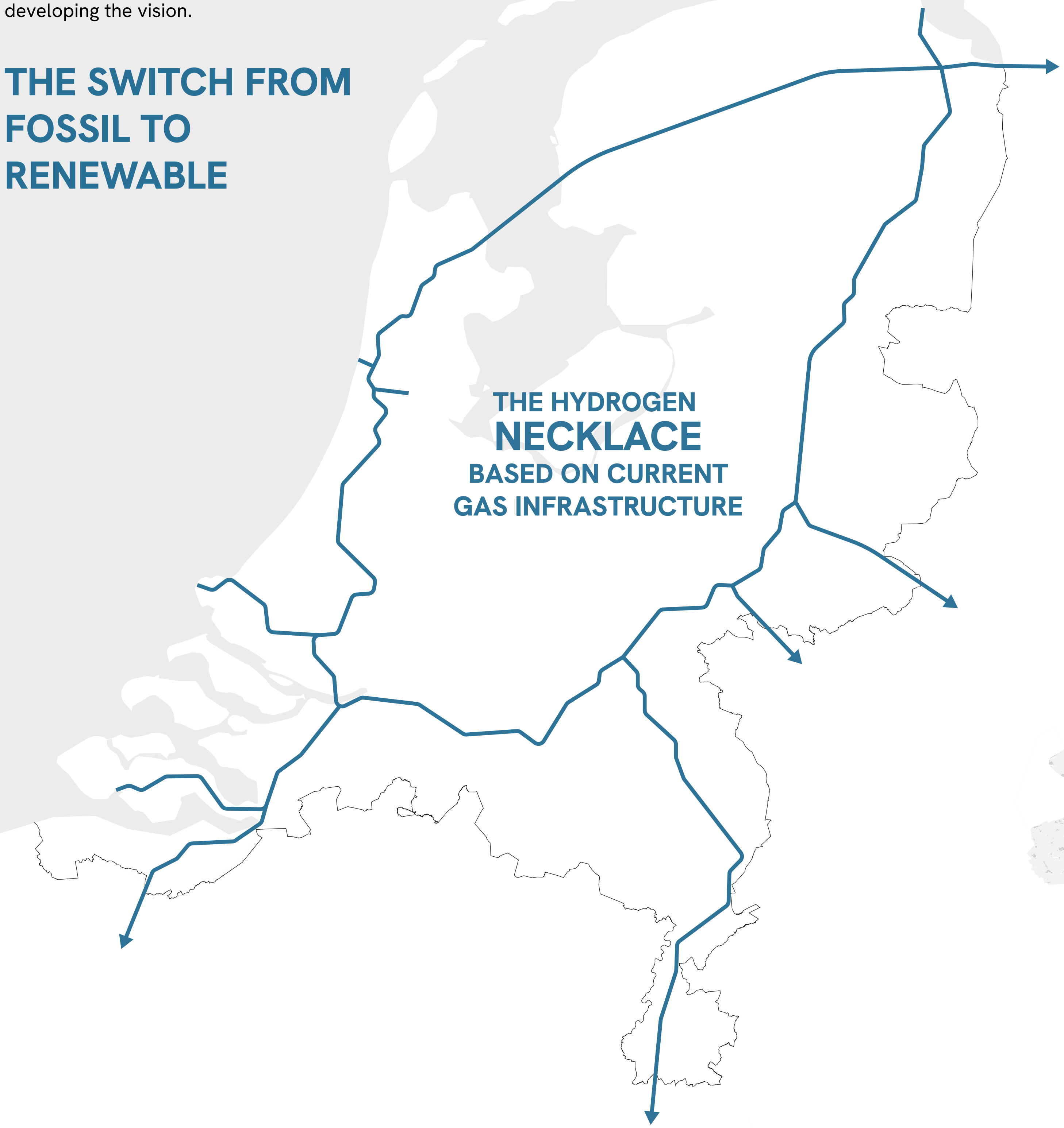


Figure 43: ***the hydrogen backbone as a necklace around The Netherlands***
source: Gasunie (n.d.)

N
0 10 20 40km

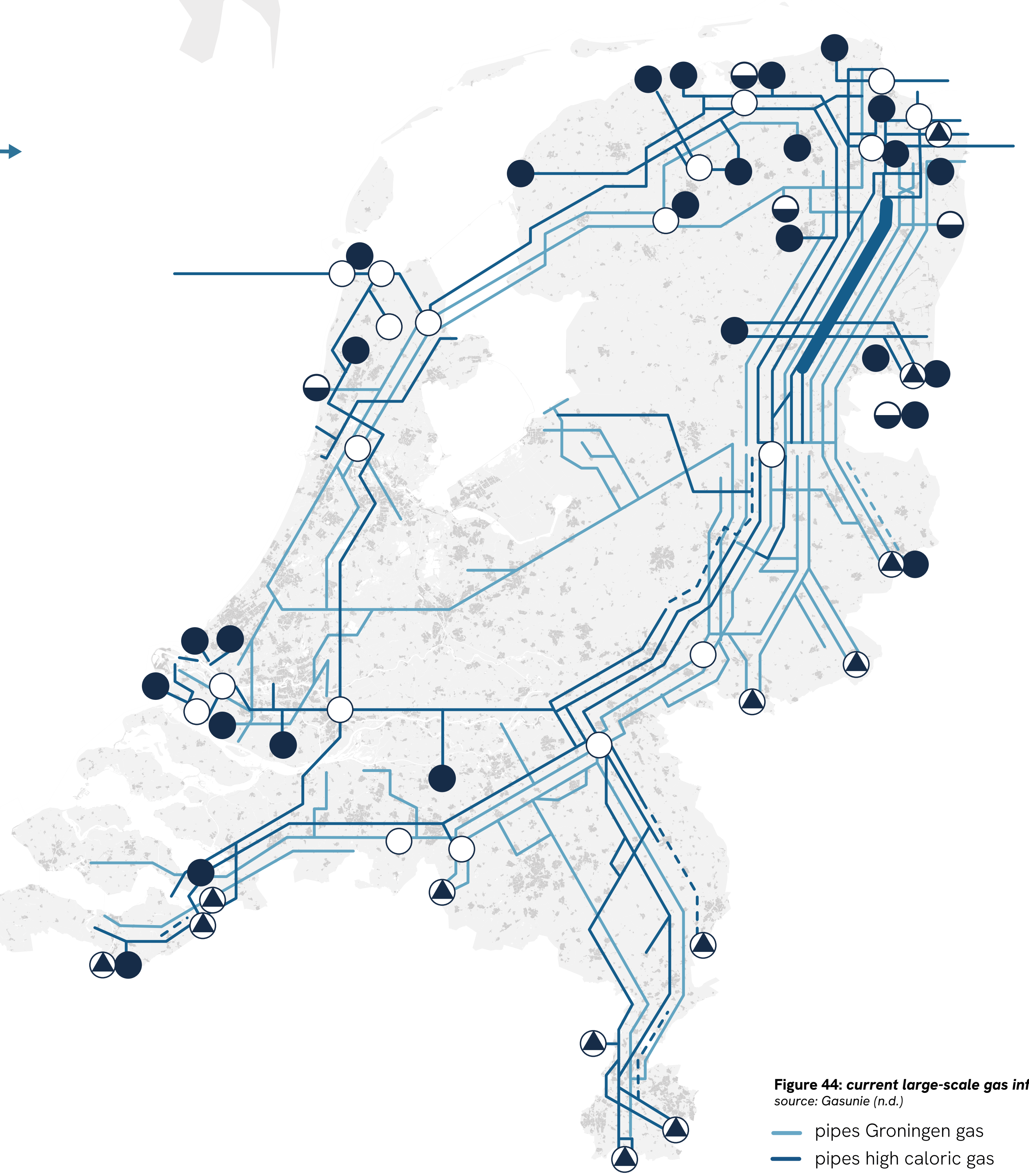


Figure 44: ***current large-scale gas infrastructure***
source: Gasunie (n.d.)

- pipes Groningen gas
- pipes high caloric gas
- entry points
- export station
- storage facility
- compressor and/or mixing station

4.3.4 What has been published in the media?

This media analysis was conducted to gain insight into the current status of hydrogen, renewable energy, and financial developments within the industry. The articles reviewed comprise a curated selection of news reports chosen for their relevance.

Notably, coverage prior to 2025 was predominantly optimistic, whereas reports from 2025 indicate a trend toward stagnation. For example, the European Commission has intervened with an action plan for the steel industry (NOS, 2025). Furthermore, the financial outlook for hydrogen investments appears less robust than previously reported in 2024 (NL Times, 2025). Eneco has also announced a halt to offshore wind turbine installations (NOS, 2025). These developments raise an important question: what has changed to create this growing sense of uncertainty?

There is no clear answer. However, there are several indications that the current knowledge of hydrogen remains insufficient. As a result, it is difficult to make accurate estimates regarding timelines, financial investments, and implementation. Additionally, the energy transition is a large-scale project taking place in a dynamic and changing world.

PORT OF ROTTERDAM

source: published Port of Rotterdam, Shell (July 6th, 2022)

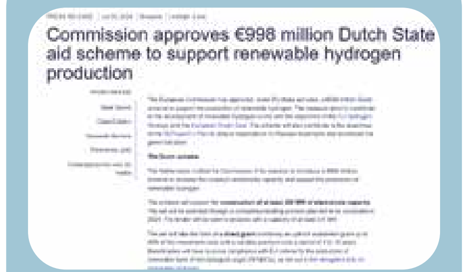
MCPHY ENERGY S.A.

source: published McPhy Energy S.A. (2023)

ENECO

source: published Eneco (November 20th, 2023)

EUROPEAN COMMISSION



source: published European Commission (July 29th, 2024)

ARGUS

source: published ARGUS, Aidan Lea (October 24th, 2024)

NL TIMES

source: published NL TIMES, Depositphotos Inc. (March 10th, 2025)

NOS

source: published NOS (March 17th, 2025)

NL TIMES

source: published NL TIMES, Depositphotos Inc. (March 23th, 2025)

NOS

source: published NOS (March 30th, 2025)

Figure 45: *media analysis on energy transition*
individual sources noted underneath separate news items

STRENGHTS

LOCAL CULTURE
- People are very proud of the local industry, e.g. steel.

SOCIAL & FINANCIAL STABILITY
- The industry provides jobs for people nearby.
- The current largest CO_2 emitting industrial clusters are along the coast, where there is a great potential for hydrogen energy development.
- The existing industry has a lot of overlapping gas infrastructure which the hydrogen energy systems could use.

WEAKNESSES

EMPOWERMENT
- Top-down strategies impairs trust and transparency.

SOCIAL & FINANCIAL STABILITY
- There is a high cost of integrating hydrogen fuel systems as a energy source into the existing infrastructure of the nation.

RESILIENCE
- The need to deal with lock-ins: a centralized electricity generation system along the southern Netherlands.

SOCIAL EQUITY
- Hydrogen will be reducing CO_2 emissions drastically, but will not solve the problem of particulate matters emitted.

OPPORTUNITIES

EMPOWERMENT
- People could benefit from the industrial hydrogen infrastructure, e.g. selling extra electricity to the hydrogen power plant.

SOCIAL & FINANCIAL STABILITY
- New hydrogen-based communities could emerge along the backbone: fully sustainable.
- Inclusion of hydrogen within the current systemic design of fossil fuel flows will attract new industries.

RESILIENCE
By removing parts of fossil fuel infrastructure we can redevelop or reassign sites that have been abondoned ecologically.

THREATS

SENSE OF BELONGING
- The transition into hydrogen energy might lead to unemployment, if the workers in the conventional energy industry is not well prepared for it.

SOCIAL & FINANCIAL STABILITY
- Hydrogen can react with metal, causing higher maintenance cost.

RESILIENCE
- Since hydrogen is highly explosive, its storage could pose a risk, especially geopolitically, making people hesitant to adopt it.

5

HOW ARE WE CHANGING IT?

VISION ON IMPLEMENTING HYDROGEN

Empowering the community through the energy transition: shaping their own identity.

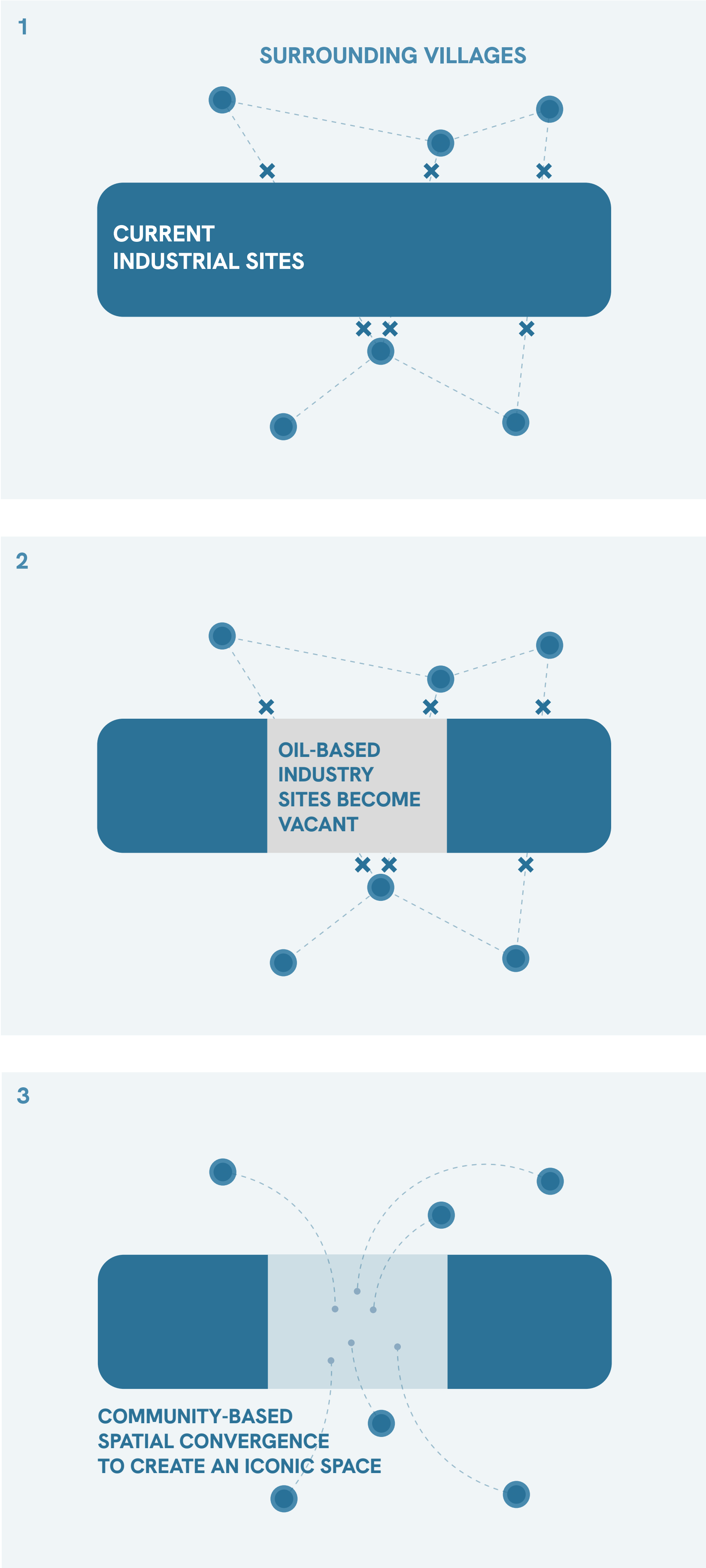


Figure 46: ***diagram of the vision: from oil-based land to community-based iconic space***

CREATING AN ICONIC SPACE IN EVERY CLUSTER

REVITALIZING INDUSTRIES BY HYDROGEN

By 2050, the Netherlands will be transformed into the new center of sustainable energy production, driven by green **hydrogen**. No longer constrained by fossil fuels of a by gone era, the country will use renewable energy to produce, store and distribute hydrogen efficiently. The strategic integration of hydrogen will follow a clear priority: first revitalizing industries, then decarbonizing heavy mobility and logistics, next transforming the built environment and finally integrating into the electricity grid through power-to-X solutions.

Hydrogen is not just a technical solution, it will also reshape industrial landscapes, labor markets and governance structures. The transition must not only address the needs of the present but also prepare for the Hydrogen Generation of the future. Besides repurposing current industries and infrastructures, we must actively involve the community in creating their new identity. Using a bottom-up strategy, the community will participate in shaping the transition and ensuring a future-proof environment.

AN OPPORTUNITY TO CREATE MUTUALISM BETWEEN COMMUNITY AND INUDSTRY

When oil usage decreases in the industry, a lot of storage space will disappear. Large areas in the ports will become available for new purposes. This is an opportunity to create **mutualism** between the community and the industry by literally bringing people into industrial areas and breaking down industrial barriers.

The Hydrogen Generation will grow up in a world where they have the future. On a large scale the Netherlands will produce hydrogen and put innovative industry on the map, on cluster scale the community will work on an urban plan where they can live and work in symbioses with the industry. Together these scales will make the Netherlands transition into a **Hydrogen Age**.

A hundred years ago, Rotterdam changed the world with industry. Now hydrogen changes the industry for the world.

NORTHSEA COAST: EUROPE'S GATEWAY TO HYDROGEN

A central hydrogen-driven economy with easy connections through the main ports of Europe.

Figure 47: *hydrogen exported to the largest ports in Europe*
source: Sinha (2025)

With this transition into a Hydrogen Age, the Netherlands will become a leading example for the rest of Europe. At first, hydrogen will be produced, stored and used within the country to make the Netherlands more self-sufficient. In the long term, however, the Netherlands is expected to become the largest producer and exporter of hydrogen, becoming the core of Europe's hydrogen generation. From the port areas, hydrogen will be transported to locations across the continent.

On the one hand, the Netherlands will lead in terms of technology. Universities, research centers and schools will open to study the large-scale shift from fossil fuels to hydrogen. This knowledge can then be shared with other countries to help make the overall transition smoother.

On the other hand, the Netherlands will also set an example for the social side of the energy transition. By focusing not only on economic and technical aspects, but also on the communities connected to industrial areas, a mutual relationship will develop between industry and society. This will help break down industrial barriers and create a more inclusive and balanced transition.

From the research into the concerns of the community, several key values have emerged. These values form the foundation for the three goals of this project. Together, these goals aim to create mutualism between the community and the industry.

The first two values are *resilience* and an *innovative character*. The energy transition will bring major changes to industrial areas. Both companies and communities will need to show resilience in order to adapt to their new environment and to each other. The port areas will also need to regain an innovative spirit, similar to the one they had decades ago during the rise of the oil industry. This way, these areas can once again become future-proof; economically, socially and ecologically. These values lead to the first goal: **adaptive identity**.

The next set of values includes *inclusivity*, *social equity* and *empowerment*. The transformation of industrial clusters offers a major opportunity to rethink and reshape these areas. It is essential that those with the most money or the loudest voice do not make all the important decisions. All stakeholders, including local communities, must be involved in the planning process and have enough influence over the decisions that will affect their living environment and that of future generations. This leads to the second goal: **social equity**.

The final values are *sense of belonging* and *social/financial stability*. The transformation of industrial areas will bring many changes in terms of employment. It is important that workers in outdated sectors are not left behind, but instead are given the chance to participate in the new hydrogen economy, maintaining their stability both socially and financially. These values lead to the third goal: **economic prosperity**.

1 ADAPTIVE IDENTITY
2 SOCIAL EQUITY
3 ECONOMIC PROSPERITY

Together, these three goals will lead to the main aim: mutualism. In the conceptual diagram on the right, these three goals are shown in dark blue. The three terms in the grey wheels (in short: industry, transition and community) form the academic foundation for reaching these goals.

Each of these academic terms (see theoretical framework in Chapter 1.6) includes several subcomponents, which contribute to two of the goals. These subcomponents help to formulate interventions that will be used during the strategy phase. This will be explained in more detail later in the report.

MUTUALISM BETWEEN INDUSTRY AND COMMUNITY THROUGH THE ENERGY TRANSITION

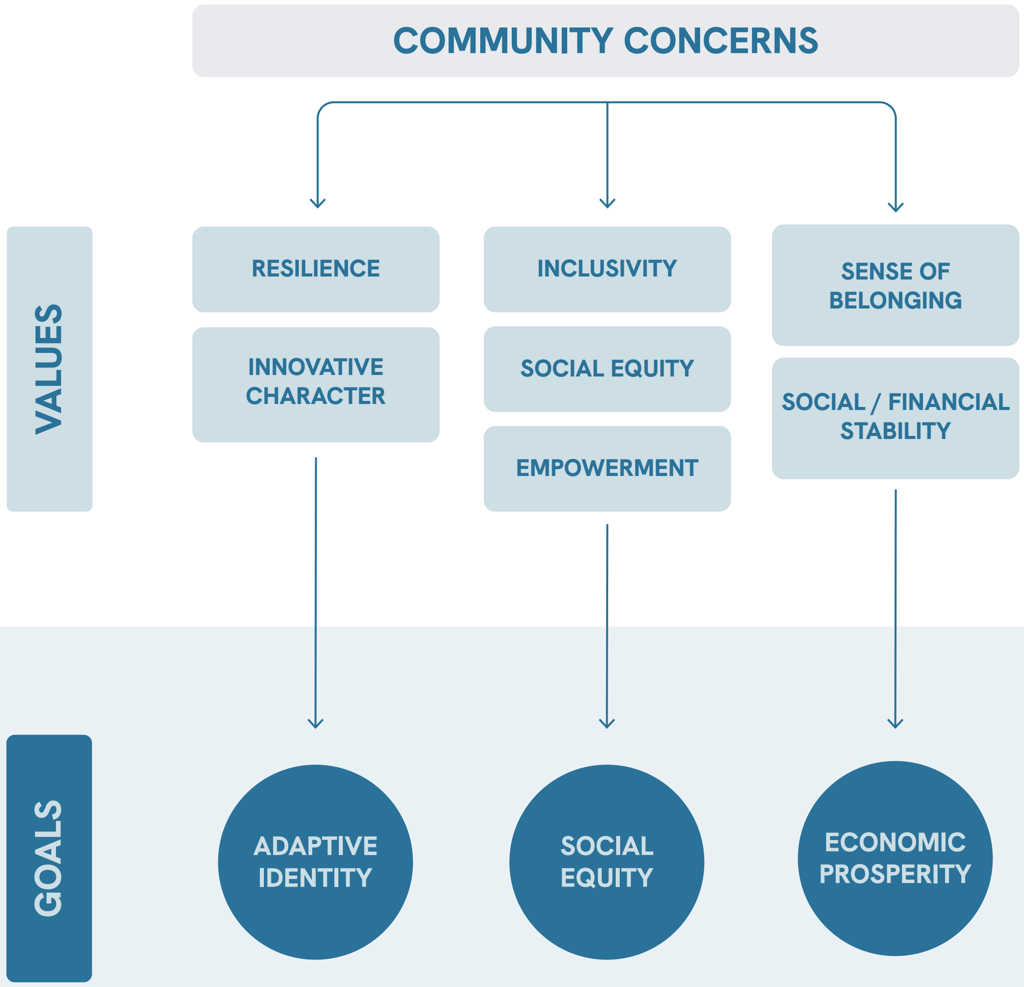
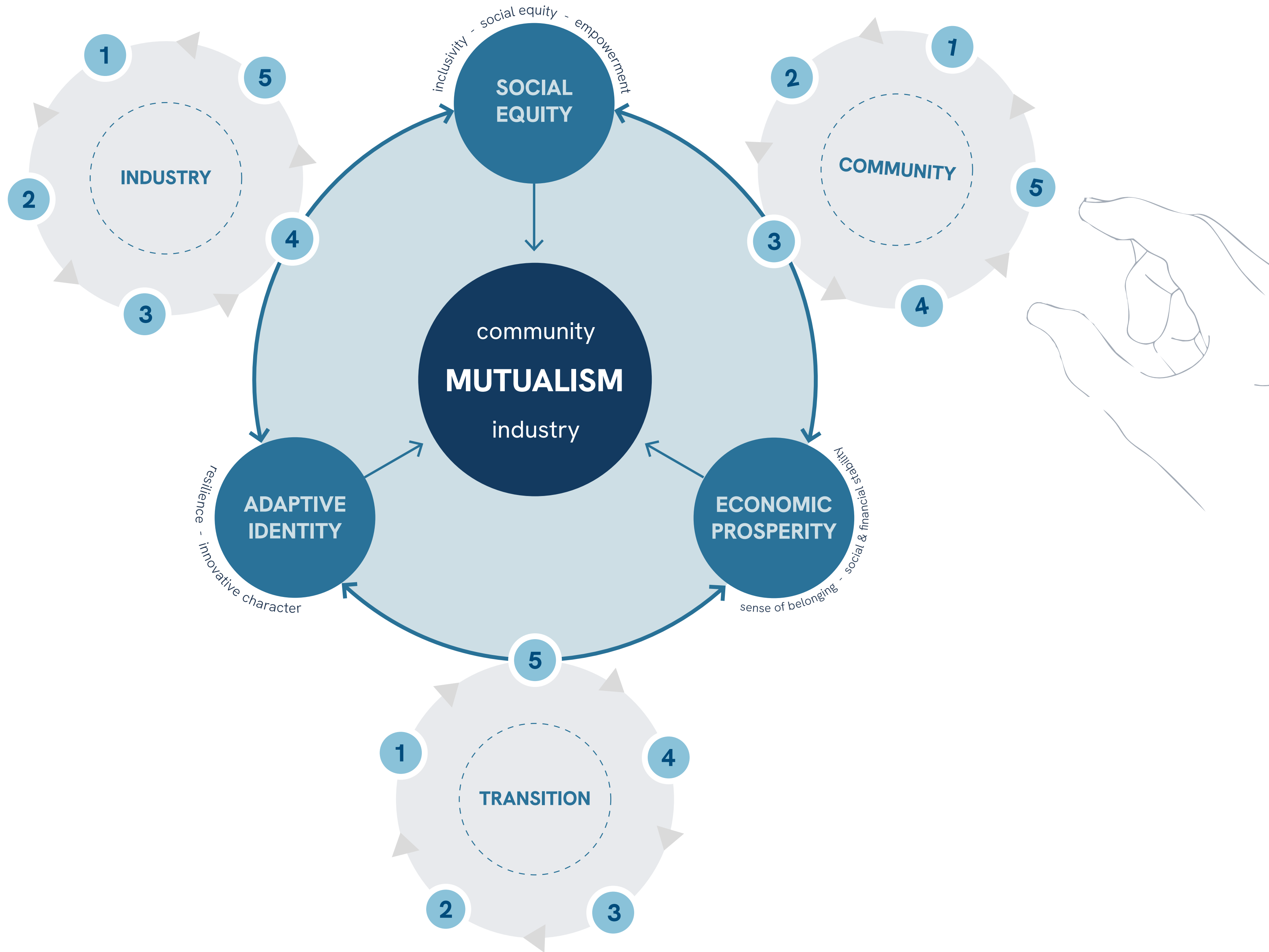


Figure 48: *conceptual framework, including the values and goals*



INDUSTRY
INDUSTRIAL SYMBIOSIS (IS)

1. revitalizing current industries
2. net-zero emission
3. foster an industry culture like silicon valley
4. pioneering new industries
5. circular resource networks

TRANSITION
TRANSITION MANAGEMENT (TM)

1. stimulate innovation
2. learning and adaptation
3. multi-scalar implementations
4. stakeholder synergy
5. law and regulation

COMMUNITY
SOCIALLY JUST TRANSITION (SJT)

1. future-proof ecosystems
2. citizen participation
3. stakeholder engagement
4. equitable job opportunities
5. enabling daily life environment

TRANSITION TO H2: THE LARGEST IMPACT TO MAKE IN CURRENT INDUSTRY CLUSTERS

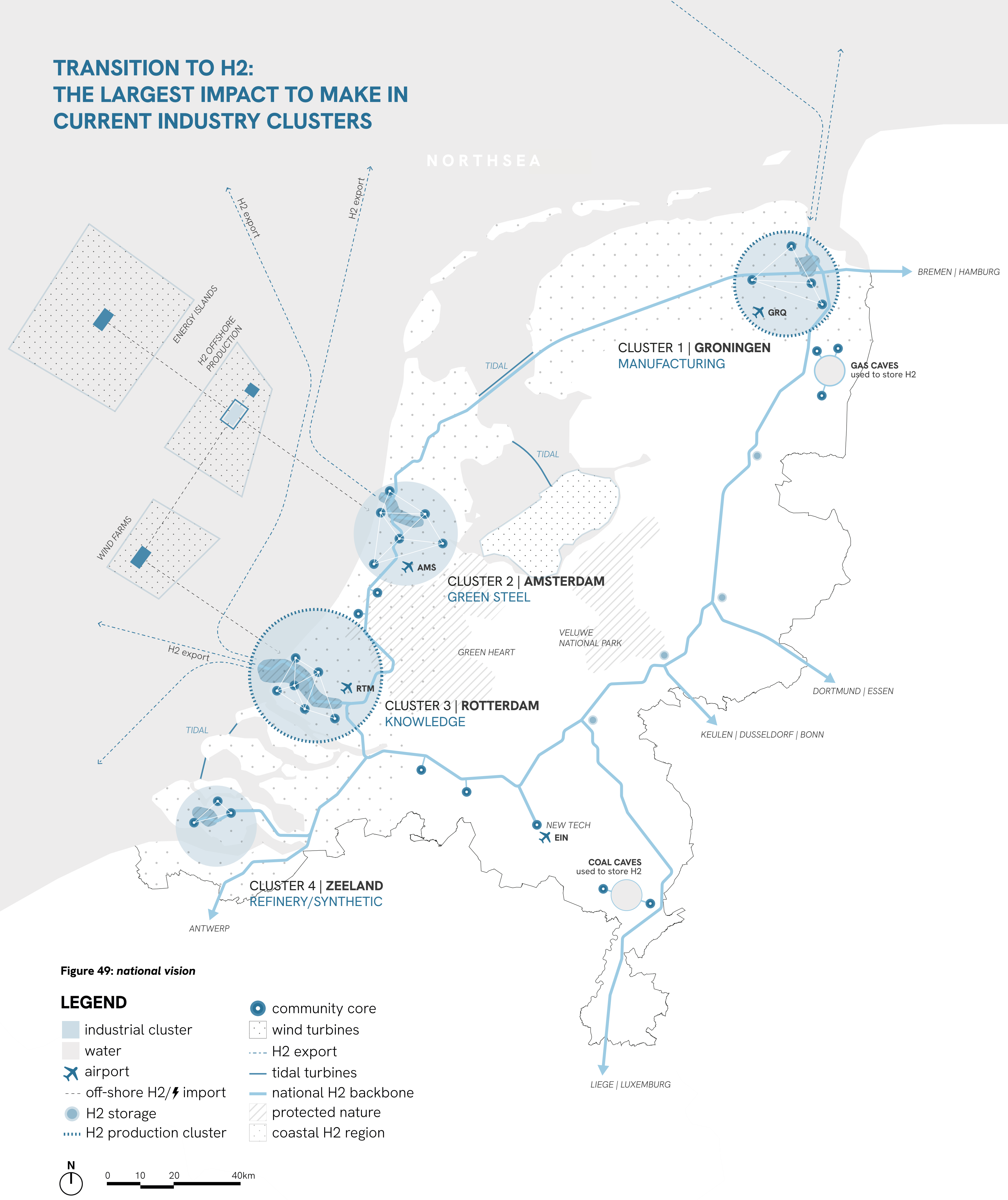


Figure 49: ***national vision***

5.4 NATIONAL VISION

SHAPING THE FUTURE BY CLUSTER SPECIALISATION

In the future, the existing main gas network will be converted for transportation for hydrogen. This will allow the whole of the Netherlands to switch to hydrogen. Industrial clusters will be connected to it. Rotterdam and Groningen will produce net, Amsterdam and Zeeland will consume net. Renewable electricity from Flevoland and offshore wind farms will be used to produce hydrogen in the clusters. The location of these clusters by the sea makes wind farms profitable and provides easy access to sufficient water. Within the clusters, the community benefits from the hydrogen infrastructure and can also switch to this energy source without much cost.

In the hydrogen age, the living conditions around industries will shift from disadvantageous to advantageous.

CLUSTER SPECIALISATION

All 4 clusters have their own identity based on current specializations. These identities can be embraced, strengthened and used as inspiration for shaping the future living environment.

GRONINGEN
Manufacturing
Agriculture
Energy Production

ZEELAND
Agriculture
Chemical Refineries
Fishing

ROTTERDAM
Cargo Logistics
Knowledge
Energy Production

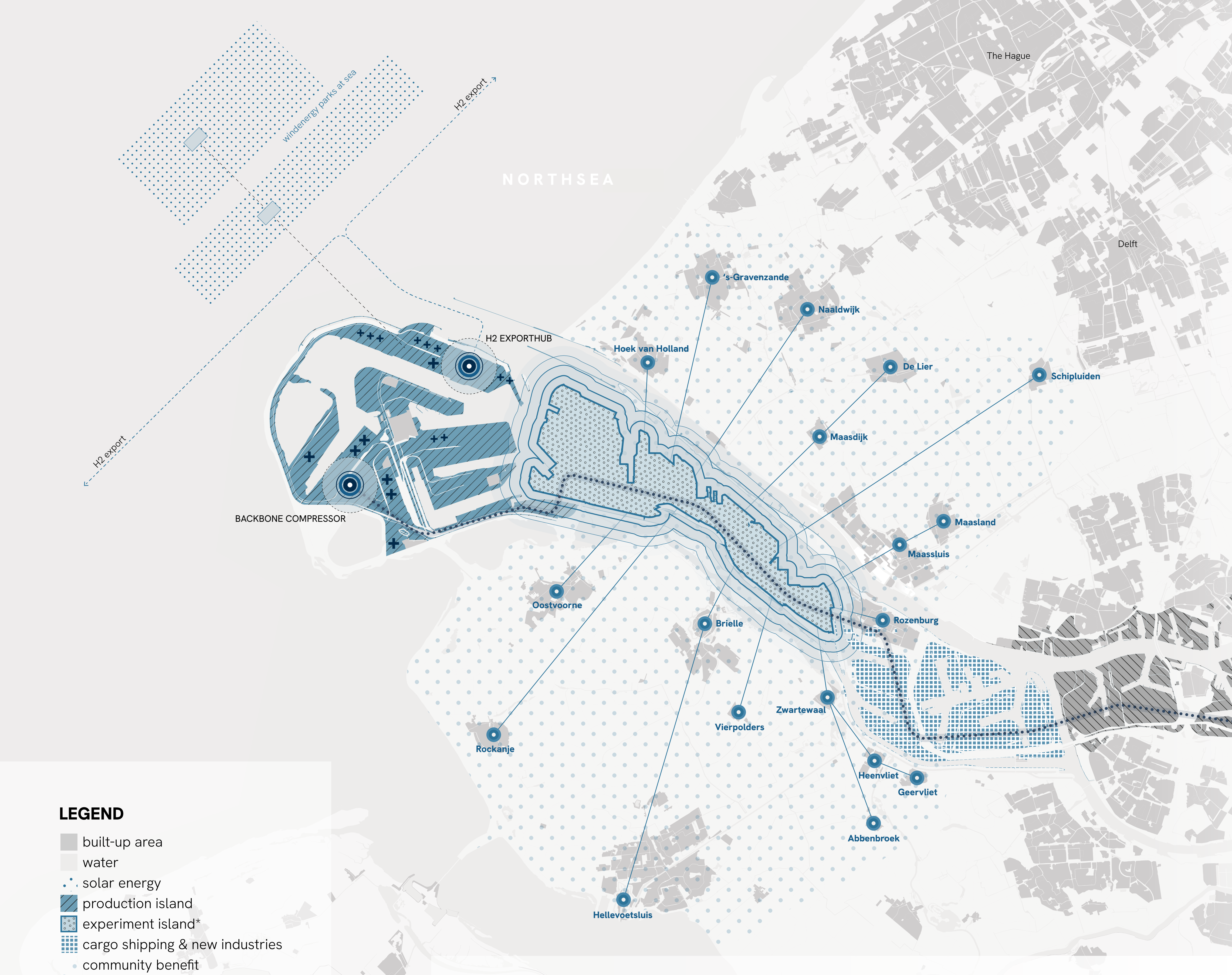
AMSTERDAM
Green Steel
Cargo Logistics
Energy Production

5.5 REGIONAL VISION

RESHAPING ROTTERDAM'S HARBOUR AREA

Zooming in on the Rotterdam cluster, these advantages of living next to industry become apparent. The Maasvlakte is being completely converted into a sustainable production island for green hydrogen. Necessary electricity from offshore wind farms thus has to travel the shortest possible distance. From the Maasvlakte, hydrogen will be transported via the backbone to the rest of the hinterland. The eastern part of the port is given back to the city and converted into new living and working areas with a former industrial character. The island in the middle will be freed up almost entirely once oil refineries and storage disappear. This is where an iconic place can be created to further expand the identity of Rotterdam's cluster. For this, the surrounding villages will come into play. Giving this place (partly) back to people will help connect industry and community.

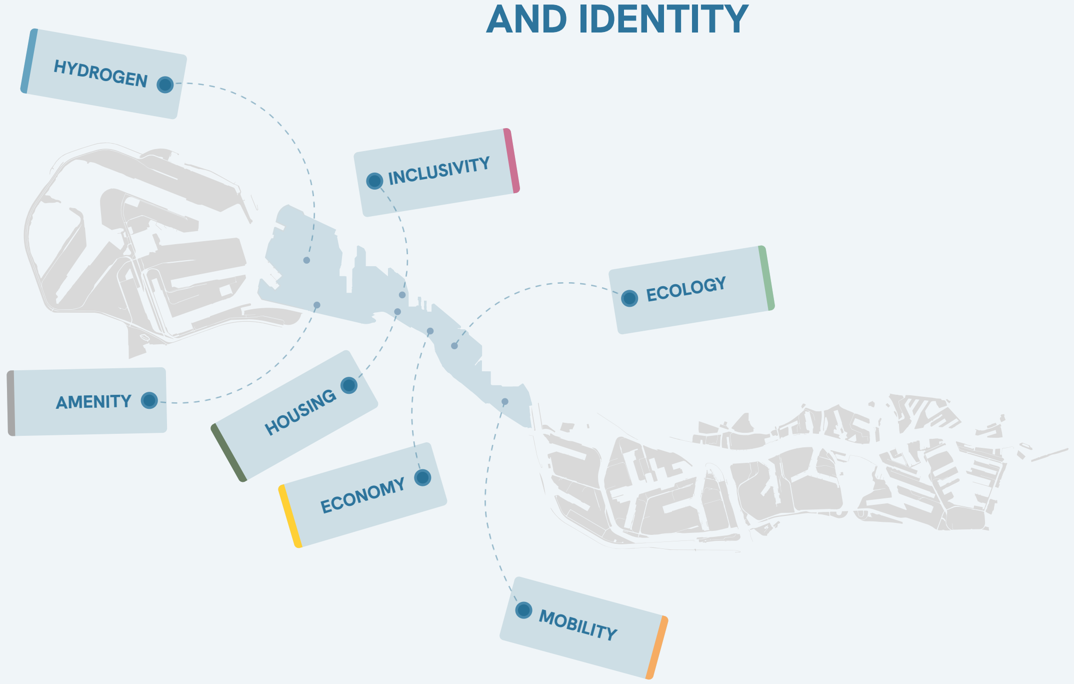
A new living environment in the middle of industry. A place where people and industry live together in mutualism.



*VISION FOR EXPERIMENT ISLAND: BREAKING THE INDUSTRIAL BARRIER

Figure 50: ***regional vision***

COMMUNITY EMPOWERED: RESHAPING THEIR ENVIRONMENT AND IDENTITY



5.5 REGIONAL VISION

CREATING AN ICONIC SPACE WITH COMMUNITY ENGAGEMENT

The vision for the redevelopment of the different clusters is based on a combination of a top-down and bottom-up approach. This ensures that the hydrogen economy can function on an (international) national scale, while also taking into account the community and their identity of each individual cluster on a smaller scale.

In the case of the Port of Rotterdam, the western part (The Maasvlakte) will serve as a production island, while the eastern part will be given back to the city center. The port originally began in the heart of the city, near the old dam, but over the past centuries it has gradually been pushed outward. This new approach continues that trend, making room for future urban expansion of the city.

To the west of the reclaimed city, space is reserved for current cargo logistics and for new industries that will emerge as part of the hydrogen transition, such as the construction of new, clean hydrogen-powered ships.

These decisions about the redesign of the port area have been made top-down, to ensure that there is enough space for both the technical development of hydrogen and the city's future growth.

How the remaining part of the area, around 25% of the total, will be developed is decided through a bottom-up process. This allows the community and other stakeholders closely involved with the port to help shape the new identity and environment of the area. Since the port area will be radically transformed, this is a key opportunity to include local needs in the design. The aim is for the area to no longer be a closed-off island next to the city, but to truly become part of Rotterdam.

To involve the community in thinking about the new design of their industrial cluster - not only in Rotterdam, but in every cluster - seven intervention themes have been developed. These can be used to guide conversations and make the complex situation more understandable for everyone. In this way, designers working from a top-down perspective can gain a better understanding of the needs that exist from the bottom-up.

INTERVENTION THEMES

ECOLOGY — Green infrastructure, biodiversity conservation and climate resilience measures contribute to long-term sustainability and public health.

INCLUSIVITY — Ensures equal opportunities and accessibility for all residents, fostering social cohesion through diverse housing, public spaces and policies that prevent segregation.

MOBILITY — Prioritizing efficient transport networks (public transport, walkability and cycling) reduces congestion, enhances accessibility and supports economic growth while minimizing environmental impact.

ECONOMY — A strong economic foundation, through business incentives, research centres, job creation and innovation hubs, ensures financial stability and employment. Economic focus is based on cluster identity

HOUSING — A balanced mix of affordable and diverse housing types accommodates city expansions, especially for lower and middle class, students and starters.

AMENITY — Cultural institutions, public service,s shops and schools enhance the quality of life and attract both businesses and residents.

HYDROGEN — Investing in hydrogen as a clean energy source can help decarbonize transportation, industry and heating, supporting energy independence and sustainability.

Figure 51: ***The four development districts. Top-down based for technological development. Experiment island is approached bottom-up. Different intervention themes for the experiment island highlight main focus points for future interventions.***

KNOWLEDGE ECONOMY EMBEDDED IN NATURE
SECOND CITY CENTRE OF ROTTERDAM
HYDROGEN INDUSTRIAL CORE: JOB GENERATOR
ROTTERDAM'S HARBOUR WETLANDS

A possible vision that could emerge from the community for this area is to transform the current oil industry into a natural landscape that can be used as a recreational area by the surrounding villages. Within this landscape, there would also be room to experiment with hydrogen production and storage, as well as other forms of renewable energy.

A new core area will be developed, including universities, research centers, schools and upskilling centers to retrain current port workers for jobs in the new industries. Additional housing, including student accommodation and new facilities will be added to make the area livable and attractive.

The surrounding villages will be connected to each other, to the new recreational landscape, and to the knowledge hub through a hydrogen-powered public transport network. This will improve the accessibility of the area and strengthen its connection to the wider region. In this way, the Port of Rotterdam will be put on the map as a showcase area for what is possible with hydrogen applications.

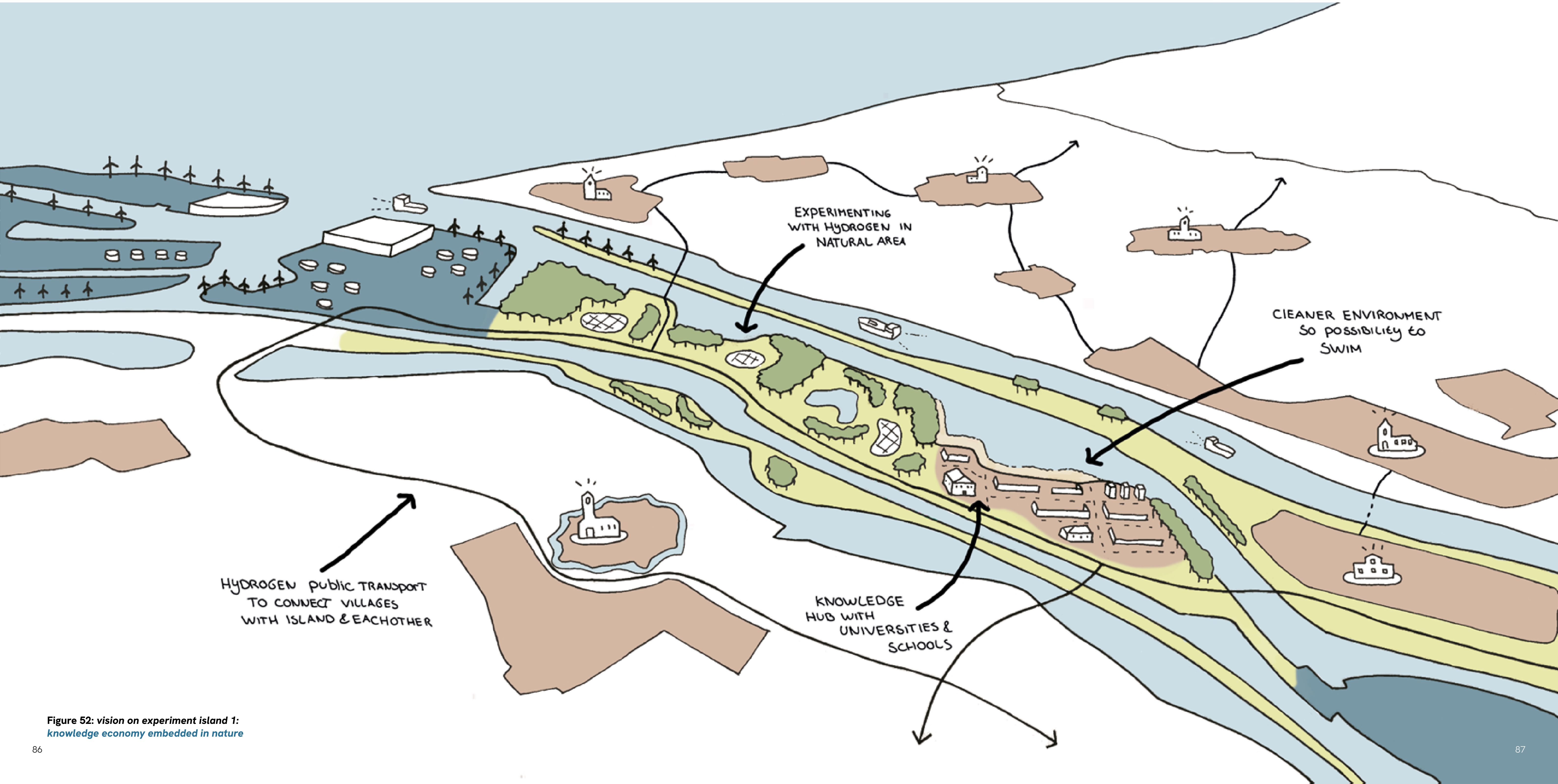


Figure 52: ***vision on experiment island 1:*** ***knowledge economy embedded in nature***

KNOWLEDGE ECONOMY EMBEDDED IN NATURE
SECOND CITY CENTRE OF ROTTERDAM
HYDROGEN INDUSTRIAL CORE: JOB GENERATOR
ROTTERDAM'S HARBOUR WETLANDS

Another possible vision that the community might develop for this area is to create a second city center in the former oil industry zone. This new city would function as a central hub for the surrounding villages, giving residents access to major services close by, without needing to travel to the current centers of Rotterdam or The Hague.

The city would include not only many new homes, shopping centers and public facilities, but also universities, schools, research centers, and new offices that make use of hydrogen knowledge and infrastructure. In this way, the new city would become the central hub for hydrogen knowledge and innovation.

All surrounding villages will keep their own identity, but will be connected to the new city through a hydrogen-powered public transport network. In addition, the existing green areas will be preserved, so that residents can continue to enjoy their natural recreational spaces.

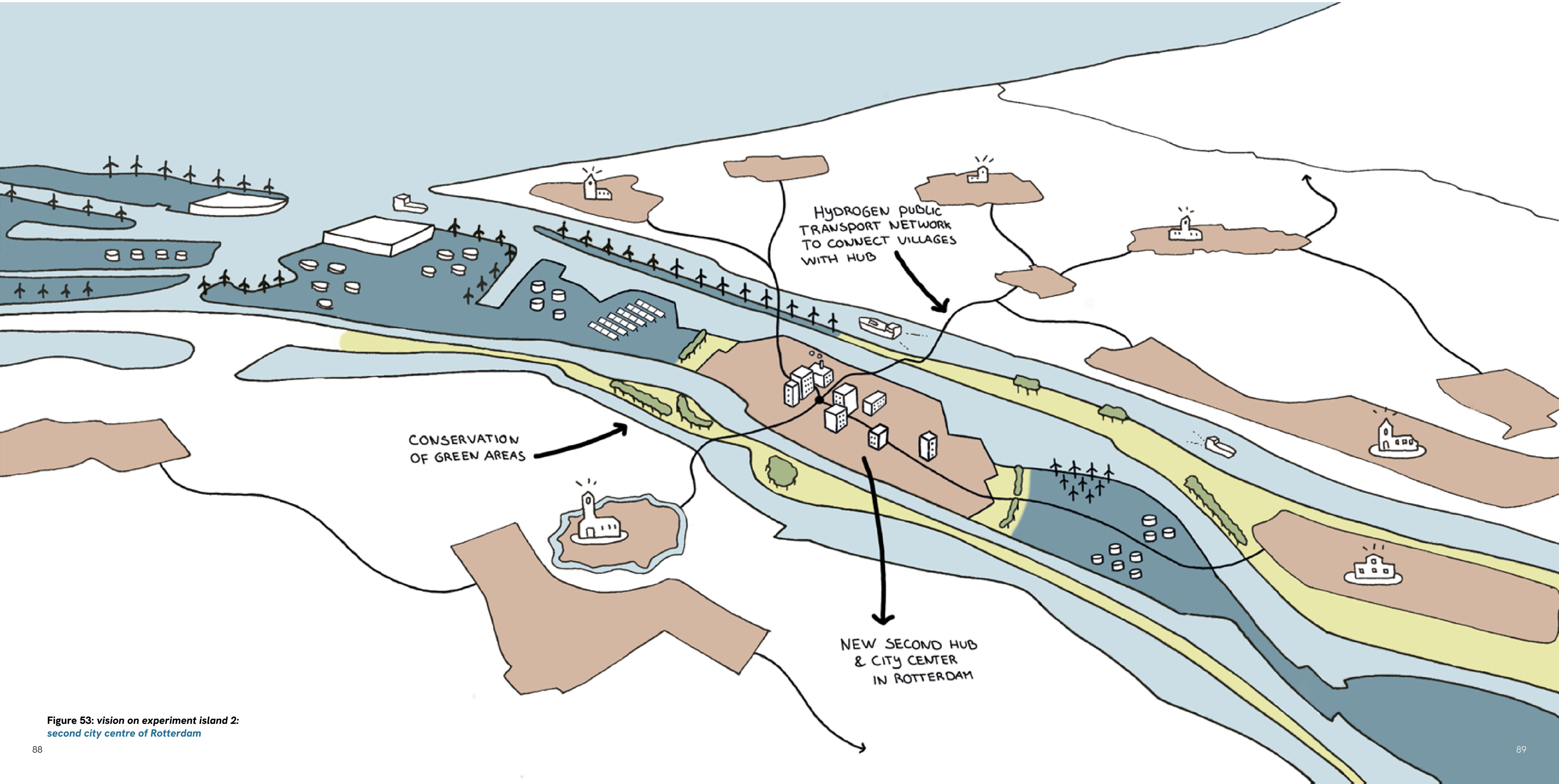


Figure 53: ***vision on experiment island 2:***
second city centre of Rotterdam

5.6 WHAT COULD THE FUTURE LOOK LIKE?

SOME RADICAL SPATIAL IDEAS

KNOWLEDGE ECONOMY EMBEDDED IN NATURE
SECOND CITY CENTRE OF ROTTERDAM
HYDROGEN INDUSTRIAL CORE: JOB GENERATOR
ROTTERDAM'S HARBOUR WETLANDS

The community might also develop a completely different vision for the port area. One alternative could be to fully dedicate the entire current port zone to the production and storage of hydrogen, the generation of renewable energy, and the industries that will grow alongside the rise of hydrogen. This would lead to the creation of many new jobs, ensuring suitable and future-proof employment.

At the same time, there would be enough job opportunities for future generations, meaning that residents of the surrounding villages would not have to worry about ageing or population decline. In the eastern part of the port, there is enough space for the expansion of the city, providing housing for the many new workers who will come to the area.

The community benefits from all the new and more affordable energy options, while at the same time avoiding large-scale energy production infrastructure, such as wind turbines and solar fields, being built in their backyards. In this way, their local identity and surroundings can remain the same.

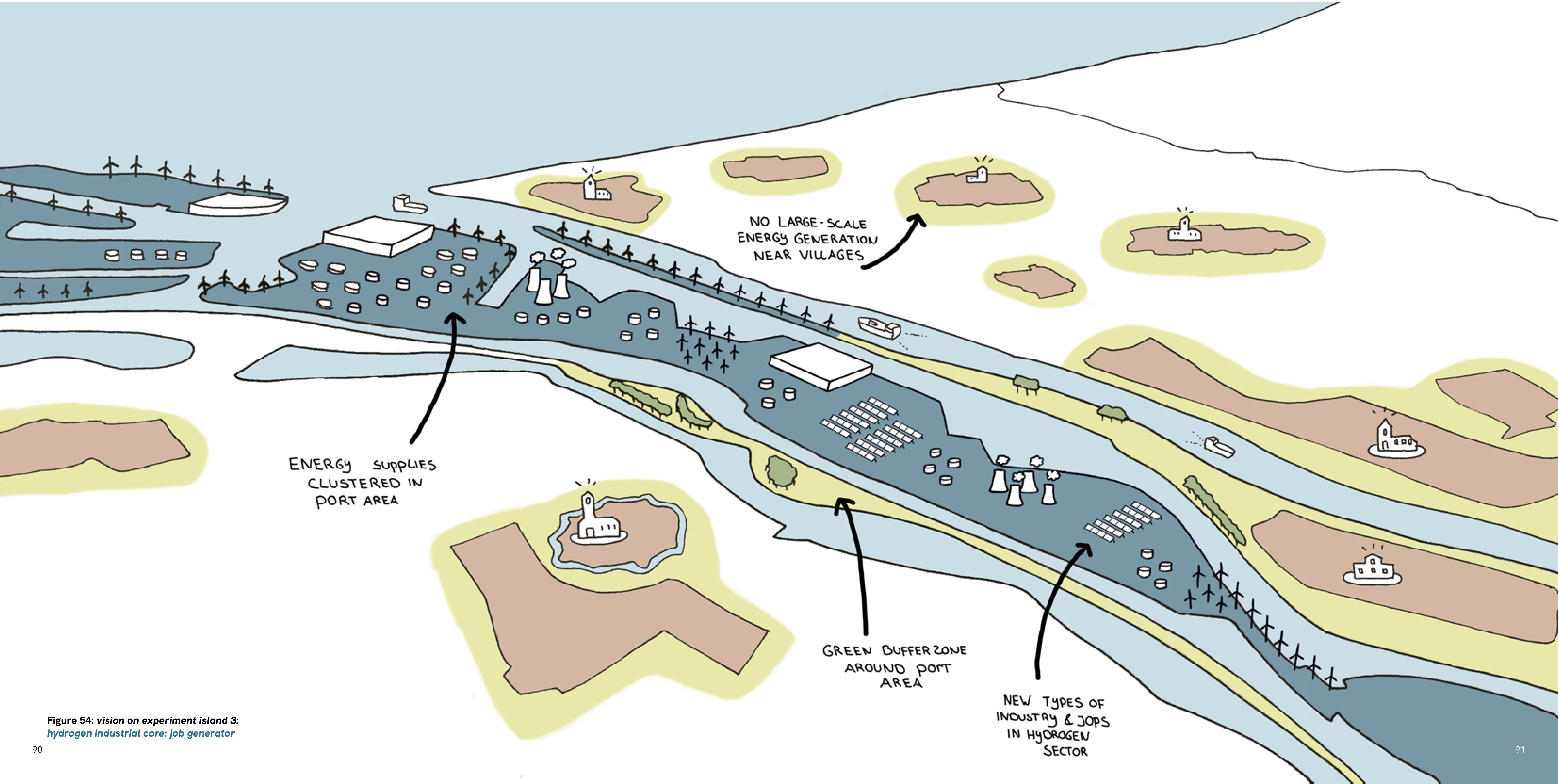
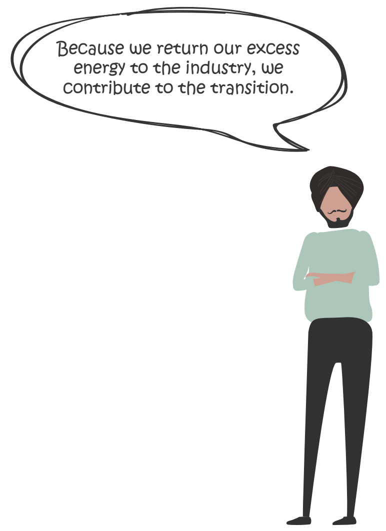


Figure 54: *vision on experiment island 3: hydrogen industrial core: job generator*



KNOWLEDGE ECONOMY EMBEDDED IN NATURE
SECOND CITY CENTRE OF ROTTERDAM
HYDROGEN INDUSTRIAL CORE: JOB GENERATOR
ROTTERDAM'S HARBOUR WETLANDS

A final example of a radical vision that the community might propose is to transform a large part of the port area into wetlands, giving the river more space and allowing it to overflow naturally. This would reduce the risk of future flooding, giving residents peace of mind about the safety of their living environment.

The area would also become much cleaner, as polluting industries disappear and plants and natural filters help purify the water and soil. With green, sloping riverbanks, biodiversity in the area would increase and residents living near the edges would be able to swim in clean, natural water. There would be no separate knowledge hub in this area near the production island. Instead, the existing university in the center of Rotterdam would be expanded.

As part of a compromise proposed by the residents, additional renewable energy sources, such as wind turbines and solar fields, would be placed along the edges of the river.

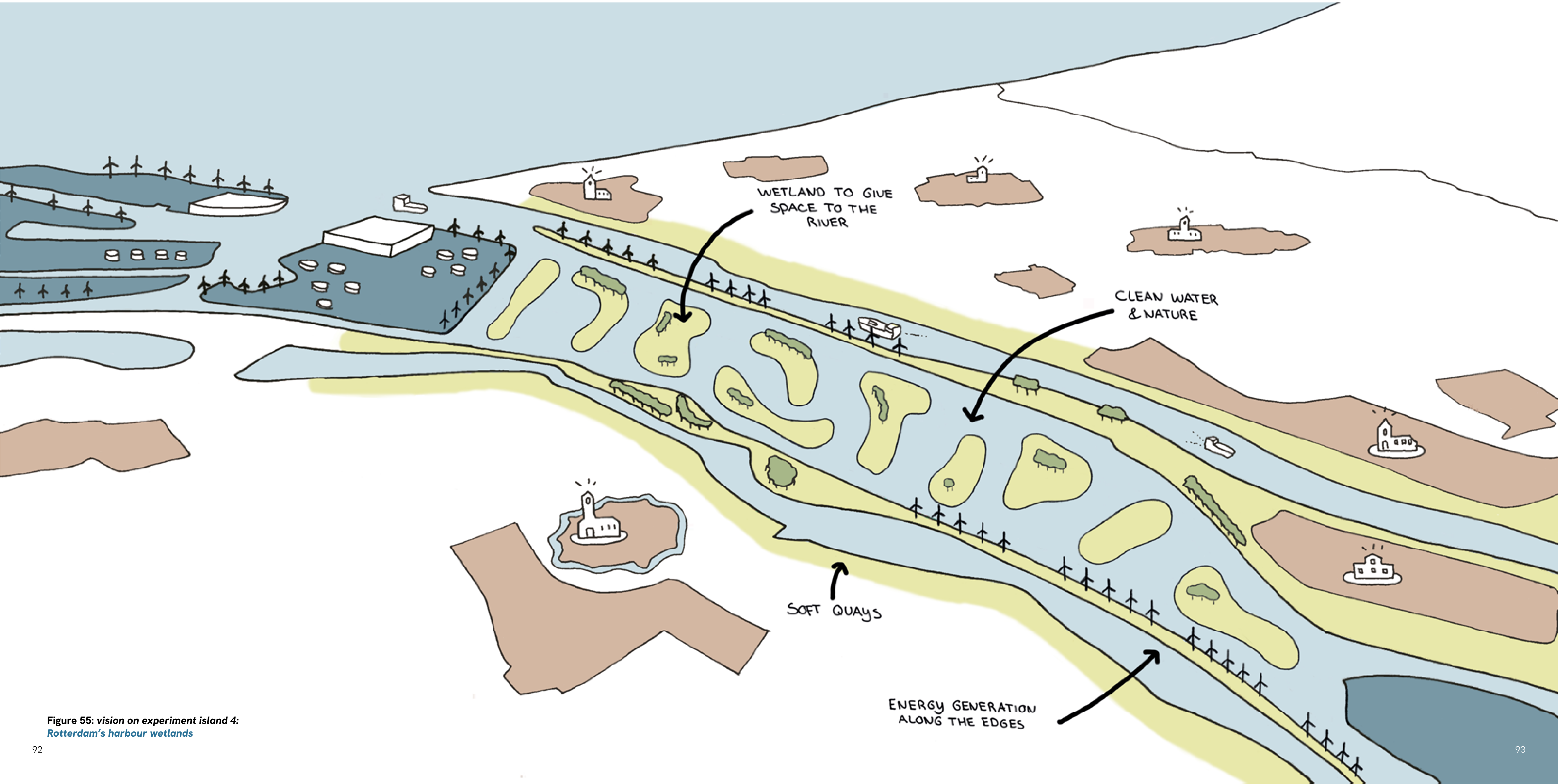


Figure 55: ***vision on experiment island 4:***
Rotterdam's harbour wetlands

H2

TOWARDS CLEAN ENERGY
A hundred years ago, Rotterdam changed the world with industry.
Now hydrogen changes the industry for the world.

6

HOW ARE WE GETTING THERE?

STRATEGY ON EMPOWERING THE COMMUNITY

Embedding people their voice in decision-making for the new industrial landscapes.

6.1 DIFFERENT PATHWAYS TO REACH THE GOALS

4 SCENARIO'S TO REACH OUR GOALS

Scenario building served as a critical methodological tool in our strategic planning process, enabling us to explore, communicate and critically evaluate multiple plausible pathways for the energy transition. As noted by Rocco (2025), constructing "what if" scenarios allows planners and designers to articulate and visualize potential futures, facilitating strategic reflection and informed decision making. In this context, four distinct scenarios were developed to investigate varying stakeholder dynamics, governance models and transition trajectories for the adoption of green hydrogen in the Netherlands.

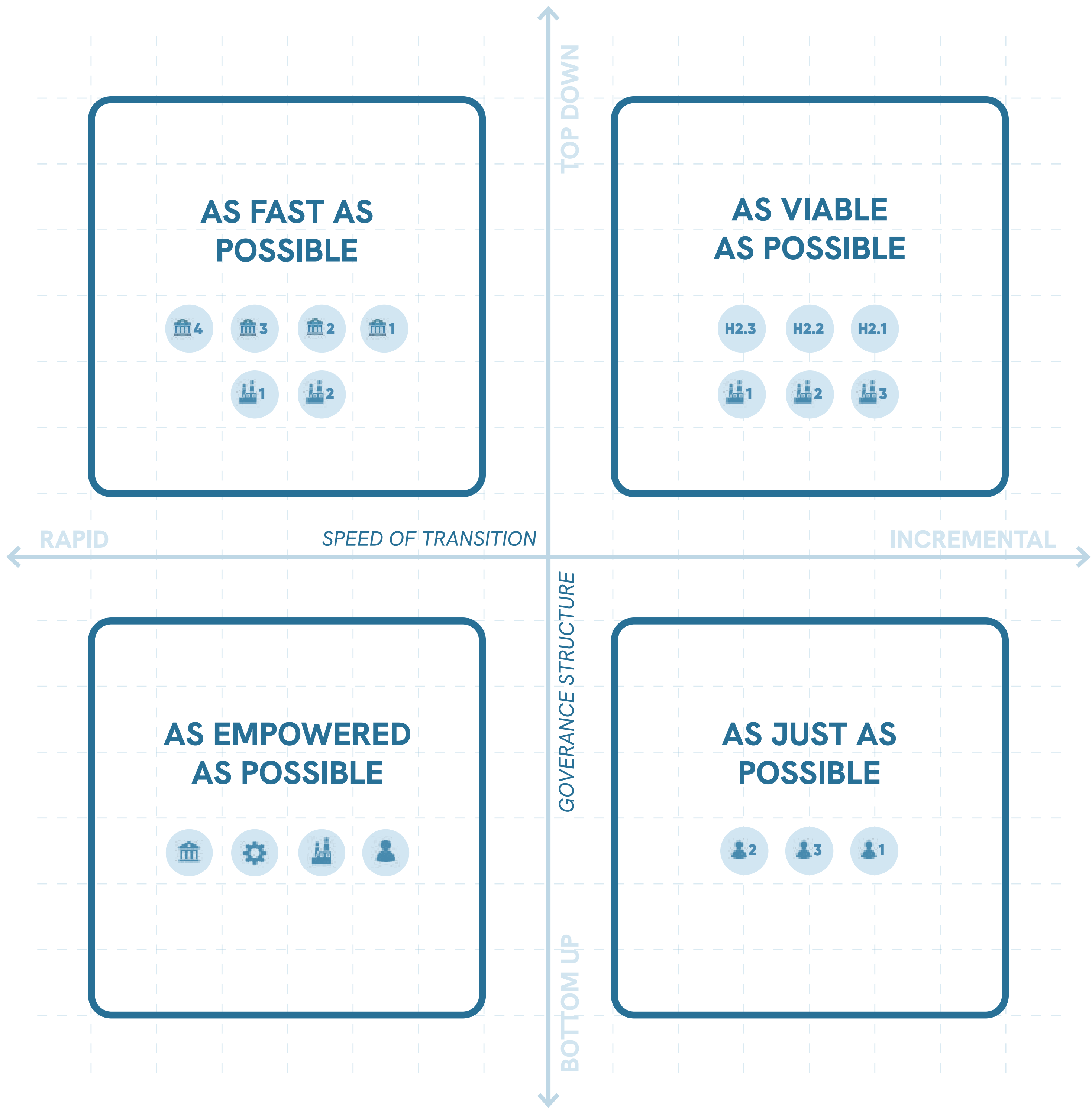


Figure 56: ***different pathways to reach the goals based on speed of transition and the governance structure***

6.1.1 SCENARIO 1 - *as fast as possible*

This scenario envisions a rapid energy transition driven primarily by the government, with major industrial stakeholders playing a supporting role in facilitating hydrogen adoption. The stakeholder mapping (Figure 57) illustrates strong institutional linkages between government agencies and large industry players, enabling swift policy implementation and accelerated development of the hydrogen supply chain. The governance model is distinctly top down, allowing for expedited decision making and large scale coordination. However, a critical drawback of this approach is the marginalization of civil society. Communities are often only engaged at the final stages of the process as end users of hydrogen without meaningful involvement in shaping policy or planning decisions. This risks diminishing public trust and long term commitment to the transition.

SCENARIO 3 - *as empowered as possible*

This scenario envisions a synergistic model in which government, industry and communities operate in a state of equilibrium, collaboratively driving a rapid yet inclusive energy transition (Figure 59). Governance is fundamentally bottom up, with community led initiatives guiding the direction of change, while institutional actors both governmental and industrial provide the necessary support, resources and infrastructure to scale up innovations. This integrated approach balances speed with justice, aiming to combine the strengths of all stakeholders to accelerate the transition without compromising democratic values or social inclusivity.

6.1.2 SCENARIO 2 - *as viable as possible*

The private sector, particularly industrial actors and the research and development community are positioned as the primary and secondary drivers of the transition, respectively. The government plays a supportive role through financial incentives, regulatory frameworks and institutional backing (Figure 58). While this market-driven approach may foster technological innovation and capitalize on existing industrial expertise, it also carries the risk of an incremental and economically contingent transition. If hydrogen adoption proves to be commercially unviable, there is a likelihood of industry stakeholders withdrawing from pilot projects, thereby stalling progress. As discussed in Chapter 5.3, this scenario leaves communities in a vulnerable position, caught between governmental aspirations for sustainability and an industry constrained by profit driven decision making.

6.1.3 SCENARIO 4 - *as just as possible*

This scenario prioritizes a socially just energy transition, with communities positioned as the central actors in both spatial and policy making processes. Drawing on the framework of just transition theory, it emphasizes democratic participation, local empowerment and inclusive governance (Figure 60). Citizens are not merely passive recipients of change but active contributors to defining energy futures that reflect their needs, identities and values. While this bottom up model promotes equity and long-term social resilience, it faces challenges in terms of pace. The decentralized and deliberative nature of this approach may result in slower implementation, potentially jeopardizing the urgency of achieving national and international climate targets.

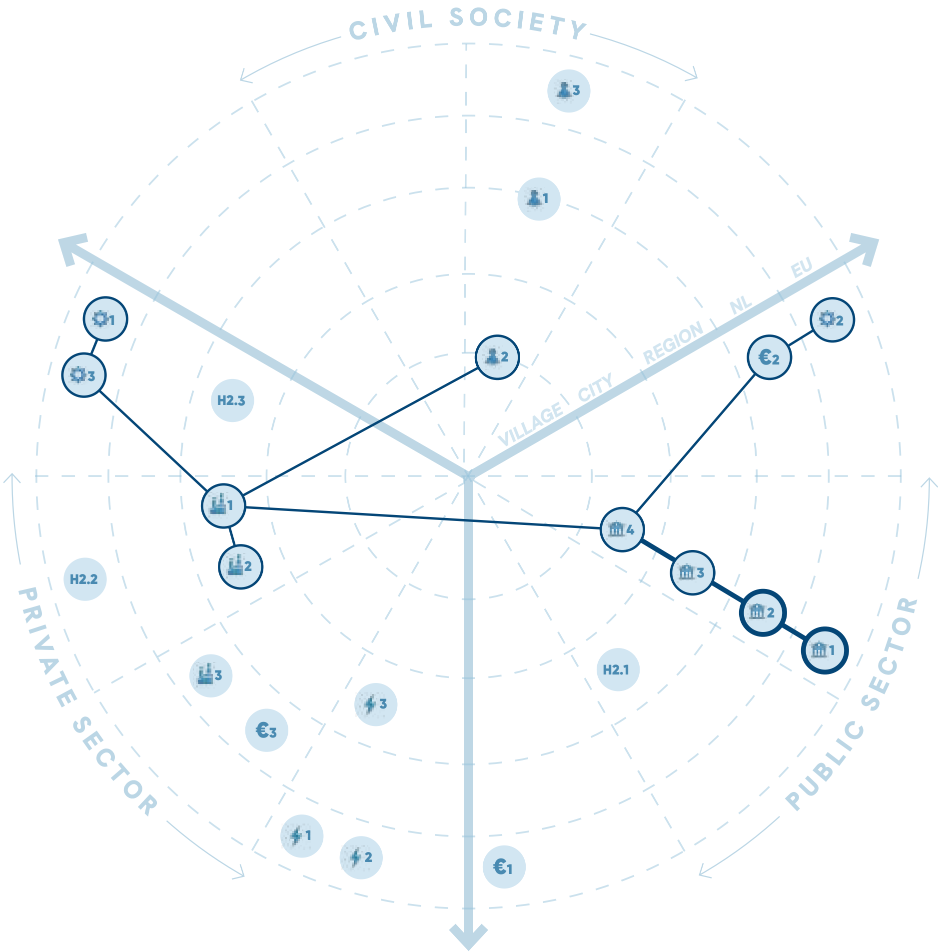


Figure 57: *stakeholders involved in 'as fast as possible'*

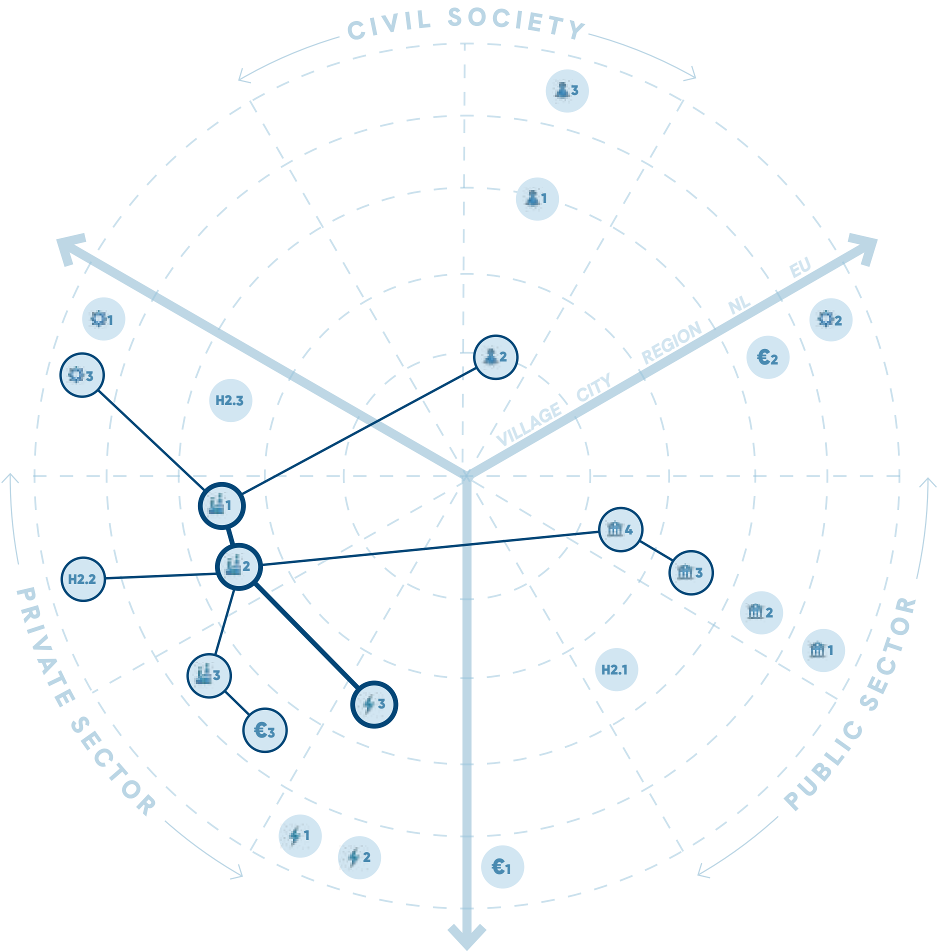


Figure 58: *stakeholders involved in 'as viable as possible'*

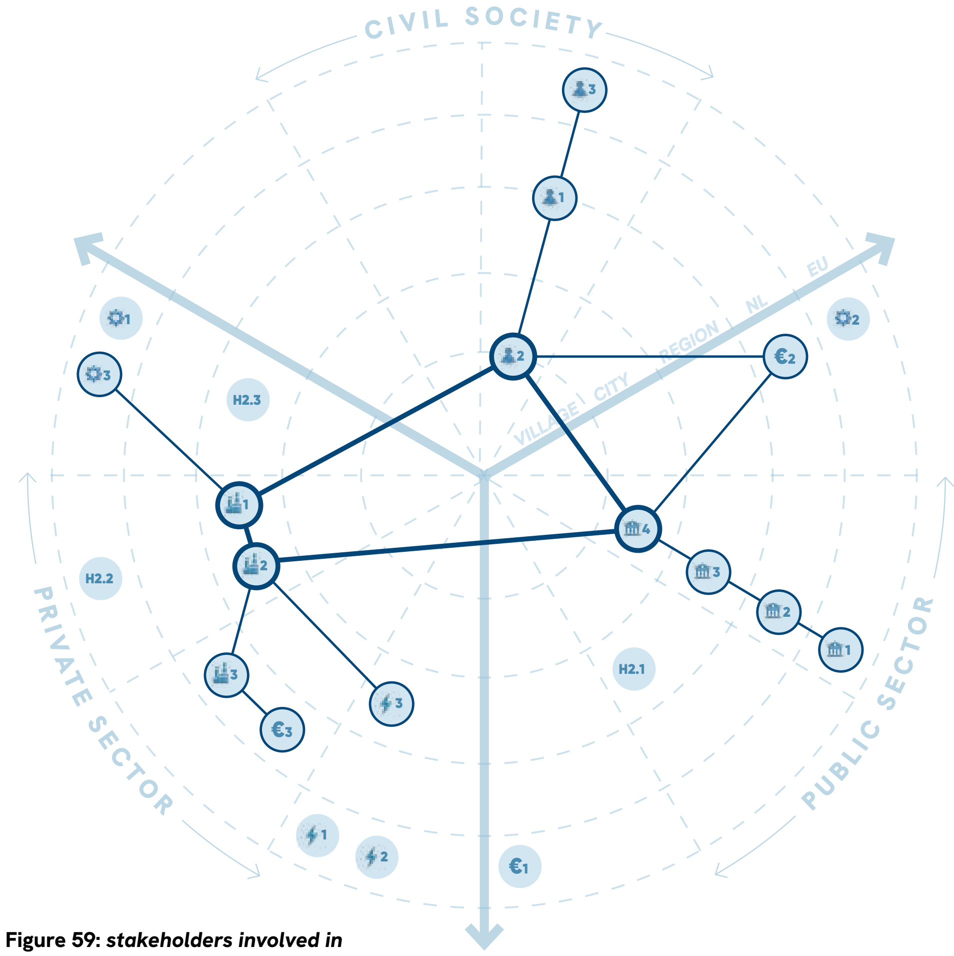


Figure 59: *stakeholders involved in 'as empowered as possible'*

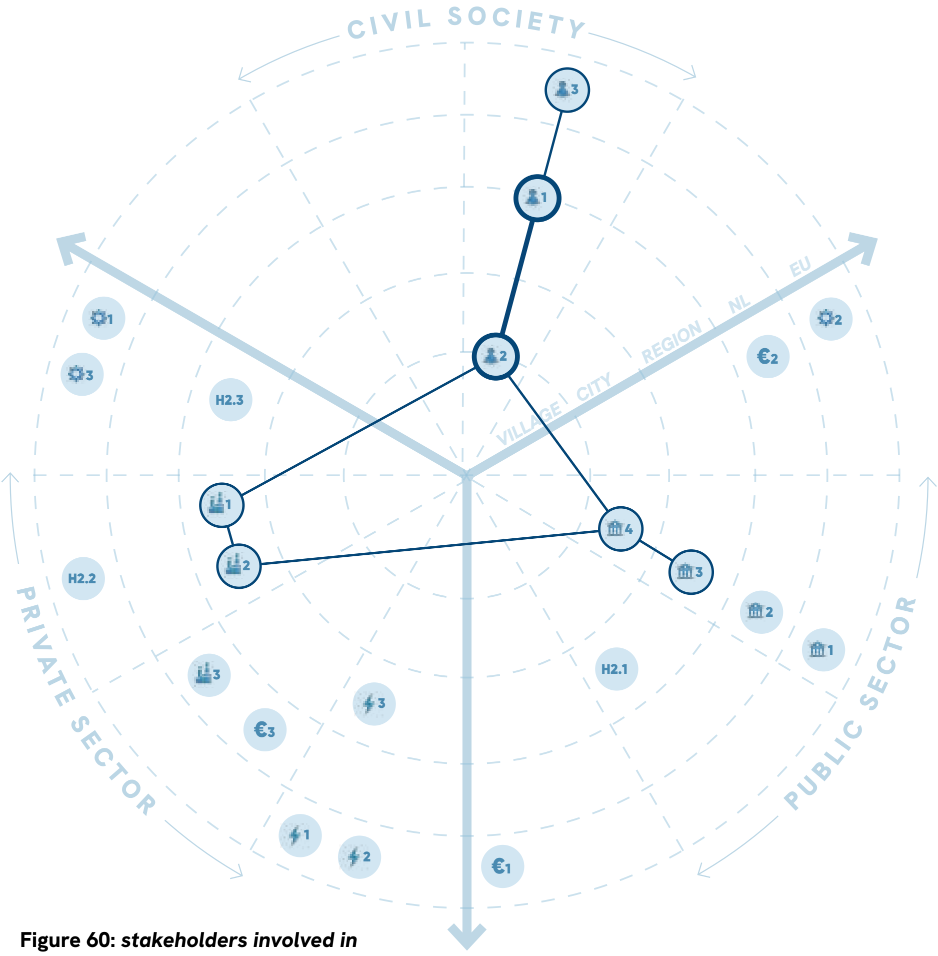


Figure 60: *stakeholders involved in 'as just as possible'*

LEGEND

- primary stakeholder
- secondary stakeholder
- primary connection
- secondary connection

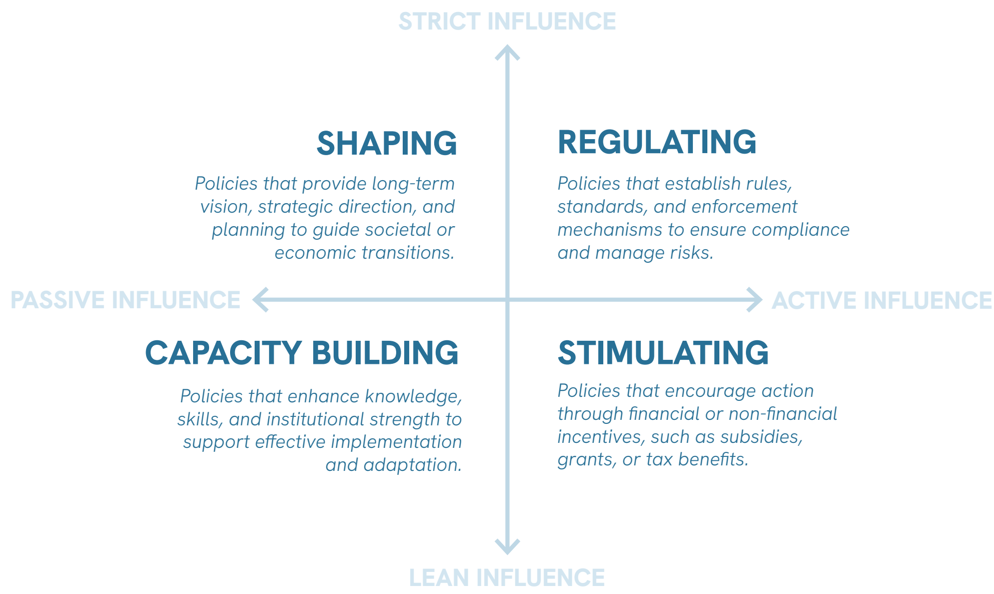


Figure 61: ***What does a governance structure provide?***
source: adapted from lecture, by Fred Hobma (2025)
SDS Lecture series - Dept. of Urbanism, Delft University

Figure 62: ***visualization of the community being informed on their empowerment via the H2 Council infosheet***

Figure 63: ***handouts of the H2 Council infosheet***
(see next page for a large version)

The establishment of a new governance structure is necessary to fill the gap with a fast but bottom-up solution for the energy transition.

At the moment, citizens' assemblies already exist in the Netherlands, where people come together to discuss and decide on important topics about their country, city, town or neighborhood. An example is Stichting G1000.nu, an independent organization created for and by citizens (Stichting G1000.nu, 2024). The G1000 Citizens' Assembly is a space where randomly selected citizens, the government and employers enter into dialogue with one another. It is seen as a supplement to the current democratic system, aiming to find shared and widely supported solutions. This should help build trust and lead to better decision-making. Over the past ten years, more than 30 G1000 assemblies have been held in various municipalities and regions across the Netherlands.

This kind of system provides clear insights into the needs, wishes and demands of the people who actually live and work in an area. However, the G1000 Citizens' Assembly is only advisory. In the end, it is up to the municipality or government to decide whether or not to use the outcomes of the participation process.

The energy transition will be a large and complex project, taking place across multiple scales. Participation projects and citizens' assemblies must not be overshadowed by governments and large companies making fast, cost-efficient decisions.

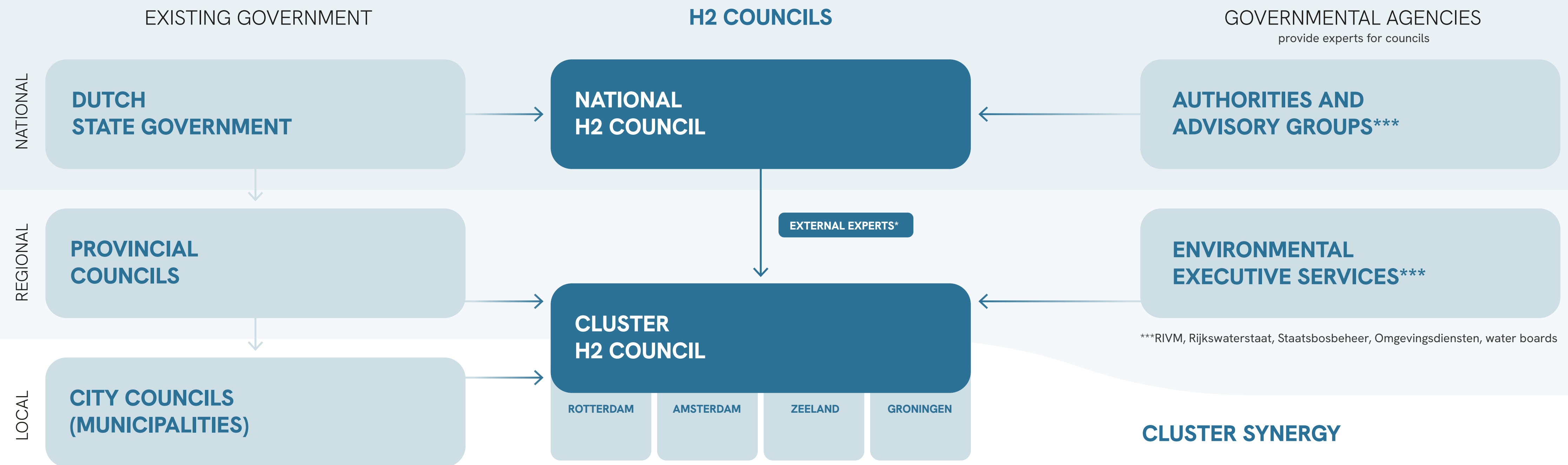
To give communities a stronger voice in the hydrogen transition, a Hydrogen Council is proposed. A National Hydrogen Council will develop the big-picture strategy and ensure nationwide coordination, but real decisions will take place in Regional Energy Transition Councils. These regional councils – made up of local experts, businesses, and community members – will decide how to use the land that is left behind by fossil fuel industries. They can choose to build hydrogen plants, invest in clean transport, or even turn old industrial areas into new green spaces.

This new system is fast, fair and bottom-up, giving local people control over their energy future. Instead of waiting for slow government decisions, regions can act quickly, guided by a national vision.

By combining fast top-down strategy with strong local participation, this new way of governing can accelerate the shift to clean energy, while making sure no community is left behind. This is not just about hydrogen; it's about building our shared future in a new and better way.

To communicate this with the community and other council members an infosheet has been made as hand-out. This could be distributed on information events.

H2 COUNCIL INFOSHEET



***RIVM, Rijkswaterstaat, Staatsbosbeheer, Omgevingsdiensten, water boards

Municipalities involved in zoning plans, permits and local citizen participation.

Clusters serve at an intermediate scale and work together with both municipalities and provinces. Councilors and provincial deputies are involved the cluster council as officials.

*national council appoints external experts to participate in regional councils

30 - 50 PEOPLE
based on cluster size

STRUCTURE OF NATIONAL H2 COUNCIL *(NATIONALE WATERSTOFRAAD)*

100%
EXPERTS
appointed by ministries**, council is assisted by an advisory group of national authorities and research agencies

Provides a chairperson to the regional council to chair the meetings.

**ministries:
infrastructure & water management
social affairs and employment
climate, policy & green growth
housing & spatial planning

STRUCTURE OF REGIONAL H2 COUNCIL *(REGIONALE WATERSTOFRAAD)*

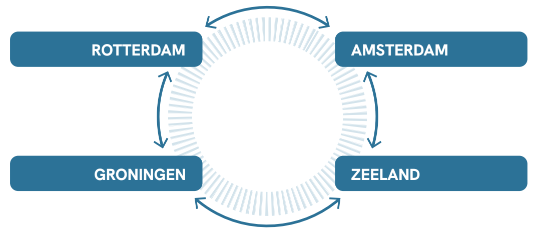
30% COMMUNITY	**30%** INDUSTRY	**20%** EXPERTS	**20%** REPRESENTATIVES
Community is chosen using a lottery system. Anyone within a 25km radius can apply to participate in the regional hydrogen council. In this way, citizen participation is embedded in decision-making. Outside the radius, it is still possible to participate in this council, but a letter of motivation must be approved in advance to enter the draw.	**Industries** are represented in this council through trade associations and trade unions. Delegates from industrial companies can also participate. This applies to both existing companies and new industries. Industries may represent their interests, but within the established climate frameworks, national & local regulations and the *'hydrogeneration'* vision.	**Experts** are appointed by the National Hydrogen Council and include sociologists, (urban) planners, biologists, real estate experts, climate & environmental consultants, mobility experts and economic advisors.	**Councilors & provincial deputies** guarantee a fair process for all by providing a publicly elected voice. In addition, they can share government plans and visions.

REPRESENTATIVES
Provide government budget at meetings and liaise with bodies such as the regional environmental executive services (regionale uitvoeringsdiensten).

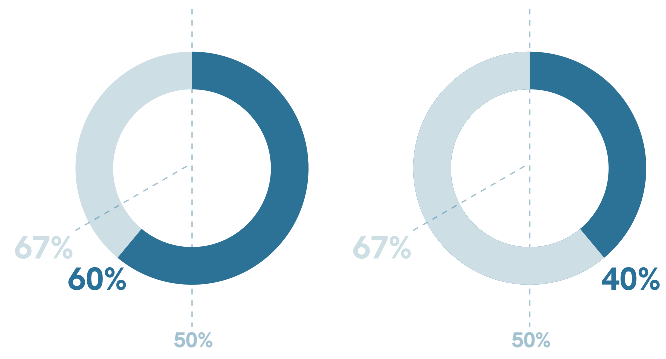
The hydrogen councils enable bottom-up creation of future living environments in which hydrogen is the main energy carrier. In the future, a lot of space will be freed up where fossil fuels are stored right now. This is a huge opportunity to redesign areas and make a living environment where people and industry live together. Therefore, we put the community and industry together at the helm in a new form of governance. In this way, the cluster's identity is shaped and/or strengthened by the community itself.

Figure 64: *H2 Council infosheet*

CLUSTER SYNERGY



Clusters cooperate among themselves by sharing knowledge, technology, expertise, strategies and funding projects.



COMMUNITY
INDUSTRY

EXPERTS
REPRESENTATIVES

TIMELINE & TASKS

1 **OIL-BASED INDUSTRY CLOSURE**
national council: establishing long-term vision
communication with stakeholders
legal procedures
final closure of an industry

2 **LAND BECOMES VACANT******
land survey & evaluation
land zoning
risk & opportunity assessment
****through buy-out or expropriation

3 **REGIONAL COUNCIL MEETS**
invite necessary experts for specific vacant area
identify policy restrictions & regulations
identify key priorities & wishes
design & vote on conceptual plans

4 **NATIONAL COUNCIL (DIS)APPROVES**
review & feedback on regional council plans
clarification requests
inspection by national authorities
reevaluation

5 **LOOKING BACK & FORWARD**
national council: updating long-term vision
evaluation on H2 council project
making adjustments to policies
introducing new policies

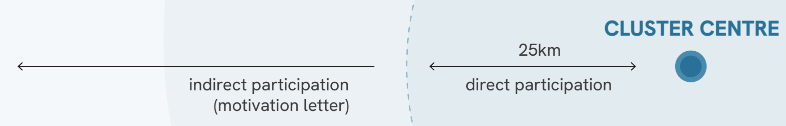
6 **PLANS GET EXECUTED**
funding & budgeting
project management & coordination
infrastructure & ecology (re)development
monitoring, reporting, launch

EMPOWERING THE PEOPLE

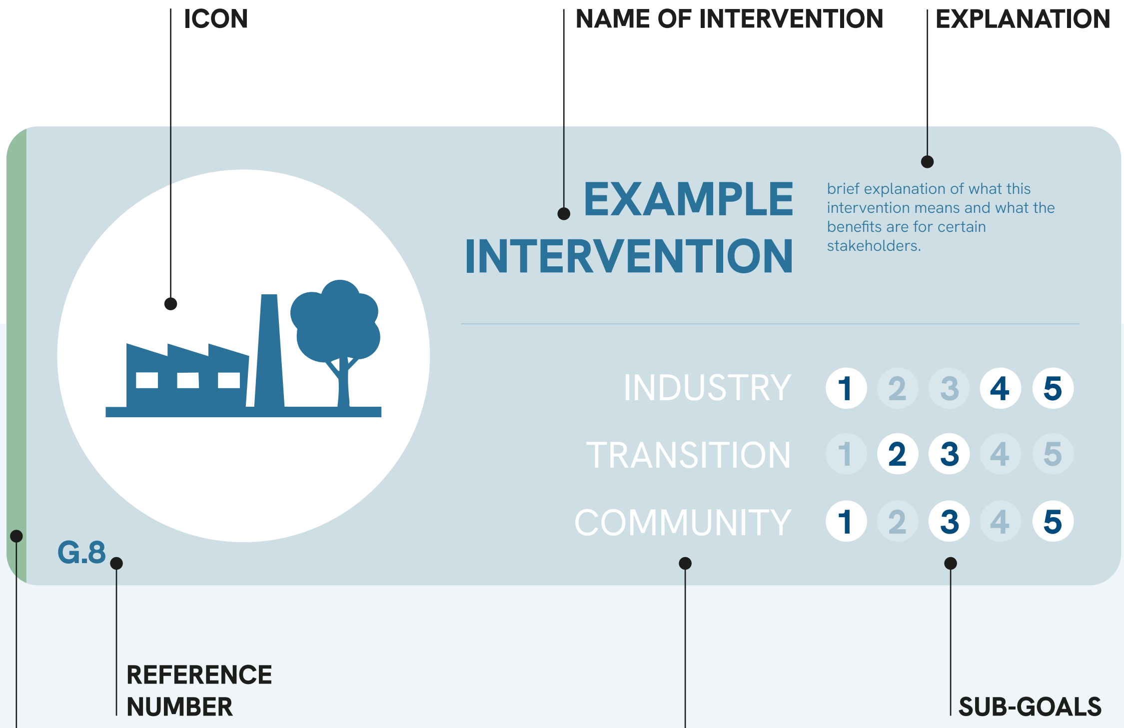
The distribution of seats in the council is based on a fair division between government, market and citizens. To give more voice to the community, they are directly included in decision-making. To promote **mutualism** between industry and community, both of these parties get 30% of the seats.

This means that in good consultation, a majority of 60% can be achieved for new plans by non-governmental parties. The plans made in the regional council are always based on expert advices and guidelines from the provincial states. For final decisions a majority of 67% is necessary. This means that experts and representatives can intervene at any time. Finally, the plans must also be defended at the national council before they can be implemented.

WHO CAN APPLY FOR A SEAT IN THE REGIONAL COUNCIL?



The hydrogen council, as explained, consists of four different parties. The difference in knowledge and expertise calls for an approach that gives these parties tools to start planning together. For this purpose, a toolkit has been developed in which various possible interventions are laid down in so-called 'intervention cards'. These are arranged in different categories. For each intervention, it has been made clear which goals it contributes to.



4 PARTIES SHAPING H2 GENERATION

INTERVENTION THEMES/COLOURS

- ECOLOGY
- HOUSING
- INCLUSIVITY
- AMENITY
- MOBILITY
- HYDROGEN
- ECONOMY

The different themes are based on potential interventions. By making these different classifications, we make the entire set of interventions more clear. What are the possibilities? What are all the different topics the council should focus on?

3 THEORETICAL FRAMEWORKS

INDUSTRY
INDUSTRIAL SYMBIOSIS (IS)

1. revitalizing current industries
2. net-zero emission
3. foster an industry culture like silicon valley
4. pioneering new industries
5. circular resource networks

TRANSITION
TRANSITION MANAGEMENT (TM)

1. stimulate innovation
2. learning and adaptation
3. multi-scalar implementations
4. stakeholder synergy
5. law and regulation

COMMUNITY
SOCIALLY JUST TRANSITION (SJT)

1. future-proof ecosystems
2. citizen participation
3. stakeholder engagement
4. equitable job opportunities
5. enabling daily life environment

INDUSTRY
INDUSTRIAL SYMBIOSIS

this theory contains the transformation of industries towards net-zero emissions by sharing resources, infrastructure and by-products.

TRANSITION
TRANSITION MANAGEMENT

by having sub-goals for transition management, we can make sure to change as rapid as possible, while involving all stakeholders properly.

COMMUNITY
SOCIALLY JUST TRANSITION

setting sub-goals for the community anchors wishes and bottom-up ideas in future plans.

TO WHICH SUB-GOALS DOES AN INTERVENTION CONTRIBUTE?

From the theoretical frameworks, sub-goals have been established. These are targets for industry, community and energy transition. For each intervention card, it has been made clear which goal this intervention contributes to.

+

MUTUALISM
BETWEEN INDUSTRY & COMMUNITY

Industry, **transition** and **community** are the three key elements in our vision. The industry and community sit down together to create a new balance in public space (mutualism). There is room to achieve this through energy transition. With a large-scale change from fossil to renewable, parts of the country can be redesigned.

GREEN INFRASTRUCTURE

GREEN CORRIDOR (G.1)
Establishing a strip of nature, connecting green spaces to support wildlife and provide environmental benefits.
- INDUSTRY **1** 2 3 4 5
- TRANSITION 1 2 **3** 4 5
- COMMUNITY **1** 2 3 4 **5**

RECREATIONAL ZONES (G.2)
An area designated for leisure activities, offering spaces for play, sports and relaxation.
- INDUSTRY 1 2 3 4 5
- TRANSITION 1 **2** 3 4 5
- COMMUNITY **1** **2** **3** 4 **5**

ECO-FRIENDLY INDUSTRY (G.3)
Businesses that minimize environmental impact through sustainable practices and technologies, for example hydrogen-based steel production.
- INDUSTRY **1** 2 3 4 5
- TRANSITION **1** **2** **3** 4 5
- COMMUNITY **1** 2 3 4 **5**

CONNECTING GREEN STRUCTURES (G.4)
Elements that link green spaces, enhancing ecological corridors and supporting biodiversity and the ecosystem in general.
- INDUSTRY **1** 2 3 4 5
- TRANSITION **1** **2** **3** 4 5
- COMMUNITY **1** 2 3 4 **5**

IMPROVING WATER QUALITY (G.5)
This intervention involves measures that reduce pollution and ensure the health of water bodies for both flora and fauna.
- INDUSTRY 1 2 3 4 5
- TRANSITION 1 2 3 4 5
- COMMUNITY **1** 2 3 4 **5**

GREEN BUFFER ZONE (G.6)
Vegetated areas that separate industry, reducing noise, pollution, and providing ecological benefits. Mainly used around industries or hydrogen storage. Combine with HY.6?
- INDUSTRY 1 2 3 4 5
- TRANSITION 1 2 3 4 5
- COMMUNITY **1** 2 3 4 **5**

*description of M.5:
Appointing areas where only vehicles and activities that produce no emissions are allowed, aiming to improve air quality and reduce pollution.

MOBILITY

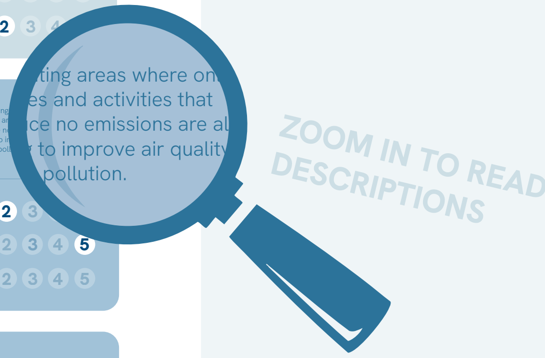
H2 FUEL STATION (M.1)
Facility that supplies hydrogen fuel for vehicles, supporting clean and sustainable transportation. Making H2 easy accessible to the people, both for private and public transport.
- INDUSTRY 1 **2** 3 4 5
- TRANSITION **1** **2** 3 4 5
- COMMUNITY **1** 2 **3** 4 5

SHARED MOBILITY HUB (M.2)
A central point offering various shared transport options like bikes, scooters, cars and public transport to promote sustainable, flexible travel. Combine with M.1?
- INDUSTRY 1 **2** 3 4 5
- TRANSITION 1 **2** 3 **4** 5
- COMMUNITY **1** 2 **3** 4 5

HYDROGEN VEHICLES (M.3)
Eco-friendly cars powered by hydrogen fuel cells, emitting only water vapor and supporting zero-emission transport. For public and private transport.
- INDUSTRY **1** 2 3 4 5
- TRANSITION **1** **2** **3** 4 5
- COMMUNITY **1** 2 **3** 4 5

IMPROVE INFRASTRUCTURE BETWEEN VILLAGES (M.4)
Enhancing roads, transportation, and communication networks to strengthen connectivity and support regional development.
- INDUSTRY **1** 2 3 4 5
- TRANSITION 1 2 3 4 5
- COMMUNITY **1** **2** 3 4

ZERO-EMISSION ZONES* (M.5)
Appointing vehicles ar produce n aiming to i reduce poll
- INDUSTRY 1 **2** 3
- TRANSITION 1 2 3 4 **5**
- COMMUNITY **1** 2 3 4 5



HYDROGEN LOGISTICS (M.6)
The obligation to use hydrogen-powered vehicles and infrastructure for goods transportation in specific areas, aiming to promote a sustainable supply chain.
- INDUSTRY **1** **2** **3** 4 5
- TRANSITION **1** 2 3 **4** **5**
- COMMUNITY 1 2 3 4 5

ENCOURAGE RENTALS TO USE H2 (M.7)
Forcing the adoption of hydrogen-powered vehicles in rental fleets, supporting cleaner transportation and reducing emissions.
- INDUSTRY 1 **2** 3 4 5
- TRANSITION **1** **2** 3 4 5
- COMMUNITY **1** 2 3 4 5

INCLUSIVITY

ACCESS TO H2 HEATING (I.1)
The availability of hydrogen-based systems for residential heating, providing a clean, efficient and cheap alternative to natural gas or oil.
- INDUSTRY 1 **2** **3** 4 5
- TRANSITION 1 **2** **3** **4** 5
- COMMUNITY **1** **2** 3 4 5

AWARENESS CAMPAIGNS (I.2)
Initiatives designed to educate and inform the public about important issues, promoting behavior change and increasing understanding of topics like hydrogen advantages.
- INDUSTRY 1 2 3 4 5
- TRANSITION 1 **2** 3 4 5
- COMMUNITY 1 **2** **3** 4 5

SOCIAL EQUITY H2 SUPPLY (I.3)
Ensuring fair access to hydrogen technologies and benefits across all communities, promoting inclusivity and addressing disparities.
- INDUSTRY 1 **2** 3 4 5
- TRANSITION 1 **2** 3 4 5
- COMMUNITY **1** **2** 3 4 5

ECONOMY

SELL EXCESS ELECTRICITY (E.1)
allowing individuals or businesses to sell surplus energy, often from renewable sources, back to the grid, promoting sustainability and supporting energy markets.
- INDUSTRY 1 2 **3** 4 5
- TRANSITION **1** **2** 3 4 5
- COMMUNITY **1** **2** 3 **4** **5**

HYDROGEN CREDITS (E.2)
Subsidies or money awarded to companies and individuals using hydrogen in an environmentally sustainable way, encouraging clean production and consumption.
- INDUSTRY 1 **2** 3 **4** **5**
- TRANSITION **1** **2** 3 **4** **5**
- COMMUNITY **1** **2** **3** 4 **5**

LOW ENERGY COST (E.3)
Making sure energy prices are affordable, by making power more accessible for households and businesses while supporting economic and sustainable development.
- INDUSTRY 1 2 3 4 5
- TRANSITION 1 2 3 **4** **5**
- COMMUNITY **1** **2** 3 4 **5**

CREATE NEW HYDROGEN JOB (E.4)
Developing employment opportunities in the hydrogen sector, supporting the green economy and workforce transition to clean energy.
- INDUSTRY 1 2 3 **4** **5**
- TRANSITION 1 **2** **3** 4 5
- COMMUNITY 1 2 3 4 5

ECO-TOURISM MANAGEMENT (E.5)
Using sites to showcase the hydrogen transition, attracting global visitors to see the mutualism and future possibilities of people living in the hydrogen age.
- INDUSTRY 1 2 3 **4** **5**
- TRANSITION 1 2 3 4 5
- COMMUNITY 1 **2** 3 4 5

COLOUR CODING:
- SPATIAL INTERVENTION
- POLICY INTERVENTION

HOUSING

RETROFITTING GAS IN H2 HOUSEHOLDS
Upgrading existing natural gas systems in homes to use hydrogen. The example 'ready-to-use H2 kettle' provides a heating solution without full infrastructure replacement.

INDUSTRY 1 **2** 3 4 5
TRANSITION **1** **2** **3** 4 5
COMMUNITY **1** **2** **3** 4 5

HO.1

STUDENT HOUSING
Affordable and accessible living spaces designed for students. This will also attract more education, causing community development near academic institutions.

INDUSTRY 1 2 3 4 5
TRANSITION 1 2 3 4 5
COMMUNITY **1** 2 **3** 4 **5**

HO.2

LABOUR HOUSING
Affordable accommodations for workers, preferably industrial workers, ensuring decent living conditions close to employment areas.

INDUSTRY 1 2 3 4 5
TRANSITION 1 2 3 4 5
COMMUNITY **1** 2 **3** 4 **5**

HO.3

SOCIAL HOUSING
implemented to provide affordable, secure homes for those in need, promoting social equity and reducing housing insecurity.

INDUSTRY 1 2 3 4 5
TRANSITION 1 2 3 4 5
COMMUNITY **1** 2 **3** 4 **5**

HO.4

HYDROGEN

BUILDING WIND TURBINES
Wind turbines can generate clean, renewable energy from wind that can be used to electrolize water for the production of hydrogen. NB: not in your backyard? where else?

INDUSTRY **1** **2** **3** **4** **5**
TRANSITION **1** 2 3 4 **5**
COMMUNITY **1** 2 3 **4** 5

HY.1

BUILDING SOLAR PANELS
Producing clean electricity for hydrogen production. They should be placed in areas with high solar exposure, such as rooftops or underutilized land, to maximize efficiency.

INDUSTRY **1** **2** **3** **4** **5**
TRANSITION **1** 2 3 4 **5**
COMMUNITY **1** 2 3 **4** 5

HY.2

BUILDING TIDAL TURBINE
Devices that harness the energy from tidal movements to generate electricity, again, also a sustainable way of electricty production to use for production of green hydrogen.

INDUSTRY **1** **2** **3** **4** **5**
TRANSITION **1** 2 3 4 **5**
COMMUNITY **1** 2 3 **4** 5

HY.3

USING BIOMASS
Converting organic materials like plants and animal waste into energy. This provides a renewable fuel source, that could be used in the chain of H2 production.

INDUSTRY **1** **2** **3** **4** **5**
TRANSITION **1** 2 3 4 **5**
COMMUNITY **1** 2 3 **4** 5

HY.4

ELECTROLYZER
This machine uses electricity to split water into hydrogen and oxygen through electrolysis. Be aware of the risks and size of the installations.

INDUSTRY **1** **2** **3** **4** **5**
TRANSITION **1** 2 3 4 5
COMMUNITY **1** **2** 3 4 5

HY.5

HYDROGEN STORAGE
High-pressure tanks, designed to safely store hydrogen for transportation and distribution. The high safety standards don't mean that this is something for your backyard, at least not at a large scale.

INDUSTRY **1** **2** **3** **4** **5**
TRANSITION **1** **2** **3** 4 5
COMMUNITY **1** 2 3 4 5

HY.6

HYDROGEN INFRASTRUCTURE
The network of pipelines required to transport and distribute hydrogen. Most of it will be sub-surface. Be aware of maintenance issues!

INDUSTRY **1** **2** **3** **4** **5**
TRANSITION **1** **2** 3 4 **5**
COMMUNITY **1** 2 3 4 5

HY.7

AMENITY

RESEARCH QUARTER
Creating innovation, economic growth, and jobs by fostering collaboration between academic institutions, businesses and the government.

INDUSTRY 1 2 3 **4** **5**
TRANSITION **1** **2** 3 **4** 5
COMMUNITY 1 **2** 3 **4** **5**

AM.1

UNIVERSITY AND SCHOOLING
Educating the next generation of engineers, scientists, and policy-makers, driving innovation, research, and a skilled workforce needed for the 'hydrogen age'.

INDUSTRY 1 2 3 **4** **5**
TRANSITION **1** **2** 3 4 5
COMMUNITY 1 **2** 3 **4** **5**

AM.2

SPORT FACILITIES
Improving physical and mental health and community engagement, fostering a sense of unity and belonging. Good for creation of specific identities.

INDUSTRY 1 2 3 4 **5**
TRANSITION 1 2 3 4 5
COMMUNITY 1 **2** 3 4 **5**

AM.3

PILOT SPACE FOR EXPERIMENTATION
A controlled environment to test new ideas, technologies, processes or bottom-up initiatives on a small scale before full implementation.

INDUSTRY 1 2 3 **4** **5**
TRANSITION **1** **2** 3 **4** 5
COMMUNITY **1** **2** **3** **4** **5**

AM.4

UPSKILL CENTERS
Providing training and development programs to help individuals acquire new skills for better employability and supporting workforce adaptation.

INDUSTRY **1** 2 3 4 5
TRANSITION **1** **2** 3 4 5
COMMUNITY 1 **2** 3 **4** 5

AM.5

HYDROGEN ENTREPRENEURSHIP
The Hydrogen Council empowers the community to create their own small scale businesses at the grassroots level.

INDUSTRY 1 2 3 **4** **5**
TRANSITION **1** **2** 3 **4** **5**
COMMUNITY 1 2 **3** **4** 5

AM.6

REGULATIONS FOR EXPERIMENTATION
Guidelines and safety standards that ensure scientific hydrogen experiments are conducted ethically, safely, and in compliance with legal requirements.

INDUSTRY 1 2 3 **4** **5**
TRANSITION **1** **2** 3 4 **5**
COMMUNITY **1** 2 3 4 5

AM.7

This toolkit is made to encourage you to combine interventions and look for possible combinations and the way the cooperate or counteract.

New ideas? Cool! Be aware to which sub-goal(s) it contributes.

INTERVENTION?

NEW IDEAS?
This toolkit is made to encourage you to combine interventions and look for possible combinations. New ideas? Cool! Be aware to which sub-goal(s) it contributes.

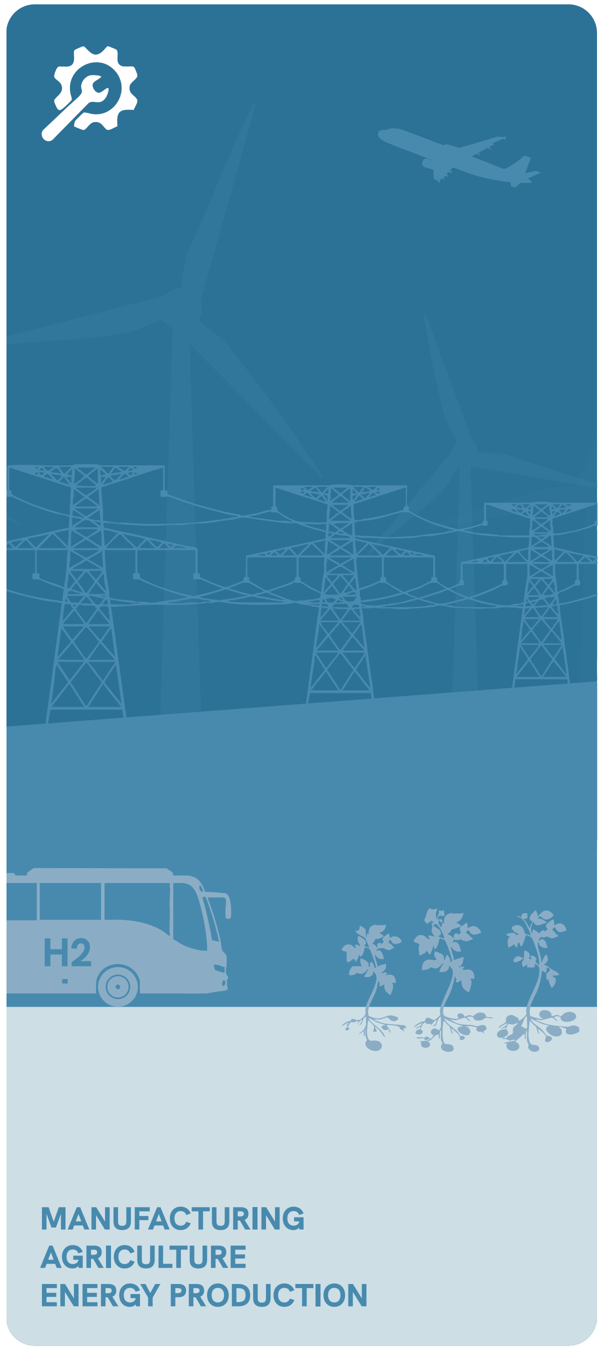
INDUSTRY **1** **2** **3** **4** **5**
TRANSITION **1** **2** **3** **4** **5**
COMMUNITY **1** **2** **3** **4** **5**

X.?

COLOUR CODING:

SPATIAL INTERVENTION

POLICY INTERVENTION



GRONINGEN

Groningen is a region with a strong industrial identity, focusing on energy production, especially from sustainable and renewable sources like wind and green hydrogen. The region is also known for its agriculture sector, with new ideas in sustainable farming and food production. It is also a centre for hydrogen technologies, including the development and production of hydrogen-powered public transport and even hydrogen-fueled airplanes in the future.

ZEELAND

Zeeland is known for its many chemical refineries, which produce essential chemicals and fuels. These refineries are often key players in the region's economy. The agriculture industry is also important in Zeeland. It is using environmentally friendly farming methods. This industry is very important for the region's food supply. The region also has a rich fishing industry, benefiting from its coastal location and playing a central role in both local economies and the European seafood market.

ROTTERDAM

Rotterdam's industrial cluster is a major energy production hub, particularly for oil, natural gas and renewable energy sources like wind and solar. The city also has many modern research organisations that work on new ideas for energy, sustainability and environmental technologies. This makes Rotterdam a leader in researching green hydrogen. Rotterdam is also Europe's largest port, and its cargo logistics infrastructure is very important for global trade and distribution.

AMSTERDAM

The cluster between IJmuiden and Amsterdam has a strong industrial identity. It is known for its focus on (green) steel production. This means it uses the latest technologies to reduce carbon emissions in the steel industry. It also wants to be a leader in sustainable manufacturing. The city also plays a key role in transporting goods, benefiting from its strategic location with one of Europe's busiest ports, which makes it easy to trade and distribute goods around the world.

Figure 65: *interventions in Rotterdam cluster mapped*
(corresponding to the images on next two pages)

6.5 FRAMEWORK FOR IMPLEMENTATION

BUILDING IDENTITY UPON INDUSTRIAL EXPERTISE

To demonstrate how the intervention cards can be used by the community within the council, the city of Rotterdam is taken as a case study. Before the council can make informed choices regarding the intervention cards, it is essential that members first become familiar with the spatial typology of the area and understand the logic behind the selection of specific cards.

For each category, such as green infrastructure, mobility and others, a set of guiding questions has been formulated to help develop a clearer understanding of the location. The three sample questions presented are merely indicative of the kinds of inquiries that may be posed. Within the council, members can engage in discussions to determine which spatial typologies are most relevant or valuable to them. Additionally, these questions can provide insight into the existing structure and identify elements that may need to be reconsidered or removed upon the potential introduction of hydrogen. This process supports a more informed and nuanced evaluation of which interventions are most desirable and suitable.

In addition to the questions (see page 114 & 116), four cards are presented, each accompanied by images depicting the current situation. A separate map (see Figure 65) indicates where these images were taken. This simplified approach aims to provide council members with a clearer understanding of the existing urban structure, aiding them in answering the guiding questions.

Finally, on page 118-121 a series of intervention sets are shown for each category. These serve as examples of possible combinations and can function as guidelines or inspiration for the council to shape their own identity.

ROTTERDAM

GREEN INFRASTRUCTURE

Is the quality of the current green structure good enough?

Are the current green structures diverse?

Do the green structures facilitate habitats for wildlife?

MOBILITY

Do you think the villages and industry are well connected?

Is it easy to use different kind of transportation?

Do you have easy access to public transportation?

HOUSING

Is there a mixed program of housing, for example social housing, student housing, etc.?

Would people who work in the industry prefer to live close by?

Would you consider using hydrogen for heating in your house?


1 Landtong Rozenburg


2 Tenellaplas


3 Maasvlakte Beach


4 polder Oosterland


1 parking / metro Hoek van Holland


2 parking Maasvlakte


3 highway A15 / railway Europoort


4 busstation / mobility hub


1 Rozenburg


2 Maassluis


3 Brielle


4 Hoek van Holland

Figure 66: *interventions in Rotterdam cluster per intervention theme*
source: Google Maps (2025)

ROTTERDAM

AMENITY

Are there enough recreation areas, like sport facilities or bike routes?

Do you think there should be more schools?

Are there supermarkets or restaurants that you can visit?

INDUSTRY

Does this cluster have fossil fuels industry?

Does this cluster have existing manufacturing plants?

Does this cluster have existing refineries?

1 sport facilities Geuzepark

2 School Maerlant

3 supermarket Albert Heijn / Jumbo

4 restaurants Oostvoorne

1 cargo

2 liquid storage

3 container storage

4 warehouses

Figure 67: *interventions in Rotterdam cluster per intervention theme*
source: Google Maps (2025)

ROTTERDAM

GREEN INFRASTRUCTURE

GREEN CORRIDOR

Establishing a strip of nature, connecting green spaces to support wildlife and provide environmental benefits.

INDUSTRY **1** 2 3 4 5
TRANSITION 1 2 **3** 4 5
COMMUNITY **1** 2 3 4 **5**

G.1

ECO-FRIENDLY INDUSTRY

Businesses that minimize environmental impact through sustainable practices and technologies, for example hydrogen-based steel production.

INDUSTRY **1** 2 3 4 5
TRANSITION **1** **2** **3** 4 5
COMMUNITY **1** 2 3 4 **5**

G.3

IMPROVING WATER QUALITY

This intervention involves measures that reduce pollution and ensure the health of water bodies for both flora and fauna.

INDUSTRY 1 2 3 4 5
TRANSITION 1 2 3 4 5
COMMUNITY **1** 2 3 4 **5**

G.5

MOBILITY

H2 FUEL STATION

Facility that supplies hydrogen fuel for vehicles, supporting clean and sustainable transportation. Making H2 easy accessible to the people, both for private and public transport.

INDUSTRY 1 **2** 3 4 5
TRANSITION **1** **2** 3 4 5
COMMUNITY **1** 2 **3** 4 5

M.1

SHARED MOBILITY HUB

A central point offering various shared transport options like bikes, scooters, cars and public transport to promote sustainable, flexible travel. Combine with M.1?

INDUSTRY 1 **2** 3 4 5
TRANSITION 1 **2** 3 **4** 5
COMMUNITY **1** 2 **3** 4 5

M.2

HYDROGEN LOGISTICS

The obligation to use hydrogen-powered vehicles and infrastructure for goods transportation in specific areas, aiming to promote a sustainable supply chain.

INDUSTRY **1** **2** **3** 4 5
TRANSITION **1** 2 3 **4** **5**
COMMUNITY 1 2 3 4 5

M.6

HOUSING

STUDENT HOUSING

Affordable and accessible living spaces designed for students. This will also attract more education, causing community development near academic institutions.

INDUSTRY 1 2 3 4 5
TRANSITION 1 2 3 4 5
COMMUNITY **1** 2 **3** 4 **5**

HO.2

LABOUR HOUSING

Affordable accommodations for workers, preferably industrial workers, ensuring decent living conditions close to employment areas.

INDUSTRY 1 2 3 4 5
TRANSITION 1 2 3 4 5
COMMUNITY **1** 2 **3** 4 **5**

HO.3

SOCIAL HOUSING

implemented to provide affordable, secure homes for those in need, promoting social equity and reducing housing insecurity.

INDUSTRY 1 2 3 4 5
TRANSITION 1 2 3 4 5
COMMUNITY **1** 2 **3** 4 **5**

HO.4

AMENITY

RESEARCH QUARTER (AM.1)
Creating innovation, economic growth, and jobs by fostering collaboration between academic institutions, businesses, and the government.

INDUSTRY 1 2 3 **4** **5**
TRANSITION **1** **2** 3 **4** 5
COMMUNITY 1 **2** 3 **4** **5**

UNIVERSITY AND SCHOOLING (AM.2)
Educating the next generation of engineers, scientists, and policy-makers, driving innovation, research, and a skilled workforce needed for the 'hydrogen age'.

INDUSTRY 1 2 3 **4** **5**
TRANSITION **1** **2** 3 4 5
COMMUNITY 1 **2** 3 **4** **5**

PILOT SPACE FOR EXPERIMENTATION (AM.4)
A controlled environment to test new ideas, technologies, processes or bottom-up initiatives on a small scale before full implementation.

INDUSTRY 1 2 3 **4** **5**
TRANSITION **1** **2** 3 **4** 5
COMMUNITY **1** **2** **3** **4** **5**

HYDROGEN

ELECTROLYZER (HY.5)
This machine uses electricity to split water into hydrogen and oxygen through electrolysis. Be aware of the risks and size of the installations.

INDUSTRY **1** **2** **3** **4** **5**
TRANSITION **1** 2 3 4 5
COMMUNITY **1** **2** 3 4 5

HYDROGEN STORAGE (HY.6)
High-pressure tanks, designed to safely store hydrogen for transportation and distribution. The high safety standards don't mean that this is something for your backyard, at least not at a large scale.

INDUSTRY **1** **2** **3** **4** **5**
TRANSITION **1** **2** **3** 4 5
COMMUNITY **1** 2 3 4 5

HYDROGEN INFRASTRUCTURE (HY.7)
The network of pipelines required to transport and distribute hydrogen. Most of it will be sub-surface. Be aware of maintenance issues!

INDUSTRY **1** **2** **3** **4** **5**
TRANSITION **1** **2** 3 4 **5**
COMMUNITY **1** 2 3 4 5

INCLUSIVITY

ACCESS TO H2 HEATING (I.1)
The availability of hydrogen-based systems for residential heating, providing a clean, efficient and cheap alternative to natural gas or oil.

INDUSTRY 1 **2** **3** 4 5
TRANSITION 1 **2** **3** **4** 5
COMMUNITY **1** **2** 3 4 5

AWARENESS CAMPAIGNS (I.2)
Initiatives designed to educate and inform the public about important issues, promoting behavior change and increasing understanding of topics like hydrogen advantages.

INDUSTRY 1 2 3 4 5
TRANSITION 1 **2** 3 4 5
COMMUNITY 1 **2** **3** 4 5

SOCIAL EQUITY H2 SUPPLY (I.3)
Ensuring fair access to hydrogen technologies and benefits across all communities, promoting inclusivity and addressing disparities.

INDUSTRY 1 **2** 3 4 5
TRANSITION 1 **2** 3 4 5
COMMUNITY **1** **2** 3 4 5

ECONOMY

SELL EXCESS ELECTRICITY (E.1)
allowing individuals or businesses to sell surplus energy, often from renewable sources, back to the grid, promoting sustainability and supporting energy markets.

INDUSTRY 1 2 **3** 4 5
TRANSITION **1** **2** 3 4 5
COMMUNITY **1** **2** 3 **4** **5**

CREATE NEW HYDROGEN JOB (E.4)
Developing employment opportunities in the hydrogen sector, supporting the green economy and workforce transition to clean energy.

INDUSTRY 1 2 3 **4** **5**
TRANSITION 1 **2** **3** 4 5
COMMUNITY 1 2 3 4 5

ECO-TOURISM MANAGEMENT (E.5)
Using sites to showcase the hydrogen transition, attracting global visitors to see the mutualism and future possibilities of people living in the hydrogen age.

INDUSTRY 1 2 3 **4** **5**
TRANSITION 1 2 3 4 5
COMMUNITY 1 **2** 3 4 5

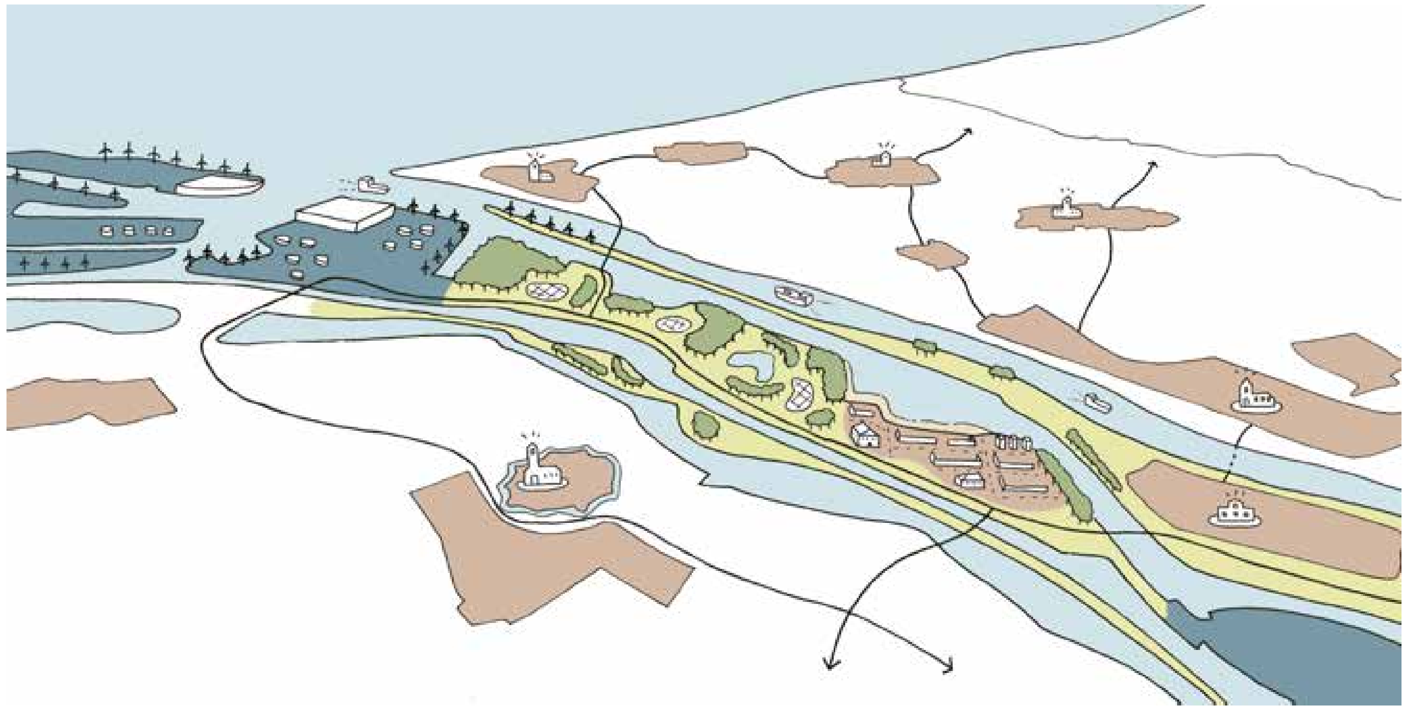


Figure 68: ***possible outcome for experiment island 1 based on different interventions according to intervention toolkit***

KNOWLEDGE ECONOMY EMBEDDED IN NATURE

M.1 M.2 M.4 M.7 G.1 G.2 G.3 G.4 G.5
E.2 E.4 E.5 HY.1 HY.2 HY.5 HY.6 HY.7
HO.2 HO.3 HO.4 AM.1 AM.2 AM.3 AM.4 AM.5

Figure 69: ***possible outcome for experiment island 2 based on different interventions according to intervention toolkit***

HYDROGEN INDUSTRIAL CORE: JOB GENERATOR

E.1 E.2 E.3 E.4 M.3 M.6 G.3 G.6
I.1 I.2 I.3 HY.1 HY.2 HY.3 HY.5 HY.6
HO.2 AM.1 AM.2 AM.5

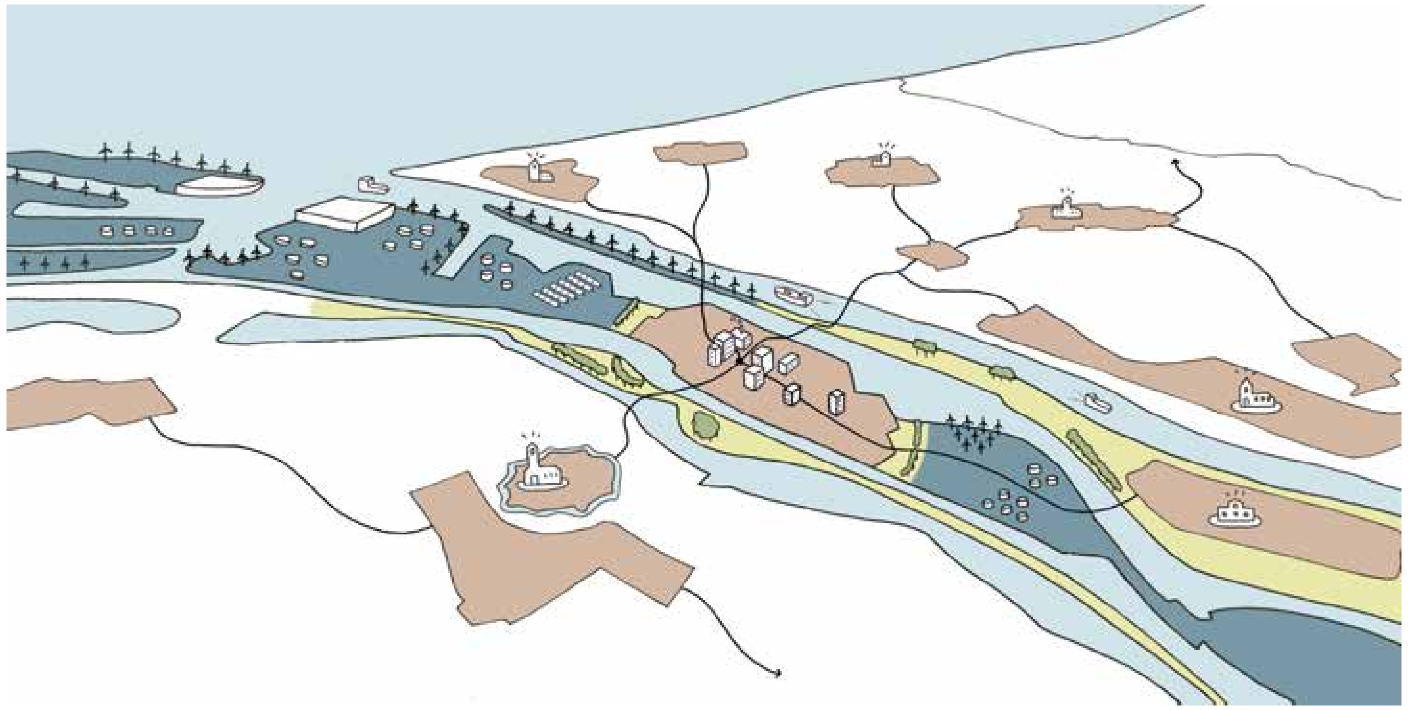


Figure 70: ***possible outcome for experiment island 3 based on different interventions according to intervention toolkit***

SECOND CITY CENTRE OF ROTTERDAM

M.1 M.2 M.3 M.4 M.5 M.6 M.7 G.2 G.6
E.1 E.2 E.4 E.5 HY.1 HY.2 HY.5 HY.7
HO.2 HO.3 HO.4 AM.1 AM.2 AM.3 AM.5

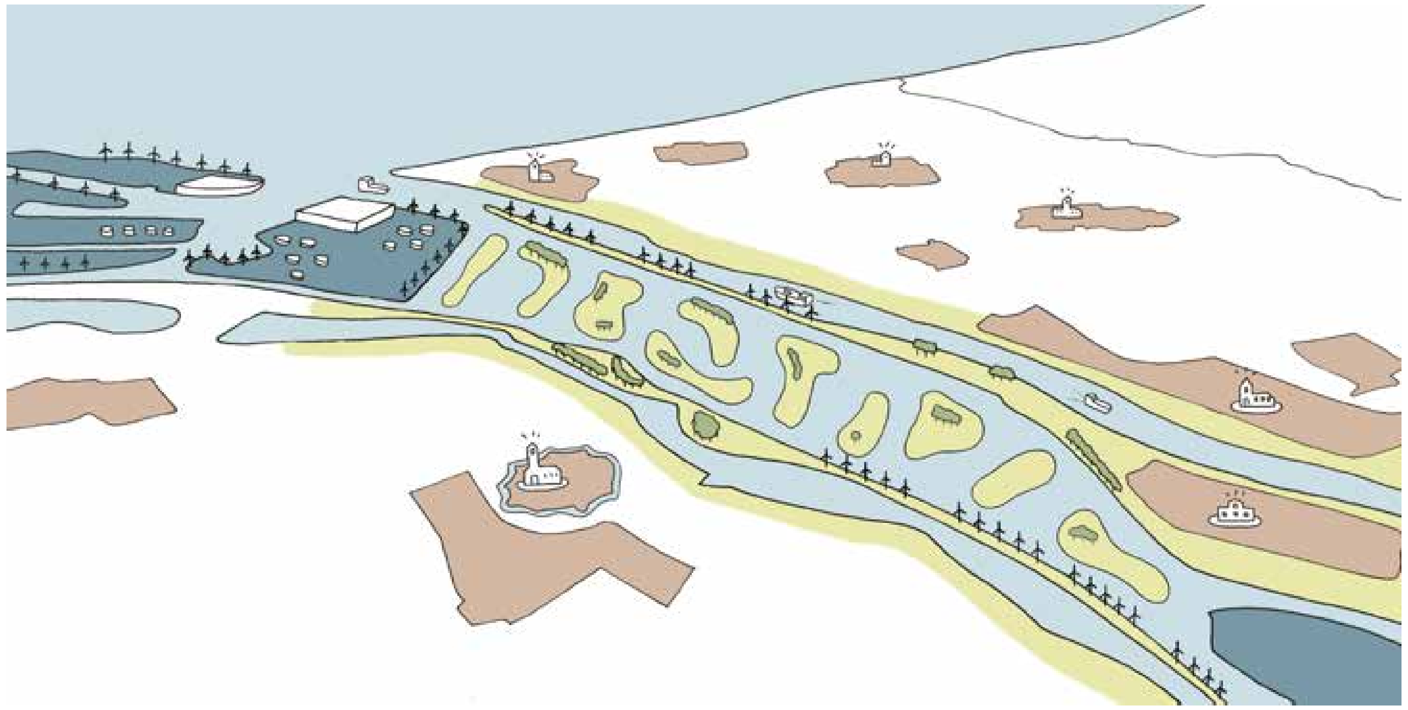


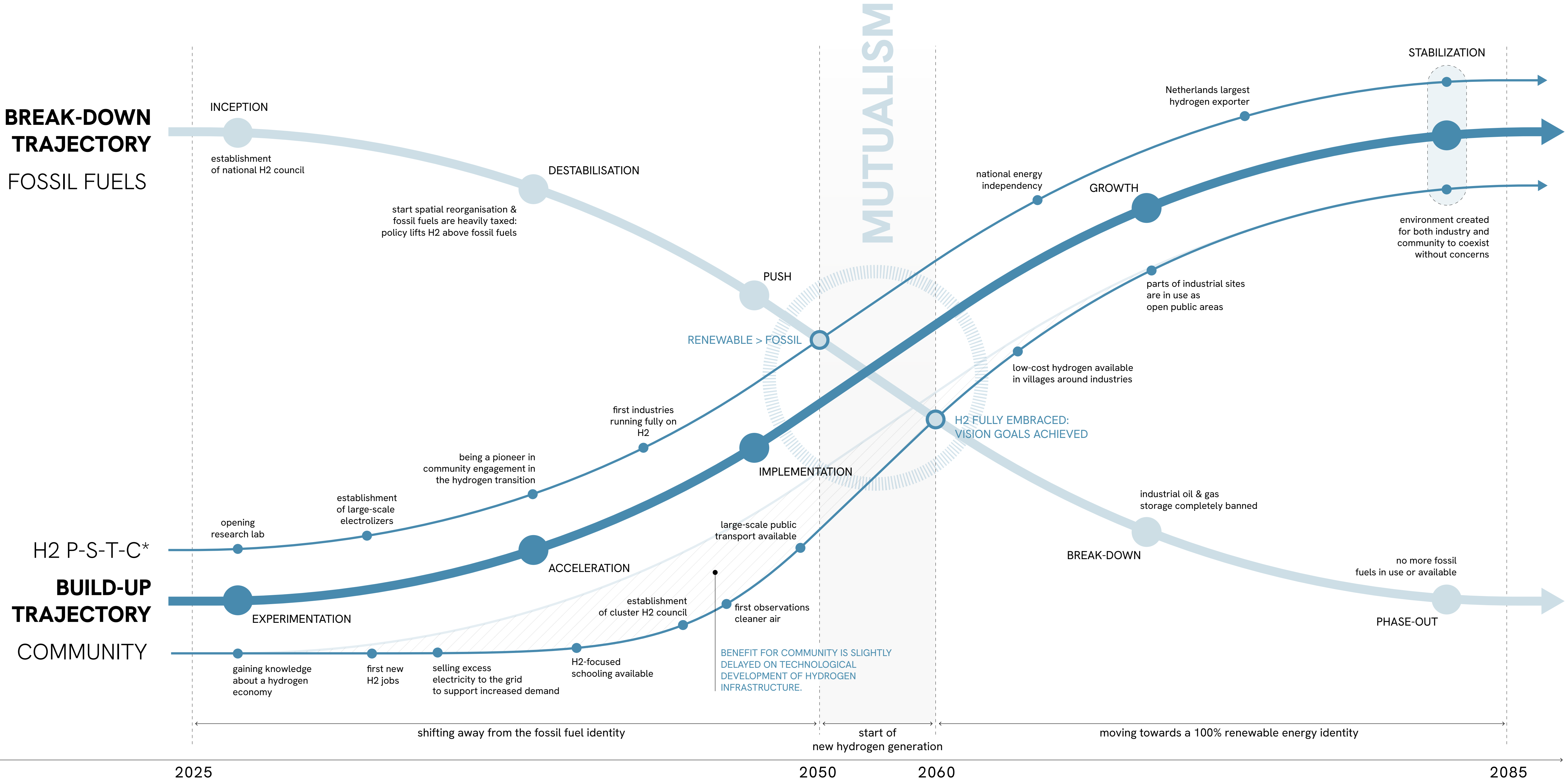
Figure 71: ***possible outcome for experiment island 4 based on different interventions according to intervention toolkit***

ROTTERDAM'S HARBOUR WETLANDS

I.1 I.2 I.3 M.5 G.1 G.4 G.5
HY.1 HY.2 HY.3 HY.4 HY.5 HY.6
E.4 E.5 HO.1 AM.3 AM.4

6.6 PHASES OF IMPLEMENTATION: TRANSITION CURVE

AN X-CURVE OF THE BUILD-UP TOWARDS STABILIZED MUTUALISM



*Production, Storage, Transport, Consumption

Figure 72: ***key points of the build-up of the H2-economy and the break-down of fossil economy***

In particular, the experimental phase will investigate the ways in which hydrogen can be implemented in the urban landscape. For the community, this mainly creates research jobs.

Making different policies can speed up hydrogen implementation. By establishing a hydrogen council, the community becomes more involved in the redevelopment of their environment. Accelerating towards a point where H2 is more convenient than fossil fuels.

CO2 regulatory laws are doing their job and give a push to the elimination of emitting fuels. The new hydrogen landscape is being defined by community and industry. This phase creates a balanced environment where people live with industry, rather than alongside industry.

Mutualism grows and people adopt industrial areas as their habitat. Industry is not banned: areas are emerging where industry is embedded in the landscape without significant inconvenience to humans.

At this stage, industry offers only positive points for humans. Fossil fuels have been completely eliminated. The hydrogen council has only a regulatory function left. The Netherlands has a strong economical position due to its H2 leadership over the years.

→ EXPERIMENTATION → ACCELERATION → **MUTUALIZATION** → GROWTH → STABILIZATION

6.7 TIMELINE & PHASING STRATEGY

GOVERNANCE, POLICY & SPATIAL INTERVENTIONS

Anchor - Key intervention which provides a strong foundation for the phase

Driver - Key intervention which is constantly shifting the dynamic forward

Milestones - Key moments in time signifying end points of certain interventions

Interventions - Spatial / policy interventions

PHASE 01 - Activating Communities & Infrastructure for H2 Inclusion

The first phase focuses on engaging local communities and developing the essential infrastructure required to integrate hydrogen into the existing energy landscape. This includes raising awareness and fostering public support for hydrogen technologies, along with the establishment of Hydrogen council and small-scale hydrogen production facilities. The goal is to create a foundational framework that incorporates hydrogen into existing systems, ensuring its feasibility in local contexts. The infrastructure focus involves retrofitting pipelines, upgrading energy grids and establishing early-stage hydrogen storage facilities, allowing the smooth inclusion of hydrogen into the broader energy mix.

PHASE 02 - Communities Embracing H2 & Large-Scale H2 Infrastructure

In this phase, the focus shifts to scaling up H2-infrastructure and increasing community adoption. With the foundation established in Phase 01, hydrogen technology becomes more mainstream, and the community begins the hydrogen entrepreneurship for grassroots hydrogen adoption. Large-scale hydrogen production plants are developed and robust distribution networks are built. The region begins to rely more on hydrogen for various sectors, including industry, mobility and heating. Efforts also expand to include training programs and public-private partnerships to ensure that local communities are equipped with the knowledge and skills to manage the new energy paradigm. This phase marks a significant shift towards hydrogen being a central part of daily life.

PHASE 03 - Hydrogen Identity of NL & Export of H2

At this stage, the Netherlands solidifies its role as a key player in the global hydrogen market. Rotterdam's identity is shaped around hydrogen, not only as an energy source but also as a critical economic driver. The city becomes a hub for hydrogen production, distribution and innovation. Export routes for hydrogen are developed, turning Rotterdam into a leading exporter of green hydrogen, positioning it as a vital component of international energy markets. Investments in hydrogen technology research and development further reinforce this transition, creating a competitive advantage for the city while promoting sustainability across Europe and beyond.

PHASE 04 - Agency Building and Transition Framework & Freedom of Interventions

The final phase empowers local communities and industries by building the agency to continue driving the hydrogen transition. A comprehensive transition framework is established to guide further innovations and policy-making, ensuring that hydrogen adoption remains aligned with sustainability goals. This phase allows for greater flexibility and freedom for stakeholders to explore new interventions and solutions that adapt to evolving needs. Industries, local authorities and communities are given the autonomy to experiment with novel hydrogen technologies and strategies, ensuring that future interventions remain dynamic and responsive to changes in both the local and global energy landscapes.

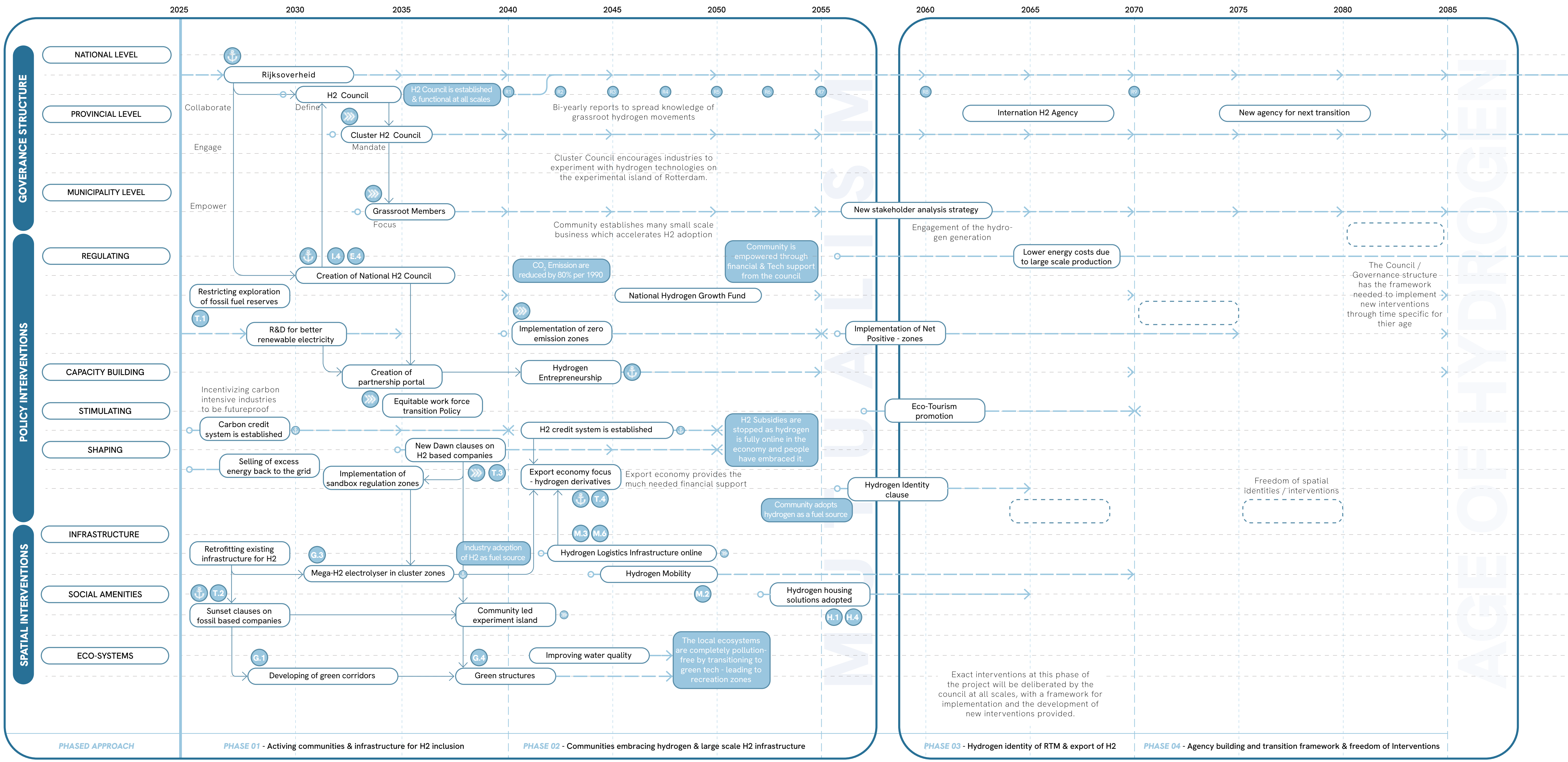


Figure 73: *detailed timeline towards the Age of Hydrogen*

EXPERIMENTATION → ACCELERATION → **MUTUALIZATION** → GROWTH → STABILIZATION

H2-ECONOMY WITH MOBILITY AND EDUCATION

Figure 74: ***Visualization of The Age of Hydrogen with H2-education, H2-mobility and H2-infrastructure merged together in the built environment.***

H2-COUNCIL CHECKING THEIR RECENTLY IMPLEMENTED PLANS

Figure 75: ***Visualization of The Age of Hydrogen: the H2 Council reporting and evaluating their recently implemented plans they made together (2045).***

H2-INDUSTRY AND LEISURE IN COEXISTENCE

Non-copyrighted images and AI-generated images are used for making these collages.

With the use of the intervention cards, the community can shape a future vision that fits the identity of the city and its people. This creates a living environment where industry, community and nature are once again in balance.

People can enjoy and relax in the former port area, which has been turned into a clean and natural space, while at the same time, hydrogen is being produced and stored there. Hydrogen becomes part of the landscape, but also part of the city and society. Universities and new high schools are built where students can learn about the energy source of the future from a young age.

Former workers from the fossil fuel sector have followed retraining programs, allowing them to find new jobs in a future-proof sector. Enough employment has been created for the local community and for their children in the future. And where will all these new workers live? That is something the community can help decide. A new urban center could be built in the port area, with facilities that also benefit surrounding villages. Existing villages could be expanded to keep their services sustainable. Space could be opened up in the western port area to give the current city center of Rotterdam room to grow. Or the Hydrogen Council might come up with a completely different, radical idea.

The most important thing is that the community can be proud of their city and their environment again. Through the Hydrogen Council, they can actively contribute to their own future and that of their children.

Get ready for The Age of Hydrogen.

Figure 76: ***H2-industry and people enjoying their free time in nature: a compatible fit.***

H2

TOWARDS CLEAN ENERGY
A hundred years ago, Rotterdam changed the world with industry.
Now hydrogen changes the industry for the world.

7

ANSWERING THE QUESTIONS

CONCLUSIONS
What are the main findings on how both people their power and their environment will change within the energy transition to hydrogen?

How can future spatial strategies enable the integration of hydrogen as an energy source to improve socioeconomic conditions of the communities along the existing industrial clusters? To provide a conclusion, several sub-questions were answered through media, literature and spatial analyses.

community

1. What are the key characteristics of the affected communities, including their concerns?

This report focuses on the communities who live around the industry, work in it or are involved in another way and want the industry to stay. These communities are generally proud of the industry and what it has brought to their town or village in the past. Also, part of the community is dependent on the industry, because they or their family members work in this sector.

These groups are worried about the future of the industry, as it is currently polluting and not future-proof. They are concerned about how the energy transition will affect the industry, and therefore also their lives, their living environment and their identity.

In general, these concerns can be divided into three categories: worries about losing their identity or the quality of their environment; worries about losing jobs or companies leaving the area; and worries about not being included in important decisions.

Still, research shows that the Dutch population is generally positive about using hydrogen as a fuel. However, people have relatively little knowledge about hydrogen. Some also mention concerns about its safety. According to researchers, these concerns are not necessarily justified, as hydrogen is not more dangerous than current fuels. We just need to learn how to handle it differently.

industry

2. What is the spatial configuration of the industrial landscape around the most polluting clusters and how does it affect the surrounding neighbourhoods?

This report first focused on the four industrial clusters located in the coastal area: Zeeland, Rotterdam, Amsterdam and Groningen. Then, a more detailed analysis was made of the Rotterdam port cluster. The analysis of the four clusters showed that all of them include areas currently used for oil and other polluting chemical industries. In each cluster, these industrial zones are now large, paved and closed-off islands in the landscape, where the surrounding communities cannot go or make use of the space. If the oil sector shrinks in the future, empty spaces will appear in these areas that need to be reimagined. This creates a chance to open up these spaces and involve the community.

At the moment, most industry still runs on oil, gas and coal, but the use of renewable sources is increasing in this sector. Hydrogen is also starting to appear in the Netherlands, but large-scale projects are still in development, so no big spatial interventions have taken place yet in the four clusters.

Rotterdam is the cluster with the highest concentration of oil and chemical industries, so their disappearance would have a big impact on the spatial configuration of the area. The space that will need to be redeveloped is a large island in the middle of the port area.

Around the Rotterdam port area, several villages are located. Some of the villages in the east are part of Rotterdam or function as satellite cities. Their accessibility is generally good because they can use Rotterdam's infrastructure. The western villages are more spread out in the polder landscape or between greenhouses. These have lower accessibility due to their more remote location.

energy transition

3. In what key ways does the hydrogen supply chain significantly influence the development of the built environment?

At the moment, Gasunie has a plan to replace the national gas pipeline network with a hydrogen backbone that connects all industrial clusters. In this report, this backbone was used as the starting point for the vision and strategy.

The pipes that transport hydrogen, like gas pipelines, are located underground, so they are hardly noticeable to the community above ground. However, the electrolyzers – the facilities where hydrogen is produced – are above-ground installations. Even so, these new buildings do not take up a significant amount of space when compared to the scale of existing industrial areas.

What does require a lot of space is the production of renewable hydrogen, which depends heavily on sources like wind turbines and solar panels. These forms of energy production are much less polluting than fossil fuels, but they do take up far more physical space. This will have a major impact on the landscape around hydrogen production sites. A key challenge, then, is to decide where this energy will be generated.

conclusion

Conclusion

In order to improve the socio-economic conditions of the communities along the industrial clusters while integrating hydrogen as an energy source, a combination of a top-down and bottom-up approach is needed. The bottom-up approach is essential to give the community, for whom the industry is an important part of life, a voice in the decision-making process. Major changes are going to take place in the industrial clusters, which offers a unique opportunity to redesign these port areas together with the communities and make them part of the city. This way, a form of mutualism can emerge between industry and community.

This could lead to innovative and future-proof industrial developments and allow the community to be proud of their industry again. At the same time, a top-down approach is needed to enable the transition from a technical and economic perspective and to ensure that all separate plans come together as a cohesive whole.

The answer to the main research question is to establish a Hydrogen Council, which makes decisions, within a certain framework and set of guidelines, about the implementation of the hydrogen backbone and the redevelopment of empty spaces that will arise after oil and chemical industries are phased out.

Each cluster would have its own regional council, consisting of members from the community, industry, researchers, and government. Together, they define the vision for their region, with the community playing a major role. Different setups are possible to ensure a majority in the decision-making process. A National Hydrogen Council will review the regional plans to make sure they align with the national strategy.

In contrast to current citizen assemblies, the community's opinion in this setup has a greater influence on the final decisions. This ensures that the community is truly heard and that a joint vision can be developed with the industry for what the post-transition future of industry should look like. In this way, we can all prepare ourselves for the Hydrogen Age.

Evaluating our own interventions means stepping back and looking at them with a critical eye. It also means recognizing the biases we brought into the process. Since our entire team consists of urbanism students, our early approach focused heavily on spatial and systemic aspects like infrastructure, networks, and large-scale design. These are important, but they often overlook the role of community.

As the project moved from visioning to strategy, we realized that without involving the community, the future we were aiming for might never take shape. This shift led us to focus more on governance specifically, how decisions are made and who gets to participate. Scenario building helped us see this more clearly. It showed us that the path we choose matters just as much as the destination. Now that we know the biases and shifts the project had due to the biases we can evaluate the frameworks and interventions utilized in the project.

Does our strategy address intra- and inter-generational justice?

The Hydrogen Council, which began as a simple policy tool in our intervention kit, gradually became the backbone of our governance approach. It touches every part of the policy framework: shaping, stimulating, building capacity, and regulating, while holding firmly to the idea of intergenerational justice. By centering community voices and allowing people to shape their own post fossil identities, it does more than guide the transition rather it empowers the people for change

For intragenerational justice, our interventions in Rotterdam through the knowledge cluster and the experimental island focus on making the energy transition both visible and accessible. These are not just technical installations. They are places where people can understand what hydrogen means in their everyday surroundings and in their working lives. By supporting re-skilling and helping current industrial workers shift into future ready roles, we are ensuring that the present is not overlooked in pursuit of a cleaner tomorrow.

Recognitional: Does our strategy recognise vulnerabilities, identities and trajectories?

We believe our strategy recognizes both vulnerable communities and vulnerable spaces in a post fossil world places like oil storage sites and refineries that risk being transformed into brownfields. Our approach brings people together through the Hydrogen Council, not just to reshape these spaces, but to reshape themselves. It's about more than adaptation. It's about creating new identities and choosing new paths forward, together.

Procedural: Does our strategy or proposals incorporate the voices of the most vulnerable/ the voices of stakeholders (including the planet)?

The intervention toolkit, combined with the implementation framework, is designed so that no single stakeholder can fully control the direction of the transition. This balance ensures that the future generation those who will live with the outcomes also has a quiet but steady influence in shaping what comes next.

What capabilities are being created or sustained? To whom are those capabilities accessible?

Our strategy centers on the creation of the Hydrogen Council and the intervention toolkit, both grounded in a careful analysis of existing fossil-based identities. This approach creates a shared platform where people, industry, government, and experts can make informed decisions together. It gives communities not just a voice, but a seat at the table especially those living closest to the industrial clusters. While the process isn't equally accessible to everyone, it's designed to be most accessible to those most affected. For them, involvement is direct and immediate.

7.3 ETHICAL REFLECTION & SOCIETAL RELEVANCE

QUESTION OF RESPONSIBILITY

As outlined in the Chapter 1.4 (aims of the project) the core objective was to pursue a just energy transition and foster mutualism between the community and industry. These goals were shaped by insights from both the media analysis and the fieldtrip. Initial assumptions regarding the relationship between industry and the surrounding communities were largely negative. It was hypothesized that pollution and large-scale industrial operations could not possibly have a beneficial impact on the lives of nearby residents.

However, the fieldtrip revealed a more nuanced reality. Residents of villages like IJmuiden and Rotterdam expressed pride in their local industries and appreciation for the employment opportunities they provide. This unexpected finding was further reinforced by the media analysis, which showed similar sentiments in other regions, including Groningen and Zeeland. As a result, the project tried to be researching from a community perspective.

Throughout the fieldwork, the group was influenced by the opinions and lived experiences of the community members we interviewed. This led to a form of positional bias, an empathetic inclination to advocate for the underrepresented voice of the community. We observed that communities are often overshadowed by powerful industrial stakeholders and a predominantly top-down energy transition driven by government institutions.

In the case of TATA Steel, for example, we found that residents appeared to be placated with superficial gestures, such as playground and window cleaning, and street furniture maintenance, while the deeper systemic issues of pollution remained unaddressed.

Although TATA Steel promotes itself as a responsible neighbor through relatively high wages and visible participation in local events, as urban researchers we observed the disproportionate environmental burden placed on nearby residents. The community experiences significant noise, smell, and health impacts, which we regarded as ethically problematic. Many residents, in our view, remain unaware of the extent of these injustices or have become accustomed to them.

In retrospect, our intention throughout this project was to envision a more ethical equilibrium between industrial power and community wellbeing. Our goal was to ensure that the community is not a ‘loser’ in the energy transition but a ‘winner’ and empowered stakeholder, such as TATA Steel. Currently, the benefits of industrial activity are disproportionately concentrated among corporations, while the community bears the cost. The transition to hydrogen, however, presents a unique opportunity to reimagine this relationship and strive for a more equitable and collaborative future.

7.4 SCIENTIFIC RELEVANCE

POSITIONING WITHIN DISCOURSE

This research contributes to the academic discourse on energy transitions by proposing a radical, scenario based thought experiment that foregrounds a rapid, bottom up approach. It is grounded in three key theoretical frameworks: Industrial Symbiosis, Socially Just Transitions, and Transition Management. Through this lens, the project offers a novel perspective on the socio-spatial implications of green hydrogen implementation in the Netherlands.

At the same time, the research acknowledges its methodological limitations. Community personas were developed based on a limited number of interviews and supplemented by media analysis. While this mixed method approach provided useful insights, the small sample size and the broad nature of media sources inevitably introduced certain biases and assumptions into the analysis.

Despite these limitations, the project is anchored in a thorough literature review on the potential of green hydrogen in the energy transition, alongside spatial analyses of the current industrial landscape. These foundations informed the development of the “As Empowered As Possible” scenario, in which the Hydrogen Council emerges as a central intervention.

While the council, in its proposed form, may not align with current constitutional frameworks, its speculative inclusion is intentional. It serves to provoke reflection on the kinds of radical institutional transformations that may be necessary to accelerate the energy transition while ensuring meaningful community participation and empowerment from the ground up.

Although our vision of positioning the Netherlands as a global leader in the hydrogen economy aligns with EU and international climate policies, it must be critically examined within the broader energy and climate context. Realizing such an ambition would require extensive systemic change not only in energy infrastructure, but also across social, institutional, and economic domains.

Moreover, as green hydrogen represents only one of several viable alternative fuel pathways, the project’s focused emphasis on it reflects an acknowledged narrative bias within our scenario development.

Given the dynamic and evolving nature of the energy transition marked by ongoing technological innovation, policy shifts, and shifting societal priorities, long term forecasting of specific interventions decades into the future remains inherently uncertain. In light of this, the project does not propose a definitive future.

Instead, it offers a flexible implementation framework that allows communities, industries, and governments to collaboratively shape and reshape their post-fossil identities. This framework aims to foster adaptive, inclusive strategies responsive to future developments, while remaining rooted in participatory governance.

7.5 REFLECTION ON PROJECT

GROUP PROCESS

At the start of this project, we were divided into groups based on our personal interests and preferences. We were all interested in topics related to production landscapes, especially in industrial or port areas. In our first brainstorming session as a team, we quickly landed on the topic of hydrogen, and from that moment on, we started diving deeper into it.

Using hydrogen as an energy source is innovative but also very complex. As urban planning students, we did not know much about it at the beginning. This became a challenge for us in the first few weeks. It took us a lot of time to understand the technical system, which meant we did not focus enough on the community and their concerns early on. We already had a solution in mind, the hydrogen transition, without having a clear problem or community to work with. Because of that, it often felt like we were a few steps behind. At a certain point, we decided to put the technical story aside for a while and went back to the basics: who is our community, what are their problems and how can these be solved? From that moment on, we started to see a clear line through all the information and stories we had gathered in the previous weeks.

In the weeks leading up to the midterm presentation, we used our Miro board as the base for our analysis and mainly used sketch paper to shape our vision. This worked well for us because it allowed everyone to contribute and explain their ideas clearly during discussions. However, this also meant we felt a bit behind other groups in terms of digital production.

In the past few weeks, we spent a lot of time discussing, reflecting and deciding how to approach things and what the best solutions were. These were interesting discussions and we learned a lot from them, but they also took up a lot of time. We often used complex diagrams to clarify our topic to ourselves, to each other and to our teachers, but this sometimes caused us to lose sight of the main line of the project. In our midterm reflection, we compared ourselves to a talk show: lots of interesting conversations, but sometimes things took a bit too long.

Still, right before the midterm, we realized that this ‘talk show’ actually helped us. Because of all these conversations, everyone really understood what our project was about and what we wanted to achieve. That made the digital production and presentation for the midterm go very smoothly. After that, we compared ourselves to an orchestra, where everyone plays their own instrument and together it becomes a symphony. Up until that moment, we worked on the project with five team members. Unfortunately, after the midterm, one team member could no longer contribute, so we continued the second half with four.

The second part of the project was all about forming a strategy. We decided that while group discussions were still important, they did not have to take so long anymore. So in the second half, we started splitting up more often to work on specific parts and systems, which made our process more efficient. While we focused mostly on the spatial and technical aspects in the first part of the project, we switched to policy and community in the second half. As a result, we did not work on the spatial dimension for a while. But in the final weeks, everything came together and because of the strong unity in our team, we were able to work efficiently on improving the vision and developing our final idea.

Looking back, we are happy with how we worked together. We all had our own strengths and different interests, which we used well, but we also challenged each other to learn from one another. We are also satisfied with all the discussions we had. We treated each other with respect, but we could also have informal conversations and openly disagree if needed.

Finally, we would like to thank Frank Xu for his contribution in the first weeks of the project.

Figure 77: ***AI-generated image as a metaphor for the group process. Most of the times we see ourselves as a talkshow: discussing a lot, mainly informational, sometimes drifting off. When in focus mode we immediately change to an orchestra: working on one goal with concentration.***

used prompt: *A highly detailed, cinematic split-screen image showing two contrasting worlds. On the left side, a modern talk show set with warm, ambient studio lighting, a charismatic host and a guest sitting across a sleek desk, cameras and a small live audience visible in the background. The atmosphere is lively, intimate, and media-driven. On the right side, a grand classical orchestra in the middle of a dramatic performance inside a prestigious concert hall, with polished wooden floors, elegant architecture, and warm golden lighting. Musicians are captured mid-motion, playing violins, cellos, and brass instruments, while the conductor passionately leads them. The image is photorealistic with deep shadows, rich textures, and cinematic color grading, evoking the feeling of a high-budget film still.*

BETTY

At the start of the studio, each student was asked to introduce themselves and briefly present their interests. I shared that I prefer thinking and designing at the regional scale, but also find it the most challenging. Striking the right balance between schematic abstraction and detailed information often feels uncomfortable. Making decisions that impact so many people leads to the question, "Who am I to decide this?" Yet, this discomfort became a valuable starting point for learning to work regionally.

For this project, we specifically focused on the energy transition through the eyes of the community. The complexity of combining these two elements, energy transition and community, soon became evident. As a group, we asked: "Can we understand the hopes and dreams of the community within a regional design process?" And if so, how? Over the past ten weeks, we explored a bottom-up approach to the hydrogen transition. Choosing the appropriate scale was crucial. We began regionally, identifying clusters and hydrogen networks, but quickly lost sight of the community. We then zoomed in to reconnect with the local scale. "But what does the community truly want? Jobs? A clean environment? To keep the industry open?" Again, we searched for a logical reasoning that could link large-scale ambitions with local values.

We experimented with an intermediate scale, but used the wrong information to support our argument. Were the clusters truly connected? Or had we once again lost the community from view? Until week seven, I was convinced that a regional energy transition was not feasible without compromising community interests. Someone has to make sacrifices. Either residents must say "yes, in my backyard," or powerful stakeholders must accept the transformation of identity and invest in innovation.

It is a natural human reaction to expect the minority to adapt, but through this project, I realized how unethical it is to ignore the health and concerns of that very minority. The community matters, and as urbanists, it is our responsibility to design fair and inclusive environments.

The SDS lectures encouraged us, as a group, to keep searching for a bottom-up strategy. Slowly, I became convinced that it is indeed possible to design from the perspective of the community. The SDS workshops challenged us to view the problem through different lenses. It requires acceptance and radical thinking to arrive at meaningful solutions. This mindset led to the creation of a "hydrogen council", an idea I discussed with a student in policy and law, who appreciated the concept but felt it was overly idealistic. The council lacked democratic safeguards. Perhaps it is too radical to give influence to people who are not energy or industry experts but in this project, we flipped the roles. If the outcome were, hypothetically, a theme park replacing industry, because that is what the community wants, then the large players would have to adapt instead of the community always paying the price. That is what designing for the community means: adapting, rethinking, and staying open. Not resisting change, but committing to it, and experimenting often. That is how a community-driven transition, rooted in hopes and dreams, becomes possible.

This project has been incredibly educational. Not only do I better understand the regional scale, but I also see how design research can underpin complex challenges. I have learned to engage with both the technical and social dimensions of the energy transition. Working in a team was essential for this process, sharing opinions, debating, and producing at a high pace led to deep learning. I am deeply grateful to the group for this project; we have learned to listen and grow together.

MEIKE

In the course Spatial Strategies for the Global Metropolis, it was the first time I worked on a project at a regional scale. At first, it was a challenge to switch from a specific design approach to one that was more focused on concepts and vision. On top of that, the topic was the energy transition: an important and interesting subject, but also extremely complex. There are so many stakeholders involved, each with different interests, opinions and levels of power. How can we ensure a just future that considers everyone? And what does "just" even mean exactly?

This year, we were challenged for the first time to develop a vision based on a self-defined community. Although it was difficult at first to define a specific community, it actually gave us a clear foundation throughout the project, which is very helpful when you are working in a team on a complex issue with many possible outcomes.

Most of the SDS workshops also helped to bring structure to our project approach. For example, the early workshops helped us to better understand what a community is. In the end, our community was simply defined as the group of people who are, in some way, connected to the industry in the Netherlands and want it to remain. Looking back now, I realize that we treated this community as one homogeneous group throughout the project. In the hydrogen council we proposed, for instance, the community gets 30% of the decision-making power, but who says that everyone within that group agrees with one another? And is a lottery-based selection really a fair method? Are all social groups equally represented in such a council?

I still believe that the energy transition should take into account the communities that are directly or indirectly affected by top-down decisions. This is important to avoid a situation where the loudest voices or those with the most money always get their way. The SHS workshop on stakeholders helped me understand this more clearly. We created a stakeholder analysis of the current situation, but also of what we believe would be a better distribution of power in the future.

However, I do wonder how our bottom-up vision and strategy would actually work in practice. I worry that, with this approach, people might focus mainly on their own interests. This is understandable, but it makes it difficult to arrive at a single outcome that benefits most groups in society and truly leads to a just result.

I think that, in a regional design process, it is too complex to fully understand and consider all the hopes and dreams of all communities. Still, I believe this course is a good foundation for us as future urban planners. To teach us to think from a specific perspective, to make the effort to talk to people, to analyze media, to understand how different communities think, and to include weaker groups with less power in decision-making.
In the end, I think it is an important task for urban planners to understand the stakeholders and to make spatial decisions that are just. The methodology course gave me a clearer idea of what the "just city" could be and what the possibilities are, but what it really means is something I do not fully know yet. It is something I hope to keep discovering during my future career as an urban planner.

PRANAV

The course Spatial Strategies for the Global Metropolis was an intense and stimulating eight week journey into the practice of regional design. Coming from an architectural background, my exposure to regional and systems thinking had been limited. However, this quarter was a compelling introduction to regional design as a discipline that not only operates at a larger scale than urban design, but also navigates multiscalar complexity, cross-sectoral interactions, and systemic transformation.

At the beginning of the quarter, our group selected a specific lens on the energy transition energy production landscapes. This focus soon evolved into a broader inquiry encompassing production, transportation, and consumption, particularly through the lens of green hydrogen. Breaking down our research through sub questions focusing on industry, community, and transition strategies allowed me to investigate the spatial and systemic dimensions of green hydrogen across different scales. The modular structure of these questions reflected the interdependent layers of the regional design process and helped us develop tailored methods of inquiry for each theme.

The SDS lectures helped me in understanding and execution of the research process. Early sessions, introduced key facts and frameworks that contextualized the current discourse on energy transitions. Subsequent sessions provided me with exploratory research tools, including Atlas.ti for media analysis and GIS-based methods to spatially map energy production chains. The Systemic Section workshop, in particular, helped me interpret the spatial typologies associated with hydrogen infrastructure across different scales. These lectures not only advanced the content of our research but also served as a foundation for meaningful group discussions and collaborative knowledge-building.
One particularly influential lecture was the session on media analysis. It helped me frame community aspirations not merely as given data, but as evolving narratives.

This shaped our "transition communities"—a concept grounded in the idea that inclusive transitions are built on co-creation, knowledge exchange, and empowerment. We experimented with participatory tools like personas to humanize the visioning process and used the Hydrogen Council as an institutional intervention to build community capacity and agency. Rather than positioning our vision as a top-down method, we began to see it as one possible future, a framework within which communities could craft their own post fossil identities.

This shift reflected a critical learning moment: in regional design, the designer's role is not to dictate outcomes but to introduce systemic change. Designing adaptive frameworks that respond to evolving knowledge, power dynamics, and community agency is vital.

Beyond the lectures and content, collaboration was a significantly positive experience. My teammates brought diverse perspectives and skills to the table, which enriched both the process and the outcome. Clear communication of expectations and shared planning allowed us to align tasks with individual strengths while fostering collective learning. This synergy between research and design was one of the most rewarding aspects of the studio.

Ultimately, this project was a foundational experience in regional design. It deepened my understanding of how spatial strategies can operate as instruments of socio technical transitions, and how design can serve as a medium for engaging complexity rather than simplifying it.

Through this course, I have come to appreciate regional design not as "urban design at a larger scale," but as a method of linking people, systems, and places to envision equitable and grounded futures.

ALLARD

Top-down or bottom-up? It is one of the questions I have been asking the most during this period. The overarching theme of the energy transition has kept bringing me back to that one question. And I honestly still haven't figured it out.

The energy transition: the need for it is clear. But whose move is it? Not only did I ask that question to better understand this research: it also touches me personally. As an urbanist, how can I contribute to this energy transition? I believe that as an urbanist it is my turn to create or ensure a healthy and future-proof living environment. But what does that have to do with energy transition?

Shouldn't it be steered by government regulation? Shouldn't the big polluters be dealt severely with emission fines? And won't those big polluters simply move to another country where they will not be fined? These questions create a lot of question marks over my head. So what impact can you still make as a designer? Making that energy transition into a reality? I do not think that is going to happen.

During the mid-terms, I took the position that bottom-up strategies in the energy transition would not work. And I'm happy to come back from that. Because ultimately, I think that this is precisely where we as urban planners can deploy our strengths. To make the transition a bit more human. That is exactly what I also discovered during these eight weeks of complete immersion in the field of strategy development. It feels like I have been introduced to a new scale that I did not know existed before.

The neighbourhood level, the city level, the region level were already known. But a strategy as we have created now feels like an overarching design to bring those scales together to be able to execute a design as well. Last two quarters, I questioned what an urbanist actually does. It mainly felt like a lot of analysis and conceptual thinking. This design research removed those question marks.

In fact, that conceptual thinking came alive in this project. Initially, I didn't understand the purpose of the conceptual framework, but eventually it fell into place. And even more than that: over the last few weeks, it was a kind of fixed beacon again and again. A coat rack on which we could hang our design coats each time. The main questions here were always 'what is our main goal?' and 'on what values do we want to base everything?'. And that provided enormous guidance: a way of designing that I definitely want to use again in the future.

Working together as a team was an incredibly nice experience and gave this project a huge boost. Especially the differences in expertise of everyone makes our project into a deeper linked design that incorporates more aspects. Frank's fundamental logic, Meike's concern for people, Betty's resolution skills and Pranav's technical knowledge. I think I was able to add my love for a conceptual base to this. With this, our project also feels much more grounded for the community. All this has created a deeper understanding of how people, systems and regulation work together.

I am looking forward to seeing how other projects deal with realising their visions. Moving from concept to reality is what I would like to learn even better for a better understanding of spatial strategies.

Finally, a big thanks to everyone in my group for making this quarter one of the best ones I have experienced.

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Datasets and layers used in QGIS for analysis and map making

Kadaster Administrative Boundaries | PDOK (WFS)
https://service.pdok.nl/kadaster/bestuurlijkegebieden/wfs/v1_0? request=GetCapabilities&service=WFS

Dutch Ministry of Economic Affairs Natura 2000 | PDOK (WFS)
https://service.pdok.nl/rvo/natura2000/wfs/v1_0?request=getcapabilities&service=wfs

CBS Population Distribution | PDOK (WFS)
http://service.pdok.nl/cbs/pd/wfs/v1_0?request=GetCapabilities&service=WFS

SOLARGIS Solar Power Potential (TIFF)
https://solargis.com/resources/free-maps-and-gis-data?locality=netherlands&utm_source=chatgpt.com

Andreas Hocevar Country Boundaries (WFS)
https://ahocevar.com/geoserver/wfs?service=WFS&version=1.1.0&request=GetCapabilities

Websites used for icons

The Noun Project (https://thenounproject.com)
FlatIcon (https://flaticon.com
Vecteezy (https://vecteezy.com)
Adobe Stock (https://stock.adobe.com)

A number of LLM softwares were used to **only help *formatting* texts.

8.2 LIST OF FIGURES

8.3 APPENDIX - A
MORE INFORMATION ON THE SUB-RESEARCH QUESTIONS

How can future spatial strategies enable the integration of hydrogen as an energy source to improve socio-economic conditions of the communities along the existing industrial clusters?

1. What are the key characteristics of the affected communities, including their concerns?
The transition to sustainable energy represents one of the greatest socio-technological challenges of the 21st century. While the urgency for such a transition is widely recognized, the process demands significant societal and technological changes. According to Vice-President of the European Commission Frans Timmermans (2023), it is critical to ensure solidarity with the most affected regions, such as coal mining areas, to garner full support for the European Green Deal.

Miller et al. (2013) highlight several enablers of the energy transition, including rising societal concerns over current energy extraction practices, exemplified by global climate protests calling for an end to fossil fuel extraction. Public interest in democratic participation in technological change is also increasing. Additionally, the cost of renewable energy has significantly decreased, with solar energy prices falling by 89% and wind energy by 70% between 2009 and 2019, making these technologies more accessible to lower-income households and businesses. Given these factors, it is crucial for the research to address key questions: Who are the affected communities, where do they live, what are their occupations, how are they impacted by the current energy system, and what are their aspirations for post-fossil fuel identities? These inquiries will be central to understanding the social dynamics of the energy transition and ensuring its inclusivity.

2. What is the spatial configuration of the existing industrial landscape around the most polluting clusters and how does it affect the surrounding neighbourhoods?

The concept of spatial justice is a critical consideration in the context of the energy transition, particularly with regard to the socio-environmental impacts of industrial infrastructure. The land acquisitions for infrastructure development even in the case of environmentally progressive projects like renewable energy installations can lead to the displacement of vulnerable communities and the disruption of local ecosystems. This issue underscores the importance of carefully studying the existing industrial landscape before initiating any changes associated with a sustainable energy transition. A comprehensive understanding of the location and impact of current industrial clusters is essential to inform future planning decisions. It is necessary to assess the spatial configuration of these clusters and their effects on surrounding neighborhoods. Specifically, the question arises: Where are the current industrial clusters located, and how do they influence the adjacent communities, particularly in terms of environmental health and livability?

Moreover, renewable energy production itself can be viewed as a spatial conflict. As noted by (van Zalk and Behrens, 2018), compared to fossil fuel-based energy systems, renewable energy infrastructure typically requires significantly more space. Fossil fuel systems, in which oil or gas is extracted remotely and transported via pipelines or ships to incineration plants, generally situate these energy facilities away from residential areas. This spatial separation allows for the invisibility of energy production, making it an almost unquestioned part of everyday life for residents in such systems. The issue of where the energy production infrastructure becomes increasingly crucial in balancing environmental, social, and spatial considerations.

3. In what key ways does the hydrogen supply chain significantly influence the development of the built environment?

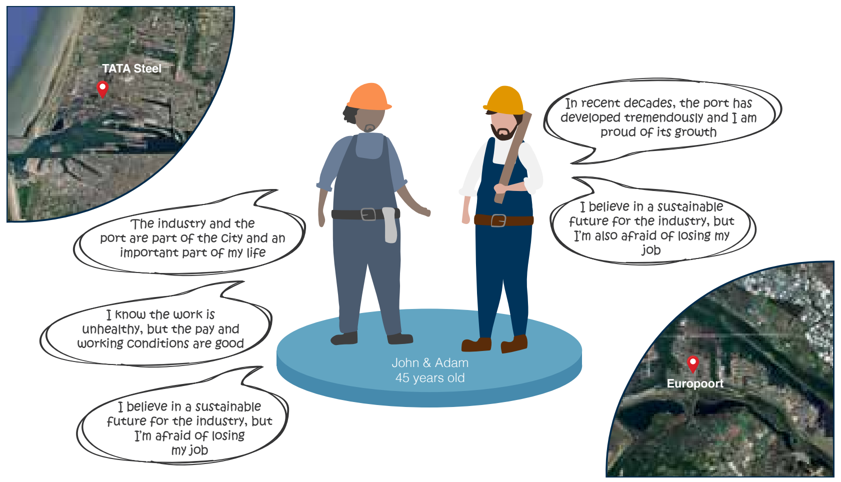
The successful execution of the energy transition necessitates substantial investments, particularly in the (re)development of existing infrastructure. The European Commission has established the Just Transition Fund, which aims to allocate approximately 55 billion euros between 2021 and 2027 to support regions and communities most impacted by the transition (European Commission, 2023c).

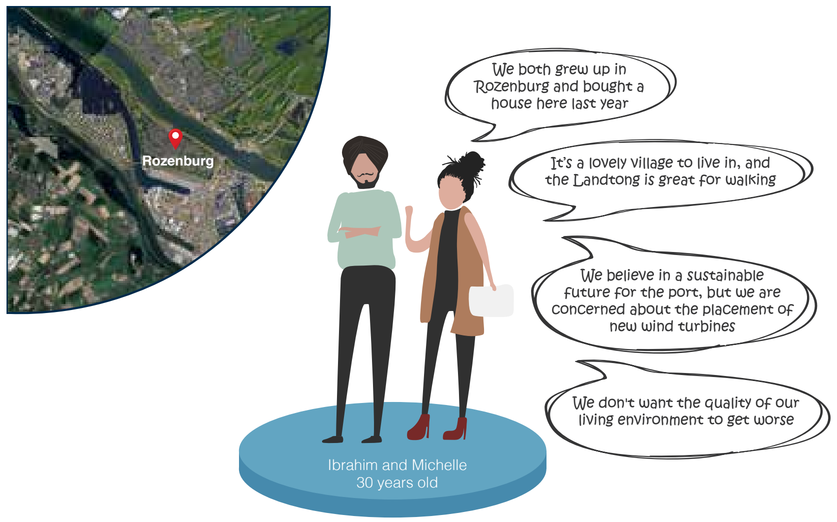
However, despite these financial commitments, the widespread adoption of renewable energy faces significant barriers, particularly with regard to the overload of existing energy grids. For example, in the Netherlands, some municipalities face restrictions on the installation of new photovoltaic panels due to the inability of the energy grid to accommodate additional energy input. This challenge is compounded by a lack of sufficient energy storage capacity. Furthermore, the intermittent nature of renewable energy production characterized by temporal mismatches between supply and demand poses another critical issue. Energy storage systems, therefore, emerge as a central solution to manage renewable energy fluctuations and ensure efficient use of generated power (Abrell et al., 2019).

In light of these challenges, this sub-research question examines the viability of green hydrogen as a potential solution to decarbonize heavy industry, mobility, and energy storage. It is crucial to understand the fundamentals of hydrogen, including its types, production methods, and possible applications. Hydrogen, as a versatile energy carrier, offers significant potential for integrating renewable energy into sectors that are traditionally difficult to decarbonize, such as industry and transport.

8.3 APPENDIX - B

MEDIA ANALYSIS ON COMMUNITIES AFFECTED BY ENERGY TRANSITION





Zeeland/Vlissingen

Energy transition

350 million euros for mega battery in the port of Vlissingen
The money will be used to build a battery system that can supply and discharge as much electricity as 200,000 households will consume from 2027. This makes this the largest battery energy storage system in the Netherlands.

https://www.nt.nl/havens/2025/02/18/350-miljoen-euro-voor-megabatterij-in-haven-vlissingen/

Residents happy with switch to green hydrogen, but there is also criticism: 'This is imposed on us'
A whole village that goes off the gas and switches to green hydrogen. City on 't Haringvliet, good for 637 homes and businesses, is going to do that nicely. A Dutch and European first

https://www.pzc.nl/goeree-overflakkee/bewoners-blij-met-overstap-op-groene-waterstof-maar-er-klinkt-ook-kritiek-dit-wordt-ons-opgedrongen~ae41c1a6/?utm_source=chatgpt.com&referrer=https%3A%2F%2Fchatgpt.com%2F

A group of residents started the City of Natural Gas Free initiative a few years ago. The municipality of Goeree-Overflakkee has conducted a survey in recent weeks to gauge the mood among residents. The municipality calls the turnout high at 84.8 percent. **77.6 percent of people with a natural gas connection voted in favor**, 6.4 percent voted against and 15.2 percent didn't vote. This means that the municipality will continue with the further elaboration of the plan.

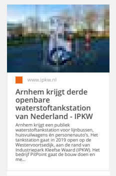
https://www.rtl.nl/nieuws/economie/artikel/5393709/waterstof-stad-haringvliet-energietransitie-huizen-verwaremen#:~:text=Het%20hele%20dorp%20Stad%20aan,vandaag%20gestemd%20voor%20de%20overstap.&text=Een%20groep%20inwoners%20startte%20enkele%20jaren%20geleden%20al%20het%20initiatief%20Stad%20Aardgasvrij.

https://www.nefit-bosch.nl/informatie/persberichten/waterstofketel-h2-ready

H2 'ready' kettle makes It possible to easily switch from gas heating to hydrogen heating.

Port of Rotterdam

positive/general



Arnhem gets the third public hydrogen refueling station in the Netherlands

Local party 'Leefbaar Rotterdam' - municipal/city council:
energy transition towards gas free is too expensive.

Energy transition

Rotterdam makes 'natural gas-free' tangible for Pendrecht residents

People become more convinced of the usefulness of freeing their home with natural gas if they can experience the benefits it brings. That is the idea behind the living room of natural gas-free Pendrecht in Rotterdam.

https://www.nplw.nl/praktijkvoorbeelden/rotterdam-maakt-aardgasvrij-tastbaar-voor-bewoners-pendrecht?utm_source=chatgpt.com

In numerous places in our city there is a lot of resistance to the arrival of wind turbines near residential areas. The GGD and other health authorities are concerned about the negative health effects of wind turbines for local residents.

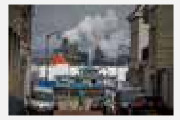
Local party 'Leefbaar Rotterdam' - municipal/city council:
energy transition towards gas free is too expensive.

negative

Port of Amsterdam

positive/general

negative



Energy transition

HYDROGENERATION