The Energy and Feedstock Transition in the Port of Rotterdam Industrial Cluster

INSIGHTS FROM THE FIELD AND RECOMMENDATIONS FOR QUANTITATIVE SPATIAL ANALYSES IN THREE TIERS

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THE ENERGY AND FEEDSTOCK TRANSITION IN THE PORT OF ROTTERDAM INDUSTRIAL CLUSTER

Insights From the Field and Recommendations for Quantitative Spatial Analyses in Three Tiers

Research by CIEP

Commissioned by SmartPort

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Preface

The energy and feedstock transition in the Port of Rotterdam's deeply integrated industrial cluster is a dynamic process. The factors that have created the current cluster of hydrocarbon-based industrial activities over many years have been a combination of geopolitics, geo-economics, location, and the seizing of opportunities both within and outside the industry. Events and opportunities coming from outside the industry can be an important impetus for change. For example, the flow of fuel oil from Russia, freed up after the break-up of the Soviet Union and the subsequent collapse in Russian domestic demand, stimulated investments in the Port's refineries to convert this flow into more valuable oil products for international markets. Another example is the NATO pipeline system, which served the post-war political balance of power in Western Europe but also created the possibility for Northwest Europe to expand these initial military supply lines into the integrated system of today's industrial clusters. NATO's decision to construct a pipeline system to supply military bases and airfields was an 'event' outside the realm of the industry but had a profound impact on the way the Rotterdam cluster began to build out and connect to the other clusters in the region. The pandemic may very well become another example of an outside event with profound impact on the industrial cluster because of the large imbalance in markets for oil products and the way the industry is forced to handle it by blending away kerosene. If this situation persists for much longer, new solutions will need to be found, and the industry will have to adapt to the new circumstances.

Dynamic change is not new to the cluster but is part and parcel to the way the cluster has grown, integrated, and adapted to new circumstances and opportunities. This will be the same in the future. Just like in the past, assets will be converted to fit into the new business and market environment, while other assets are retired and space freed up to engage in different but often related activities. Some owners may reorganize their geographic orientation on certain markets or market segments, others may sell parts of their business activities, while yet others may expand their businesses to fortify their portfolios.

The dynamic changes that are foreseen for the period 2021 to 2050 are not different from the dynamic changes in earlier periods. They carry similar uncertainties and risks, but also new opportunities because many of the building blocks, however radical the feedstock and energy transition may seem, are already part of today's industrial activities. As in the past, intermediate solutions will change the path and open up new solution spaces. Much of the challenge lies in the organization of large volumes of new energy carriers and feedstocks, and the conversion into useful intermediates and end products. In the end, a deeply integrated cluster like the one in Rotterdam will move forward when they, as a group of plants/companies, can largely agree on how best to facilitate this change and how they can contribute with their investments.

In this report, CIEP explores the opportunities and uncertainties in the energy and feedstock transition with many stakeholders from the Rotterdam extended fuel cluster. It is clear that many investment plans and transition paths are being prepared by the business development departments but also that there are serious concerns about the investment climate in which these, often concerted plans, have to be realised. The energy and feedstock transition is a dynamic process, it should be studied and approached as such, and it could greatly gain from focusing on what connects the stakeholders in the HIC rather than on what separates them.

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Executive Summary

Activities in the Port of Rotterdam industrial cluster (Haven-industrieel Complex, HIC) will change over the next twenty years as a result of the energy and feedstock transition. To assess what spatial possibilities and limitations the companies now active in the extended fuel cluster envision due to this change, this project has collected, analysed and interpreted these companies' views on the future of the HIC. It considers activities that will gain and lose in importance, as well as the spatial implications, both onsite and offsite company terrains. By defining three dimensions of uncertainty, the report presents suggestions for narratives that can be used for creating (alternative) transition scenarios for the HIC. These results aim to enable SmartPort to better shape future quantitative research.

Views on the availability of land in the years leading up to 2030 differ among companies. Interviews with 34 high-level professionals of major companies active in the HIC revealed that some companies foresee spatial limitations as being a key barrier to developing new projects, while a few others indicated that sufficient land is currently available to realize new developments on site. Most companies take a moderate position between these extremes. For the period beyond 2030, the general view is that the availability of land will be a larger concern.

Although it is an increasingly pressing issue, the exact degree to which the availably of land will be a limitation is uncertain. This confirms that a scenario approach is an appropriate method with which to explore future land use. Transition pathways that are currently used to enable thinking about and preparing for possible future developments could be enriched with insights that are particularly relevant for a spatial analysis. More specifically, uncertainties affecting demand for hectares in the HIC could be explored in three dimensions (see Figure 1).

Figure 1. Three uncertainties will determine demand for hectares for the energy and feedstock transition

The first dimension represents the dominant technologies. To this end, the transition pathways introduced in the 2016 study by the Wuppertal Institute for Climate, Environment and Energy are still largely adequate. These pathways can be updated for the years leading up to 2030, based on the developments of the past five years. Suggestions for such an update are provided in this report.
The second dimension represents the nature of the process of change in the HIC. The process can be defined either as coherent or incoherent. Coherent change implies clear, facilitating and consistent public policies and a strong willingness among companies to invest and cooperate. Incoherent change implies ambiguous, erratic and inconsistent policies, coinciding with companies avoiding or delaying investment. Demand for hectares will be impacted by the level of renewal taking place on the existing industrial sites.

The third dimension represents the future of international trade and markets, which can be characterized either by relatively unbounded global trade or by a more strategic EU economy. In the past decades, a relatively strong belief in unbounded global trade was dominant. Political choices for a more strategic economy could require a range of new and adapted production, conversion, storage and transport capacities. The extent to which this will impact demand for land can be explored by setting unbounded global trade and a strategic EU economy as extremes of this dimension. These three dimensions can be used in creating alternative transition scenarios for the HIC.

Based on the presented analysis, this report recommends five priority areas for future Port dialogues:

- Recognize the existence of a looming spatial challenge that already plays a role at some individual sites and is expected to become more pronounced in the post-2030 period, in part because the energy and feedstock transition will progress in an asymmetrical manner. Regular meetings that constructively address these issues based on updated research findings can help remedy some of the uncertainties.
- Highlight examples of how existing plants and sites in the Port contribute to a space-efficient transition. The transition could greatly gain from focusing on what brings the stakeholders in the HIC together rather than what divides them.
- Acknowledge that the transition is part of a dynamic process of industrial change by taking a forward-looking perspective, accepting the present and being discrete when echoing results of back casted scenarios. The three dimensions of uncertainty presented in the report can serve as a basis for such repeated forward-looking assessments.
- Embed future (modelling-based) results of land use assessments in a wider set of narratives of Port development, and avoid the potential alienation of stakeholders by presenting (quantitative) assessments as isolated facts, inattentive to the wider discourse and the onsite developments.
- Weigh the costs and benefits of the dynamic process of energy and feedstock transition on existing sites as opposed to developing new sites.

The interviews highlight a commitment to the transition. Yet the ambitions expressed for the transition are no guarantee of industrial renewal in the HIC. The widely shared view is that it is imperative to ensure that the political, regulatory and societal framework enables the attainment of the targets. It is essential to avoid the opposite, a situation in which companies are merely tantalized with high targets, while investments in new and retrofitted activities cannot be organized or realized. The years leading up to 2030 will reveal what framework for the energy and feedstock transition will materialize.

Introduction

The energy and feedstock transition in the Port of Rotterdam industrial cluster (Haven-industrieel Complex, HIC) requires substantial technological changes to the cluster's industrial processes. Revised and new facilities for receiving energy carriers and feedstock for transport, transit and storage, but also for conversion, are essential for establishing new value chains for a net-zero society by 2050.

The SmartPort knowledge hubplatform is engaged in a long-term research programme focusing on the spatial implications of this energy and feedstock transition. CIEP was tasked with performing a preliminary analysis before additional research is carried out by other knowledge organizations.

A large share of the land surface in the present-day HIC is used by what is known as 'the extended fuel cluster', referring to sites which are largely used for handling and adding value to international flows of hydrocarbons. Oil and oil products are received, transported, stored and converted into a range of products including road transport fuels, aviation fuels, marine fuels and feedstock for the chemical industry. Chemical sites within the extended fuel cluster add additional value by converting the feedstock into a variety of chemical products that are widely used in society.

The objective of this qualitative research project is to collect, analyse and interpret the views on the future of the companies active in the extended fuel cluster in the Port of Rotterdam. It considers activities that may gain and lose in importance, as well as the spatial implications both onsite and offsite the company terrains. Suggestions are made for narratives which can be used for creating (alternative) transition scenarios for the HIC. The results are meant to enable SmartPort to better shape a future research project aimed at quantitively exploring the spatial question. The main research question is: What spatial possibilities and limitations do the companies now active in the extended fuel cluster see in relation to the changing activities in the extended fuel cluster as a result of the energy and feedstock transition over the next twenty years?

To answer this question, 17 semi-structured confidential interviews were conducted with major companies, involving 34 high-level professionals working in the extended fuel cluster. Instead of abstract and top-down analyses of the future development of the HIC as we move towards 2050, this study reflects insights from a bottom-up assessment. This report does not contain a verbatim reconstruction of the interviews. Instead, broader insights into the foreseen steps towards lower CO_2 emissions and the energy and feedstock transition, and the uncertainties surrounding these steps, were derived from the interviews, in a process aided by knowledge developed by CIEP researchers in earlier studies. These insights were then mirrored against a 2016 study by the Wuppertal Institute for Climate, Environment and Energy.

Additionally, the way in which the terms 'greenfield' versus 'brownfield' and 'infrastructure' are used in these interviews was analysed. The identification of (in)consistencies and patterns aims to support SmartPort in better shaping a future dialogue within the HIC. The results of this analysis can be found in Appendix I.

This report is structured as follows. Chapter 1 sketches the relevant historical and spatial background of the constant evolution of the HIC, describes the background of earlier scenario explorations in relation to the HIC and summarizes the main findings of the Wuppertal pathways. Chapter 2 presents the insights derived from the interviews. In four sections, this chapter presents a structured and anonymized portion of the interviews, i.e., relatively certain expectations, relative uncertain alternative possibilities, spatial matters, and the Rotterdam HIC in an international context. Chapter 3 draws lessons for future quantitative assessments of spatial questions regarding the energy and feedstock transition in the HIC, from the insights obtained. The conclusion highlights the main messages.

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Background

Depending on one's perspective, the logic of which activities take place at what location in the Port of Rotterdam can be described in multiple ways. One adequate starting point from which to understand the apparent spatial design is to consider the industrial cluster's organic growth as well as the strong connections with Antwerp and the German hinterland.[1] This is especially true for the Port's extended fuel cluster, a highly integrated ecosystem that is comprised of multiple refineries, biofuel production sites, chemical plants, producers of industrial gases, tank storage terminals, electricity and heat generators, energy grid operators, waste processing facilities and service companies.

1.1 Development of the HIC through the years

Although the history of the Port dates back to the Middle Ages, the origin of the Port's fuel cluster is rooted in the petroleum handling and storage facilities that were established in the late 19th and early 20th centuries (see Figure 2). At that time, petroleum's main use changed from lamp oil to fuels for internal combustion engines. Standard Oil was already present with a petroleum storage facility in what is now known as Waalhaven, an area at the west side of Rotterdam's Charlois district, a few kilometres east of the town of Pernis. This is also the location where KNPM, one of the legal predecessors of Royal Dutch Shell, opened an oil refinery in 1902. Spatial limitations led to the decision to relocate the refinery operations in 1936 to its current location in Pernis.

To meet the post-war demand for oil products, Caltex opened a second refinery in Pernis in 1950.[2] In addition, development of the Botlek area started. Here, ExxonMobil opened a refinery with an integrated aromatics plant in the early 1960s. The Botlek area evolved into a highly efficient patchwork of plots, including various storage terminals, biofuel producers and integrated petrochemical plants. In addition to ExxonMobil's petrochemical facilities for the production of Phthalic Anhydride and Plasticizers, Huntsman polyurethanes facility and LyondellBasell's PO-TBA plant are located here. Furthermore, AVR's waste incineration plant and the Port's chloride cluster can be found in Botlek. The latter comprises the integrated plans of Nobian, ShinEtsu and Hexion.

1 As an introduction to the structure of the Port of Rotterdam, the cluster's industrial complex is described here along the lines of its historic development. For a discussion of how the Port of Rotterdam industrial area is integrated in the ARA fuel cluster and ARRRA petrochemical supercluster, as well as an overview of petrochemical pipeline and waterway connections, see CIEP (2021), 'The Dynamic Development of Organic Chemistry in North-West Europe'.

2 This Caltex refinery changed ownership multiple times, first to Chevron and later to Texaco and Nerefco. In 1997 the refinery was closed, and the site was transformed into a power plant and a tank storage terminal.

When tankers increased in size – among others a result of the closure of the Suez channel from June 1967 until June 1975 – the Port of Rotterdam had to increase its accessibility for a new generation of ships (VLCC, Very Large Crude Carriers), leading to the development of Europoort. In the 1960s, Gulf Oil and BP opened refineries in this area. Gulf Oil sold the refinery to Q8 (Kuwait Petroleum) in the mid-1980s, which in turn sold it in 2016 to Gunvor, which is now operating the facility.[3] Europoort also houses a vast number of tank storage terminals and dry bulk storage, as well as Indorama's PTA and PET plant, Ducor's PP plant, the Enecogen gas-fired power plant, Vitol's facility and Alco energy's biorefinery.

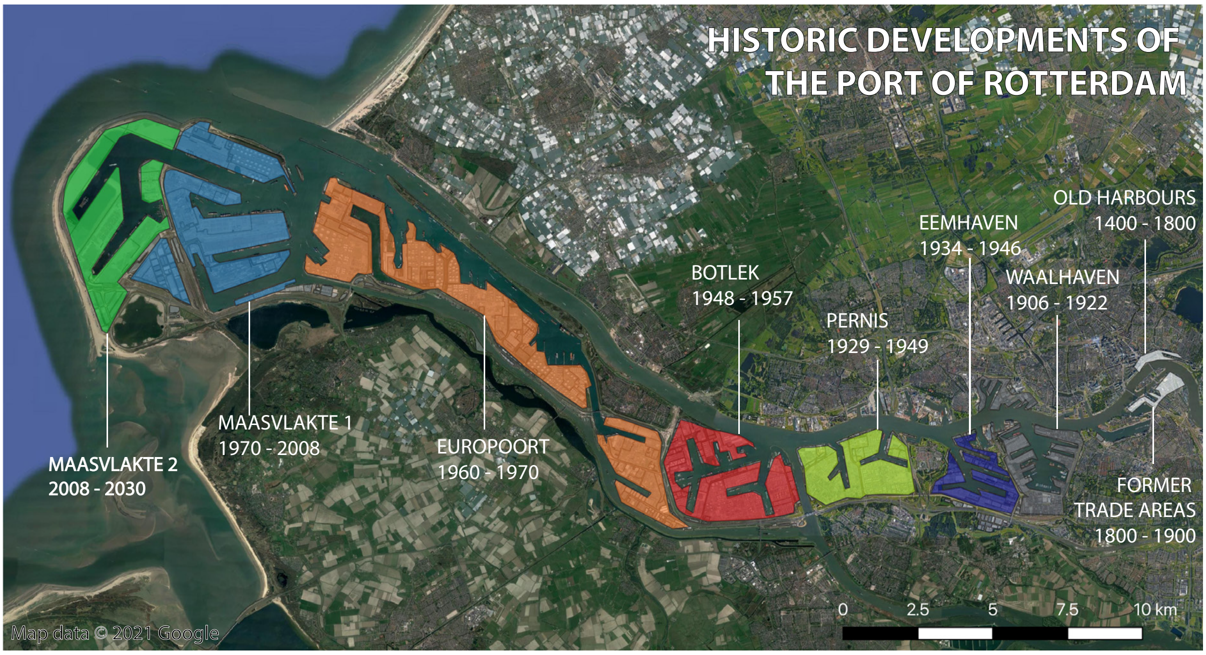

Figure 2. Historic developments of the Port of Rotterdam

The fuel cluster extends to the most recent additions to the port, Maasvlakte 1 and 2, where the Gate LNG terminal, the MOT crude terminal and the EMO coal terminal are located. In addition, Neste's biorefinery, LyondellBasell's plant for the production of propylene oxide and styrene, and the Uniper and Onyx power plants are located here. Maasvlakte furthermore includes a number of plots which are still under development and locations that are used by grid operators Gasunie, Tennet and Stedin. To provide their services, these companies, as well as producers of industrial gases, have locations throughout the port industrial area.

1.2 Earlier analyses of the future of the HIC

A multitude of studies have explored the future of the HIC and the geographical regions of which it is an intrinsic part. An overview is given in Table 1. The studies differ in scope (geographics, time horizon and technological focus) and they serve different purposes. Moreover, the studies use different terminology to describe the way they approach the uncertainty that is inherent to future developments.

To conceptualize the extremes in the uncertainty space – often referred to as 'the corners of the playing field' – some studies define 'pathways', others describe 'road maps', and yet others use 'scenarios'. No matter what terms are used, the studies all use frameworks to describe possible versions of the future. The rightmost column in Table 1 shows the names used for these frameworks.

3 In April 2021 Gunvor confirmed that it has permanently closed its crude distillation units at the Europoort Refinery. Argus (2021) 'Gunvor confirms permanent closure of Europoort CDUs'.

Table 1. Studies exploring future developments in the HIC and surroundings

Name	Year	Conducted by	Commissioned by / for	Focus (geographic; sector; time; aim)	Chosen framework to conceptualize uncertainty
Decarbonization Pathways for the Industrial Cluster of the Port of Rotterdam	2016	Wuppertal Institute	Port of Rotterdam	Port of Rotterdam; power plants, refineries, chemical industry, waste; 1990-2050; explore consequences of global decarbonisation for the Port's industrial cluster	Pathways: Technological progress; Biomass + CCS; Closed Carbon Cycle; Business as usual
Net voor de Toekomst	2017	CE Delft	Netbeheer Nederland	The Netherlands; multiple sectors; 2017 – 2050; explore possible contours of the future energy supply, depending on how sociocultural and political factors play out	Scenarios: Regional steering; National steering; International; Generic steering
CO_2 Reductie Roadmap van de Nederlandse Raffinaderijen	2018	DNV GL	VNPI	The Netherlands; refining sector; 2017-2030-2050; analyse CO_2 reduction potential of different technologies	Technology road maps: carbon capture; hydrogen as fuel; electrification
Chemistry for Climate, Roadmap for the Dutch Chemical Industry towards 2050	2018	Ecofys, Berenschot	VNCI	The Netherlands, chemical industry, 1990-2005-2030-2050; analyse potential pathways towards 80-95% reduction of greenhouse gas emissions	Thematic pathways: circularity & bio-based; electrification; CCS; and plausible combination pathways: 2030 compliance at least costs; direct action and high-value applications
Klimaatneutrale Energiescenario's 2050	2020	Berenschot, Kalavasta	Integrale Infrastructuur-verkenning 2030-2050 (II3050)	The Netherlands, multiple sectors, 2030-2050; outline four possible visions of the future for a climate-neutral energy supply in 2050	Scenarios: regional steering; national steering; European CO_2 steering; international steering
Systeemstudie Energie-infra-structuur Zuid-Holland	2021	CE Delft, Quintel, TNO	Provincie Zuid-Holland, Stedin, Havenbedrijf Rotterdam	Zuid-Holland; build environment, mobility, horticulture, industry, electricity; 2030-2050; explore impact of energy transition on energy-infra-structure and investigate required solutions and developments	Scenarios: regional steering; national steering; European CO_2 steering; international steering

When comparing scenario frameworks and discussing how various conceptualizations of uncertainty differ, the risk is to engage in highly abstract meta-discussions. At the same time, scenario frameworks do matter. After all, these frameworks are concretized with assumptions, translated into numbers, and subsequently form the basis for the modelling results that are reported, analysed, and compared and which, in turn, are used to build real-world strategies. Because decision-makers often aim to develop strategies and policies that are robust for multiple scenarios, the scenario framework chosen must adequately consider and describe the dimensions of uncertainty.

This study does not intend to provide a complete comparison of the scenario frameworks used in the Rotterdam energy and feedstock transition discourse. However, it does explore narratives that could be used to describe transition scenarios for the Port of Rotterdam industrial cluster, based on a series of confidential semi-structured interviews with companies presently active in the HIC.

Coming up with narratives devoid of the conclusions of earlier work would have been inattentive to the wealth of research that has been conducted earlier. This study uses the Wuppertal 2016 study to reflect on information derived from the confidential semi-structured interviews. Although the Wuppertal study was conducted five years ago, it is an adequate reference for this study because of its explicit focus on the Port of Rotterdam industrial cluster (particularly its industrial processes and activities), its relative familiarity to companies in the cluster, and its detailed and well-documented modelling. The remainder of this chapter provides a summary and interpretation of the pathways used in the Wuppertal study.

1.3 Wuppertal Pathways

In its report, the Wuppertal Institute for Climate, Environment and Energy sketched four pathways for the industrial cluster, taking into account public climate policy objectives:[4]

- Technological Progress,
- Biomass & CCS,
- Closed Carbon Cycle, and
- Business as Usual.

A simplified and slightly adjusted interpretation by the Port of Rotterdam is shown in Figure 3.

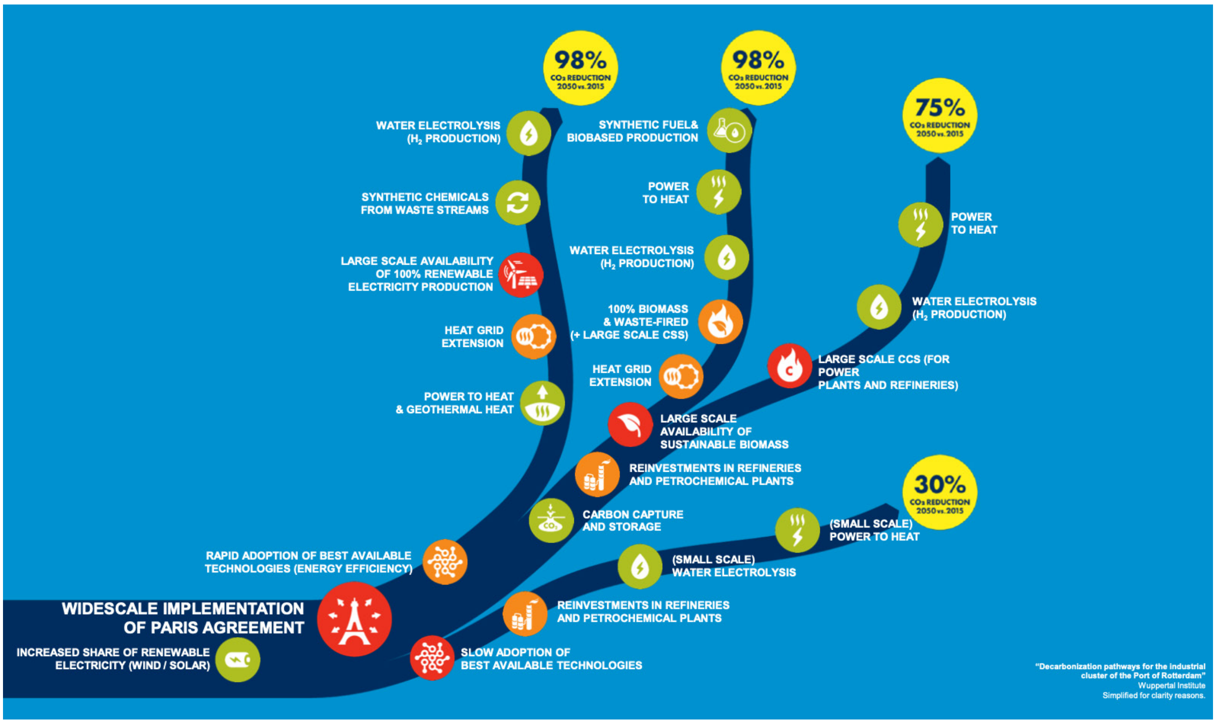

Figure 3. Pathways based on the Wuppertal study, as illustrated and adjusted by the Port of Rotterdam[5]

4 Samadi, Lechtenböhmer, Schneider, Arnold, Fischedick, Schüwer, Pastowski (2016). 'Decarbonization Pathways for the Industrial Cluster of the Port of Rotterdam'. Final Report. Commissioned by the Port of Rotterdam. Wuppertal Institute for Climate, Environment and Energy.

5 CIEP Energy Lecture, April 13, 2017. 'Pathways to a Decarbonised Port'. Allard Castelein, CEO, Port of Rotterdam.

The Technological Progress pathway achieves a substantial reduction of CO_2 emissions by 2050. It is realized through strong market coordination by carbon price signals from the European Union (EU) Emission Trading Scheme (ETS), leading to the rapid adoption of best-available technologies and the large-scale adoption of CCS. The Business as Usual pathway also leads to lower emissions, yet it falls substantially short of achieving public climate policy objectives, an insight which helps increase awareness of the challenge ahead throughout the cluster and beyond. Net-zero emissions are approximated through the Biomass & CCS pathway as well as through the Closed Carbon Cycle pathway. These pathways also assume the largest changes from a technological and organizational perspective.

A range of technologies is adopted, to a greater or lesser degree, in both the Biomass and CCS pathway and the Closed Carbon Cycle pathway. Each pathway name can best be understood from the aspect that sets it apart from the other. The Closed Carbon Cycle pathway lacks a strong emphasis on biomass and CCS in the Port, which is on the other hand very pronounced in the Biomass and CCS pathway. In turn, the Biomass and CCS pathway lacks the prominent role for closed carbon cycles through recycling plastics and keeping carbon molecules in a closed system without storing them underground in large quantities (or volumes), which is a central feature in the Closed Carbon Cycle pathway.

At first sight, the Biomass and CCS pathway and the Closed Carbon Cycle pathway appear to be very distinct from each other. In the Biomass and CCS pathway, the chemical industry is largely crude oil based, while the hard-to-abate sectors of the fuel market are served by synthetic fuels, produced through a Fischer-Tropsch (FT) process which takes imported biomass as input. In the Closed Carbon Cycle pathway, from the 2030s onwards none of the refineries (nor the Moerdijk steam cracker) will operate in their current role or capacity. One of the refineries' hydrocrackers will be used to convert imported FT wax into finished synfuels and naphtha, while methanol, produced from imported waste streams, will serve as a platform for the production of chemicals.

Aside from their differences, these two pathways share important technologies, such as water electrolysis to produce hydrogen. By highlighting a sharp distinction, the Wuppertal Institute managed to present clear images for fundamentally differently arranged set-ups of the industrial cluster, greatly supporting the discourse among stakeholders in and beyond the cluster. Yet it is important to keep in mind that multiple combinations of the pathways can easily be envisioned.

-02-
Insights from the field

Given the multitude of top-down studies, which usually depart from the target emissions goal in 2050 and work back to explore the routes of how to achieve this target, a stylized picture of the future of the industry appears. In practice, it is clear that competitive pressures in certain product markets, investment appetites, investment climate and government policies, as well as the portfolio of activities of companies, ownership, and technological and economic developments, play an important role in the dynamics of industrial change. Moreover, in many of the top-down approaches the 2050 target of net-zero emissions obscures the impact of intermediate targets and their instrumentation. For instance, the EU Renewable Energy Directive 2 (RED2), the Dutch CO_2 tax on avoidable CO_2 emissions and the Dutch SDE++ public support scheme also play an important role in the short- to medium-term planning of industrial change and emissions reduction investments. Also, the investment cycle is relatively long for most plants and needs to be planned ahead of time, leaving only a few options for plants to comply with the 2030 targets while positioning themselves for post-2030 changes in the industrial processes. Nevertheless, all companies are highly active in planning their future activities, reducing their CO_2 emissions and reorganizing flows within the cluster.

To obtain perspectives on industrial activities in relation to the energy and feedstock transition in the coming 5, 10 and 20 years in the HIC, a total of 17 confidential semi-structured interviews were conducted, involving 34 high-level field experts from major companies active in the cluster. These interviews took place in the months of February, March and April of 2021. The professional backgrounds of the interviewees range from strategy professionals to business developers, HIC site directors, chief executive officers and chief operational officers. Table 2 provides an overview of the consulted companies.

It must be stressed that the aggregate picture presented here cannot be attributed to any individual interviewed, nor can they be attributed to a single company. It is an aggregate reflection by the CIEP researchers involved in this project. This aggregate picture brings together views which were not shared by all; sometimes they were shared by many and other times by just some. As in any group, the views expressed are diverse, and different perspectives co-exist. As mentioned in the Introduction, a detailed report of the interviews is not presented here due to confidentiality reasons. Instead, broader insights into the foreseen steps in the transition and the uncertainties surrounding these steps were derived from the interviews in a process aided by knowledge developed by CIEP researchers in earlier studies. Interpretation of these insights follows in the next chapter, where they are mirrored against the Wuppertal study.

Table 2. A total of 17 Interviews were conducted with 17 companies, involving 34 high-level field experts

Refineries	BP ExxonMobil Shell
Biorefineries	Neste
Tank storage	HES International Koole Terminals Vopak
Chemicals	LyondellBasell Nobian
Industrial gases	Air Liquide Air Products
Waste, electricity, grids, Port	AVR Eneco Gasunie Port of Rotterdam Stedin Uniper

The semi-structured interviews took 90 to 120 minutes each and covered four broad themes. The template used is shown in Table 3. It must be noted that the template was tailored each time to the companies' respective roles in the cluster.

Table 3. Template for the structure of the interviews

Theme: Your expectations for the future • How do you see your company's activities in the Port of Rotterdam industrial complex (HIC, haven-industrieel complex) in the next 5, 10, and perhaps 20 years? What kind of activities dominate? What 'certainties' form the basis for your vision? • What kind of uncertainties, both inside and outside your company, play a crucial role? What kind of uncertainties do you consider most worrisome? • What kind of cargoes (raw materials, products, etc.) do you see coming in? Is material being processed further at your locations in the HIC? In this regard, what is your assessment of the development of new supply chains and new value chains, either from imported raw materials/intermediates/products, or based on local/regional NW-European production? • Over time, do you expect more or fewer cargoes, and larger or smaller annual volumes, to be shipped in and out – for your business activities and for other industrial activities in the Rotterdam HIC?
Theme: Alternative or additional developments which could have great impact • What kind of energy carriers, raw materials and products do you expect to be traded internationally in the longer term (electricity, hydrogen, steam, waste, pyrolysis oil, syngas, synfuel, ft-wax, biomass, CO_2, etc.)? In what manner and to what extent might these play an important role for your future business activities? • What are the main uncertainties with respect to the availability of such energy carriers, raw materials and products (and the timing of their availability)? • What kind of moments in the coming years and decade(s) could turn out to be the crucial ones for decision-making, with respect to the development and use of such energy carriers, raw materials and products for your business activities?

Theme: The area around your sites in the Rotterdam HIC

- What kind of companies and what kind of activities would you prefer to have in the vicinity of your business activities and at sites in the Rotterdam HIC?
- What kind of industrial sites do you expect will become available in the HIC for new activities? What type of development by third parties would you prefer for these terrains, that would benefit your company's objectives? What kind of developments do you expect in practice?
- Is it relevant for your company that such preferred developments take place in the vicinity of your activities and sites, or could they still benefit your company if they are realized on sites elsewhere in the Rotterdam HIC (or hinterland)?
- What kind of 'newcomers' do you expect in the Rotterdam HIC, what kind of activities do you expect from them, and do you think they will offer opportunities for cooperation?
- What are your expectations with regards to crude oil refineries, the petrochemical industry and the tank storage terminals in the Rotterdam HIC (and hinterland)?

Theme: The Rotterdam HIC in Europe and the world

- What do you see as preferred developments for the Rotterdam HIC, also in relation to the hinterland?
- How should the Rotterdam HIC position itself vis-à-vis other competing (existing and new) industrial clusters and ports in Northwest Europe?
- Do you expect 'policy competition' between EU countries? If so, is it problematic, and how should it be dealt with by governments?
- The centre of gravity of the global economy has shifted to Asia. How would you characterize activities and developments in petrochemical industrial clusters in that part of the world in the coming 5, 10 and perhaps 20 years?
- Is the Dutch and European energy transition policy agenda a mitigation opportunity or a threat to the Rotterdam HIC in this internationally competitive environment?
- Do you expect the Rotterdam HIC to continue to serve as a major hub in Northwest Europe in the future, and what is needed to ensure this?

The interviews confirmed that some of the terminology used in the energy and feedstock transition discourse in the Port of Rotterdam is used differently and perhaps inconsistently by the different stakeholders. The appendix to this report discusses factors that play a role and recommends an 'add and ask' approach to prevent future confusion.

The remainder of this chapter presents the insights from the interviews, loosely following the four themes. The first section presents an aggregate picture of the expectations from interviewees in relation to the energy and feedstock transition. The second section is an aggregate reflection on more uncertain possibilities, followed by a third section which provides some insights gained into spatial matters and cluster integration. The fourth and final section provides aggregate views on the position of the HIC in Northwest Europe and the world.

2.1 Aggregate expectations for the future

The role of biofuels in the cluster, specifically hydrotreated vegetable oil (HVO), is poised to grow between now and 2030. In addition, biokerosene capacities may be developed. The EU RED2 directive will be a major driver. Bioethanol will continue to be blended with road transport fuels. Coal combustion for power generation will be phased out altogether by 2030.

Carbon Capture and Storage (CCS) will take shape through the Porthos project.

The low-carbon hydrogen economy is advancing. The first electrolyser projects of substantial scale (order of magnitude of 100+ MW for individual projects) should take shape in the coming years, although hydrogen volumes will remain relatively small compared to hydrogen production from conventional hydrocarbons, including residual refinery gases (through steam methane reforming, SMR or autothermal reforming, ATR). A small part of the CO_2 emissions from SMRs are now being captured for delivery to greenhouses in the region.

In time, low-carbon hydrogen supplies will replace hydrogen from existing production facilities in the HIC. Ultimately, hydrogen produced through electrolysis will be destined for the (heavy) transport sector, but the backstop option for using it for industrial purposes in the HIC mitigates early market development risks in the transport sector. In the decade from 2030 to 2040, the role of hydrogen is set to grow. Before 2030, hydrogen from water electrolysis will not achieve sufficient scale, compared to SMRs and ATRs using hydrocarbons as feedstock.

The traditional market for road transport fuels in Europe is expected to be smaller but still very substantial by 2030, while overseas markets for these fuels will remain highly competitive. Whereas export markets for liquid fuels are challenging to serve by most European refineries, best-in-class refineries could remain cost-competitive in overseas markets, thanks to a broad product portfolio. They create much value from one barrel of oil, while cluster integration in the HIC adds to their efficiency. Markets for marine fuels and aviation fuels will not be challenged as much by alternative fuels, even beyond 2030. Marine fuels are difficult to replace, since many ships and carriers sail all over the globe, while a global network for alternative fuels is non-existent. The market for naphtha, an important feedstock for the chemical sector, is substantially more solid, too, than demand for fuels for road transport. Nevertheless, competition from lighter cracker feedstocks will continue to play a defining role in the sector. While biobased oil products, such as hydrotreated vegetable oils (HVO), will gain in importance, volumes will remain modest up to 2030 compared to liquid volumes based on conventional hydrocarbons.

Overseas shipments of hydrogen will begin before 2030, and imports will become available for Europe. Initial volumes will be small. In the 2030s, volumes are expected to increase substantially.

Heat demand in the cluster will remain substantial. Residual heat from coal-fired power plants will not be available after 2030, which is a concern since alternative renewable heat sources are not readily available and the development of additional heat grids is advancing only slowly.

Current electricity transport infrastructure does not always allow for the early adoption of electric boilers and furnaces, while an electricity supply dominated by variable wind and solar energy may not offer affordable baseload heat, though it is essential for many industrial processes. Whether or not it is techno-economically the most desirable, a widely shared conviction is that it is more realistic in the short to medium term that pipeline transport infrastructure for hydrogen will be developed in the HIC than grid reinforcements into every vein of the cluster. This conviction is steering heat consumers' plans and investments, to the benefit of projects that generate heat from (biobased) waste streams and potentially hydrogen, while large-scale geothermal projects remain distant ideas.

Pyrolysis plants for the chemical conversion of plastic waste into oils that can serve as feedstock for chemical process presently play a negligible role globally. Towards 2030 more experience will be gained so that the next generation of plants will be more reliable and larger in scale. For closing carbon cycles by recycling plastics, this development is desirable and essential. By 2030, pyrolysis plants could make a limited contribution to handling specific plastic waste streams. At the same time, the volumes of pyrolysis oil being produced in these plants will remain limited in relation to the feedstock needs of the chemical industry – globally, in Europe, and in the HIC. Costs are generally higher, but in specific markets feedstock from recycled plastics has a higher value, too, so some business cases can already be realized. Between 2030 and 2040, it may further gain in importance, but it is unlikely to become the dominant feedstock for the chemical industry over the time horizon in this study. Feedstock such as naphtha from conventional oil refineries, natural gas liquids (NGLs), and liquefied petroleum gas (LPG) will remain the dominant source of hydrocarbons for the chemical industry.

2.2 The mixed picture: Uncertainties

Political and societal preferences in the areas of technology and fuel choices have been experienced as erratic. The technological options for the future are sometimes quite clear to researchers, public policy officers and the business environment. But the degree to which these options are available for actual implementation is uncertain. Moreover, concerns exist over the political and societal support for integration of new approaches in the existing industry ('transition'), versus the idea that an entirely new industry can be built from scratch while the existing industry should fade way soon and fast ('revolution!').

A clear view on the future organization of the new value chains could not be obtained in the interviews. What parts of the new value chains will be organized in the HIC and what parts overseas? Techno-economic analyses also leave room for uncertainty. Additionally, supply chain security concerns, against the background of a changing geopolitical landscape, reinforced by the Covid-19 crisis, could imply that crucial sectors and products will be identified politically (for instance the EU energy and feedstock production and conversion capabilities, and products such as base chemicals). This could imply that parts of the value chains will be supported in the EU as strategic activities.

The role of biobased fuels, including HVO, is set to grow between now and 2030. Yet it is uncertain what its relative contribution will be in the energy and feedstock demand between 2030 and 2040. The availability of sustainable, societally accepted volumes of vegetable oils, including from waste streams, remains the largest barrier for widespread adoption. 'Volumes of used cooking oil are limited', is a central idea. Also, the contribution of bioethanol, biomethanol and biobased feedstocks for chemical processes is uncertain. Their availability and the political and societal support for them are concerns, in light of another technological option that may gain traction in that decade and beyond 2040, namely syn-fuels, e-fuels and compounds obtained from closing carbon cycles, among others through the recycling of (plastic) waste. There is a fair degree of uncertainty here, in part due to questions of how much renewable electricity will be available and to what extent hydrogen imports from overseas will contribute. The recent discussion on the use of biomass for power generation adds to the uncertainties.

It is very likely that the European market for road transport fuel will be smaller in 2030 than today, and it will probably shrink further towards 2040 due to the growth of electric passenger cars, light trucks and vans. But it is difficult to predict what the implications will be for the three largest refineries in the HIC. In part, this is because their position depends on what happens to other EU refineries and on what value they can generate by serving overseas markets or other market segments. Commercial managers of refineries will seek to create value in new markets, such as serving hydrogen demand in the transport sector, meeting and creating demand for an array of biobased products and managing hydrocarbon waste streams, potentially including the recycling of (plastic) waste. While closures cannot be ruled out, it must be borne in mind that divestment and ownership change is another possibility, and that a repositioning of terrain and assets can generate value.

The degree to which CCS will be upscaled post-2030 is uncertain, too. There is clear interest in follow-up projects such as a Porthos 2 project. A connection and the integration with the Athos project further north up the coast were mentioned as an interesting opportunity.

In today's societal and political discourse, CCS is often framed as a temporary solution for the period up to the 2030s and will not be upscaled much further than 7 megatonnes per annum. But it may continue to be essential at a larger scale and for longer, in order to remain within the emissions boundaries and stay close enough to the net-zero pathway. The pace of growth for creating hydrogen from water electrolysis may affect outcomes, since insufficient progress there could demand more low-carbon hydrogen from the thermal reforming of gases. The latter requires CCS to ensure that it is a low-carbon source of hydrogen. This in turn can be placed against the background of low-carbon hydrogen imports from overseas. The more that is available at low cost, the less hydrogen might be produced in the HIC region from hydrocarbons, demanding more or less CCS to ensure that local hydrogen production is low-carbon.

The H-Vision project aims to produce hydrogen from residual refinery gases (through autothermal reforming, ATR), which allows for the production of low-carbon hydrogen, is still struggling to get to a final investment decision by the consortium of companies. This relatively large project is awaiting government support, and financial hurdles must still be overcome. Large-scale, low-carbon hydrogen projects are essential for building critical mass for hydrogen developments in the HIC.

With respect to hydrogen imports from overseas, another uncertainty is the technological process of importing hydrogen. Three competing approaches are being investigated with increased attention and are likely to co-exist for some time. The first approach is ammonia, which is already shipped in tankers today for the fertilizer industry. Its toxicity is a concern. The second approach is the use of liquid organic hydrogen carriers (LOHC), which would fit well with today's oil infrastructures (tankers, barges, tank storages, pipelines), also for transport to the hinterland. Cost hurdles still need to be taken. The third is liquified hydrogen (LH2), which is relatively challenging due to the cryogenic conditions. Yet a radical redesign of hydrogen transport logistics may be justified by the new scale at which hydrogen trade could potentially take off and the new role hydrogen could play in the energy system. The varying energy densities of these carriers play a role in the discussions but, at this stage, do not rule out one or multiple options.

In the coming years, some hydrogen (carrier) shipments will take place, targeting several industrial ports and demand centres around the world, but volumes will remain small. More substantial volumes are expected sometime between 2030 and 2040, but it is unclear exactly when and how. A related uncertainty stems from the question of whether gaseous hydrogen will be injected in pipelines in the HIC for consumption elsewhere, or whether it will be transited in part in its cryogenic or liquid form for conversion elsewhere.

In the past decade or two, limited progress was made with extending heat grids and integrating those in the HIC with buildings in residential and business areas around the HIC. It remains uncertain whether it will succeed before 2030, and if so, whether heat grids will become an even larger pillar of heat supply infrastructure for buildings in the years up to 2040 or whether competing options will prevail, such as electricity, low-carbon gases and hybrid solutions. Within the HIC, the availability of sufficient quantities of high-temperature heat, which can only be transported a couple of kilometres, is another concern. It remains unclear what the relative contributions of electricity-based solutions, (bio-based) waste options, and hydrogen technologies will be up to 2040. Much depends on the extent to which grids are reinforced and extended in the cluster and elsewhere, and on the extent to which biomass will be available (and deemed politically and societally acceptable).

2.3 Spatial questions and cluster integration

A substantial degree of change is demanded by government and stakeholders (witness the industry tax on avoidable CO_2 emissions), by policies and regulations, and by clients (from the companies active in the

HIC). Up to 2030, some companies already see spatial limitations as a key barrier to developing new initiatives, while a few other companies indicated that sufficient land is currently available (on site) for new projects. Most companies take a moderate position between these extremes. In this period, a range of limiting factors complicate agendas, including the availability of workers and expertise, access to essential grids for energy (carriers) and CO_2, environmental permissions (particularly for nitrogen oxide emissions) and permits for new construction works, and the availability of space and terrains.

Even though the availability of space and terrains is a concern for some as they look towards 2030, presently it is not the prime concern for most interviewees. This is likely to change as we move closer to 2030 and 2040, given the spatial requirements of many of the technological options available for the energy and feedstock transition. These range from the footprints of electrolysers, electricity substations and transmission lines, and carbon capture and storage projects, to the logistics surrounding plastics recycling, receiving and storing hydrogen carriers and sustainable carbon from overseas, and the production of syn-fuels, among others.

The change process in the HIC is by no means symmetrical. Lower utilization of existing facilities will not immediately free up space used by those facilities, while new activities related to the energy and feedstock transition must already be built. Also, the present arrangements in the HIC have been optimized over decades. The exchange of flows between sites contributes not only to energetic/ feedstock efficiency and carbon efficiency, but also to spatial efficiency. Whereas in a net-zero world the HIC is ideally highly efficient as well, a phase can be expected in which suboptimal arrangements are bound to emerge and which will require re-optimization later. Residual flows from one (new) site may not be available right away to alleviate the energy or feedstock needs of another site.

Reinforcing and extending electricity grids in the HIC is a complicated matter. Conversion stations and transmission line corridors require substantial space. To the extent that reinforcements and extensions are possible, they require time to organize. At the same time, substantial CO_2 emission reduction results must be delivered by 2030. Many energy consumers in the HIC appear to prefer to facilitate these CO_2 reductions by gaining access to hydrogen and CO_2 pipeline infrastructure, which they deem more realistically achievable than electricity grid reinforcements and extensions. However, some stressed that hydrogen and CO_2 pipeline infrastructure may lead to technologically less efficient solutions. Others argued that the most efficient option is not achievable and that sufficiently efficient alternatives should be embraced. A shared conviction was that major electricity transmission lines bringing offshore wind electricity to shore can easily reach the western-most portion of the HIC (Maasvlakte), close to the open sea. Conversion of offshore wind electricity into hydrogen through water electrolysis in that area is therefore a realistic option. Ideally, the heat produced by electrolysers would either be used locally or fed into heat grids, after boosting temperatures if required.

2.4 The Port of Rotterdam industrial cluster in Europe and the world

In the interviews it was confirmed that the Rotterdam HIC is well positioned in Europe and is expected to remain so in the future. Waterways, pipelines, roads and railways connect it to major demand centres in the hinterland, while the deep-water port is accessible for a wide variety of large cargos from overseas. Such cargos include or could include crude oil shipments, oil products, biofuels, base-chemicals, biomass and, gradually over time, hydrogen carriers (ammonia, LOHCs, LH2) and sustainable carbon (e.g. methanol, ethanol, FT-wax).

What the future exactly holds is inherently uncertain. A portion of any supply chain or value chain is developed near production centres, while other portions are organized efficiently enough near consumption centres. Clear historic examples of the latter can be seen in the refineries (converting crude oil into oil products) and petro-chemical industries (adding value) which chose locations not close to low-cost primary supplies, but instead close to their consumer markets, in a time and socio-political environment when having capital stock near production centres was deemed insecure. As stated, it is neither a given that new energy and feedstock processing will be organized primarily near low-cost primary supply centres, nor near the consumer markets. This is uncertain because it depends as much on the political-institutional arrangements that seek sufficient supply chain security as on the economics of the production, transport and conversion technologies.

A more recent trend, witnessed by the companies, is China's growing importance in crude and chemical flows. Additionally, the altered position of the US in global crude and chemicals markets as a result of the shale revolution is of grave importance to many of them. Internationally operating petrochemical companies active in Rotterdam can benefit from these developments, as they typically operate a portfolio of plants around the world. Yet these developments could affect the competitiveness of European plants that are geared towards global markets. Here, integration of the plants in the vast network of Northwest European industrial clusters is beneficial to ensure future competitiveness, especially for those plants that produce multiple (by)products.

Within (Northwest) Europe, a consideration for the HIC is the potential policy competition among the EU member states. Policy competition involves the adoption of policies by one member state, aimed to attract or maintain certain parts of the industry, potentially to the detriment of other member states.

Factors that will contribute to the competitive edge of the cluster are the future availability of large volumes of renewable electricity from North Sea wind farms, good access to hydrogen connections to the (remote) hinterland, liquid pipeline connections with other industrial clusters elsewhere (in the Netherlands, Belgium, Germany and France), CO_2 infrastructures offshore, a highly qualified workforce and supporting institutions (in finance, ICT and knowledge). The process of change in the coming years and decades will inevitably be challenging for all stakeholders involved, and at times there will still be a certain degree of misunderstanding, mistrust and conflict with government and other institutions and organizations active in the public debates. Trust, mutual understanding, acceptance of each other's positions and priorities, willingness to invest, and consistency and predictability in public policies can all contribute to industrial renewal, helping the HIC to position itself well in a net-zero future.

-03-
Uncertainty in three dimensions

This chapter revisits the insights gained from the interviews and mirrors them to the earlier work by the Wuppertal Institute on the HIC. Crucially, the interviews confirmed that technological uncertainties remain, but also that additional uncertainties will play a major role in shaping the course for investments related to the energy and feedstock transition. This chapter therefore explains three dimensions that should be recognized when exploring possible future demand for hectares for industrial activities in the HIC. First, the technological uncertainty is described, taking the 2016 Wuppertal analysis as a point of reference. Second, uncertainty with respect to the character of the change process in the HIC is highlighted, acknowledging the vastly different positions of the many stakeholders involved. Ultimately, these players will jointly shape the process by their individual actions, while they also strongly influence each other's options, given the integrated nature of the HIC. The degree to which terrains can be reconfigured to include the new activities or re-used has an impact on demand for 'new' hectares for industrial activities. Third, uncertainty with respect to the global context is explained, stressing that the way international trade and markets are organized can impact demand for hectares.

3.1 Dominant technologies

Taking the Wuppertal framework as a point of reference and comparing it to the aggregated image that emerged from the interviews, three conclusions can be drawn. First, the Wuppertal pathways adequately represent the key (technological) uncertainties up to 2050. The timely and wide-scale availability of CCS, sustainable biomass and renewable electricity remains undecided. Second, for the years between now and 2030, the 2016 Wuppertal pathways can already be updated, based on new insights. Third, from the interviews it can be derived that a business as usual pathway is not expected. Instead, an 'impracticable ambitions' scenario is feared. In such a scenario, the industrial renewal of the cluster would not really take off, for an array of reasons. Such a pathway does limit additional demand for hectares, but it also implies that the HIC would not contribute to or benefit from the early energy and feedstock transition that is essentially required to achieve net-zero emissions in Europe and the Netherlands by 2050.

CIEP

Figure 4. Technological pathways towards 2030 (dark blue) and 2040 (light blue)

Figure 4 summarizes the interpretation of the findings by the CIEP researchers. In dark blue, it shows that the three pathways characterized by substantial industrial renewal towards 2040 share commonalities in the period towards 2030, while the fourth pathway diverges. Already it is certain by government decision that using coal for power generation will be phased out by 2030 and that by then the first hydrogen projects will have been developed. This is highlighted in the figure, as it was not known at the time of the initial Wuppertal analysis. High expectations also exist for the rapid deployment of CCS infrastructure (including CO_2 pipelines in the HIC), for hydrogen pipelines in the HIC, and for an increased role for biomass for fuel production. RED2 drives the latter, while broad though sometimes implicit political support (also from the EU) for the Porthos CCS project and for the various hydrogen initiatives contribute to the former.

With respect to hydrogen, small-scale production of hydrogen through electrolysis is regarded as most certain. The H-Vision project (autothermal reforming of refinery gases, ATR) could potentially fail if the business case is insufficiently attractive for all the parties involved, despite the desire and need to produce low-carbon hydrogen in large volumes early on. If no low-carbon hydrogen projects at sufficient scale materialize, if Porthos fails to take off, and if political and societal support for the use of biomass diminishes, the scene is set for a potentially very problematic 2030-2040 period. It fits the 'impracticable ambitions' pathway, which is considered highly undesirable by all stakeholders. It is unclear what the pathway ultimately implies for the cluster in the years 2040-2050, but possibilities range from not achieving net-zero emissions to net-zero deindustrialization within the national borders.

The starting point of the three pathways, which assume substantial technological change and renewal, hinges on a successful start with small-scale hydrogen production through electrolysis using renewable electricity, substantially larger-scale hydrogen production from refinery gases contributing to economies of scale for hydrogen pipelines and use, successful development of the first CCS infrastructure, and upscaling of biofuel production capacity. The interviews confirmed that the relative contributions of renewable electricity-based approaches, CCS and biomass to the industrial change process between 2030 and 2040 remain unknown. These insights, emerging in the time since the initial Wuppertal analysis was done, should inform the technological exploration with regard to the number of hectares needed for industrial activity in the HIC towards 2040.

3.2 Process of change in the HIC

An important observation made in the interviews relates to the process of change, which is ongoing in the HIC context. Many ideas exist within the companies to position themselves constructively and competitively in the future low-carbon economy. Moreover, this positioning is largely in line with the public policy objective of reducing greenhouse gas emissions and embracing elements set out in the technology pathways. At the same time, in the private sector, it is crucial that these ambitions can be translated into business cases that ultimately contribute to the companies' 'bottom line'. Some additional risk with regard to future earning is accepted in these business models. Nevertheless, head offices, including those abroad, require a certain level of comfort before making investment financing available. In the interviews, a grave concern was that the ongoing social-political processes inhibit the companies from organizing their desired new roles and building new value chains. Such concerns could hinder the HIC plant managements in convincing (foreign) head offices to go ahead and invest so that the identified opportunities can in fact be transformed into new activities.

One clear example here relates to the changing societal and political attitudes towards the use of biomass for energy and feedstock and the way they impact the legal and financial support framework. Another recent example is the impact of past public policies regulating the emissions of nitrogen oxides (stikstof in Dutch) and the sudden uncertainties this has created for new investments that are meant to reduce greenhouse gas emissions (such as CCS/Porthos). An additional concern for some of the companies already present in the HIC today is that the petrochemical sector may be framed as 'part of the problem', meaning that it is something to be phased out, rather than 'part of the solution'. These are relevant observations, because the efficient (re-)use of existing HIC sites and infrastructure is less likely when the existing HIC players are not part of the future.

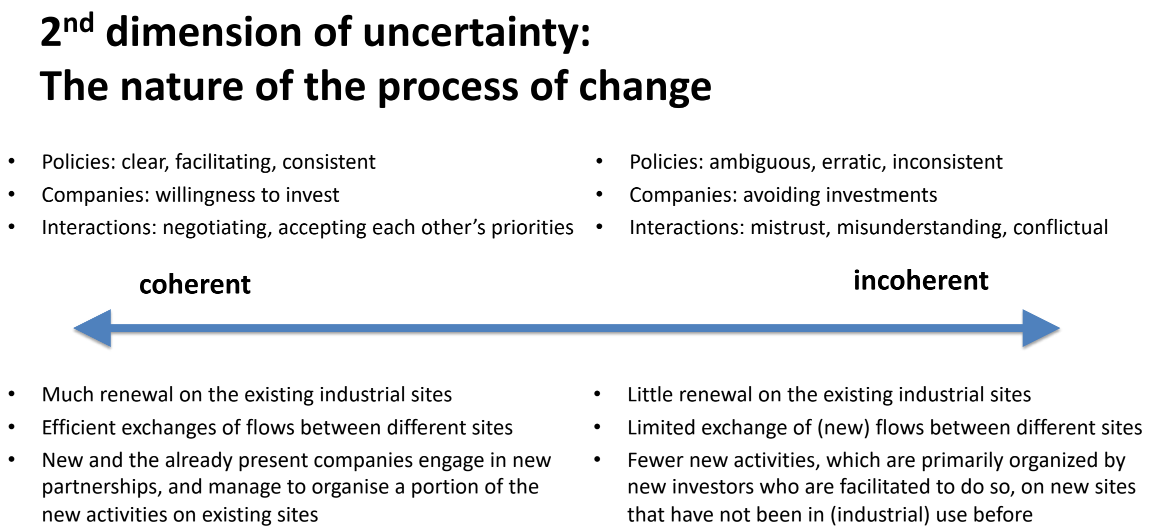

Figure 5. The nature of the process of change in the HIC

When exploring the spatial impact of the energy and feedstock transition in the HIC, it is therefore recommended to explore the future along this dimension. The second dimension of uncertainty to be included in the spatial analysis thus relates to the nature of the process of change in the Rotterdam HIC (see Figure 5). At one extreme end, the process is coherent. Public policies are clear, facilitating and consistent. A strong willingness to invest and cooperate is present among the companies that are active in the HIC as well as with new investors. Interactions between public authorities, the Port of Rotterdam, one company and another recognize, respect and accept each other's priorities, and the process is one of negotiation and bargaining. As a result, much renewal takes place on the existing industrial sites. Efficient exchanges of flows between different sites take place. New investors and the incumbents engage in partnerships and manage to organize a portion of the new activities on existing sites.

At the other extreme, the process of change is incoherent. Public policies are ambiguous, erratic and inconsistent. Companies avoid or delay investments. Interactions between all the stakeholders are shaped by mistrust, misunderstanding and conflict. As a result, little renewal takes place on the existing industrial sites, and limited exchange of (new) flows can be organized. While fewer new activities are being developed in the HIC, it is mainly new investors who are facilitated to develop these activities on new sites that had no prior industrial use.

In either case, a period should be expected during the transition in which sub-optimal arrangements are bound to dominate and will require re-optimization later. Residual flows from one (new) site may not contribute right away to energy or feedstock needs for another site.

Finally, it is essential to stress that internationally operating businesses could opt to divest from industrial sites and plants in the HIC, whereas new owners might continue to run the site for another couple of years without much investment and renewal, i.e., 'sweating the assets'. Consequently, the site would not be available for the energy and feedstock transition in the HIC for even more years. From a spatial viewpoint, lost years or a 'lost decade' for one or more large industrial sites in the cluster could turn out to meaningfully impact the need for new terrains that can contribute to the energy and feedstock transition. The latter emphasizes this dimension's relevance for spatial analyses.

3.3 International trade and markets

Another observation made in the interviews is that there is no clear view on the geographic or locational arrangements of future value chains. On the one hand, the general perception is that the energy production cost and the availability of circular or biogenic carbon is better in other parts of the world. On the other hand, (Northwest) Europe is a major demand centre for many products, and the HIC is well placed as an entry point to satisfy that demand. Transportation cost is an additional consideration when assessing future arrangements, as well as exactly where conversions can best take place based on the available infrastructures and costs. While it highlights the many uncertainties present with respect to future value chain arrangements, such a narrow economic analysis ignores political and institutional questions. Some products, sectors, feedstocks, energy carriers or energy production capabilities may be politically and economically identified as strategic. Institutional arrangements could be chosen to ensure that supply chains offer sufficient comfort. At the same time, the extent to which portions of the value chain are preferred in the EU could substantially impact the industrial activities that take place in the HIC. Another consideration for the HIC in this context is the potential competition among the Northwest European member states. Policy competition, intended to attract or maintain certain parts of the industry within their national borders, to the detriment of the HIC, should also be considered as an uncertainty.

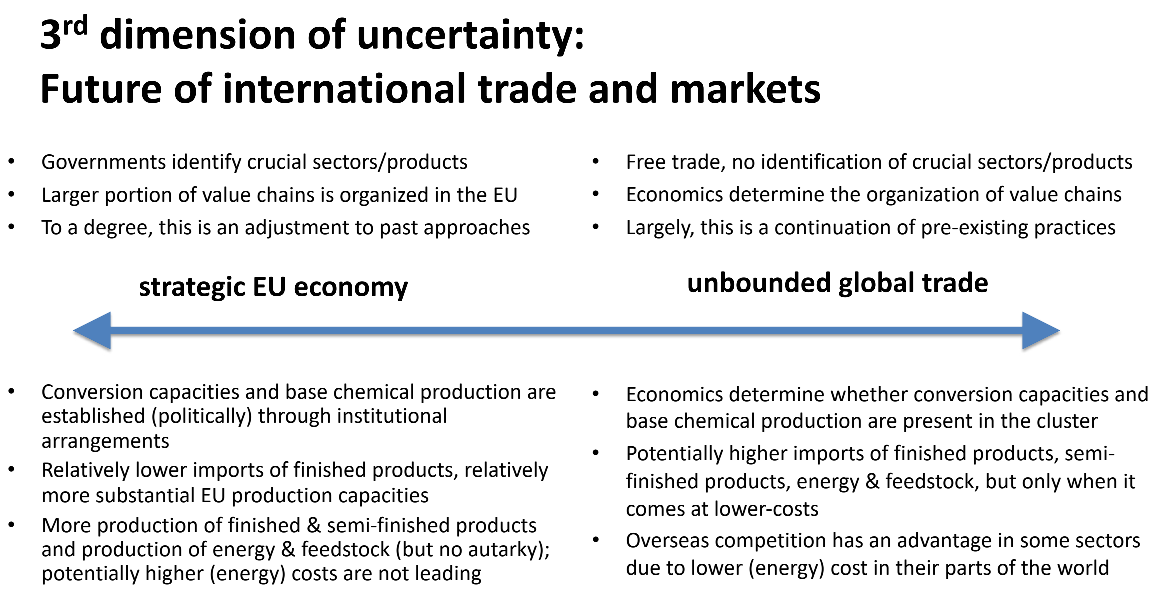

Figure 6. Future international trade and markets

Given the uncertainty observed in the interviews, it is also recommended to explore the spatial impact along the lines of future international trade and market developments (see Figure 6). At one extreme, governments would identify crucial sectors and products, implying that a larger portion of low-carbon value chains would be organized within the EU. To a degree, this is an adjustment to past EU approaches to international trade and markets. Consequently, conversion capacities and base-chemical production would be established in the EU through institutional arrangements (trade policy) to ensure political comfort with the resulting supply chains. This would lead to relatively lower imports of finished products and to relatively more substantial EU production capacities, which would then produce more (semi-) finished goods, as well as more energy and feedstock. Yet it is essential to stress that this is not meant to, and is unlikely to, result in anything close to autarky.

At the other extreme, unbounded global trade would be the norm for future international trade and markets. There is no political identification of crucial products and sectors. Economics would largely determine the value chain arrangements and would be in line with recent trade practices. As a result, the extent to which conversion capacities and base chemical production are present in the future cluster would be determined by economics. This could imply more imports of finished products, some semi-finished products, energy and feedstock, relative to the other, more strategic positioning described earlier, and only when it implies lower costs. Overseas competition would be at an advantage in some sectors due to lower (energy) costs in some parts of the world.

Against this background, it is essential to add, as was mentioned in several interviews, that the HIC holds a unique position as a deep-water port and is well connected with major population and economic demand centres. In the post-WWII period the region was politically stable, and regulation was sufficiently business-friendly, convincing multinational companies to invest their capital stock in the HIC. All these factors are considered when value chains are rearranged by international companies. Additionally, the institutional-economic context is dynamic and can shift with changing political priorities, for instance with respect to supply chain security (or supply and demand). Assessing future value chains and the geographic distribution must therefore look beyond a narrow techno-economic assessment of production costs and geography. From a spatial viewpoint, it is therefore recommended to explore how a more strategic EU economy compares to unbounded global trade in terms of spatial requirements for industrial activities in the HIC.

Conclusion and Recommendations

Activities in the extended fuel cluster will change as a result of the energy and feedstock transition in the next twenty years. To assess what spatial possibilities and limitations companies see because of this change, this project set out to collect, analyse and interpret the views on the future of the companies active in the extended fuel cluster. It considers activities that are expected to gain and lose in importance, as well as the spatial implications, both onsite and offsite company terrains. Suggestions are made for narratives which can be used for creating (alternative) transition scenarios for the HIC. These results are aimed at enabling SmartPort to better shape future research while quantitively exploring the spatial question.

Based on this research it is concluded that views differ among companies regarding the availability of land between now and 2030. Some companies foresee spatial limitations as a key barrier to developing new projects. A few other companies indicate that currently sufficient land is available (on site) for new developments. Most companies take a moderate position between these extremes. Additionally, the widely shared view is that other factors are far more restrictive for future developments. For example, the available environmental space was mentioned many times. This refers to limitations to emissions of nitrogen oxides (stikstof) and, to a lesser extent, restrictions on noise levels and the handling of hazardous substances. Finally, companies have concerns about the timely extensions and reinforcements of the electricity grid. Land required for transmission lines and substations is not readily available.

For the period beyond 2030, the generic view is that the availability of land will be a bigger concern. The interviews revealed that the extent to which it will be an issue is uncertain as a result of number of reasons.

First, the interviews reiterated that the spatial requirements of many of the technological options available for the energy and feedstock transition can be substantial, ranging from the footprints of electrolysers, electricity substations and transmission lines, and carbon capture and storage projects, to the logistics surrounding plastics recycling, receiving and storing hydrogen carriers and sustainable carbon from overseas, and the production of syn-fuels, among others.

Second, the change process in the HIC is by no means symmetrical. This means that a lower utilization of existing facilities will not free up space used by those facilities, while new activities related to the energy and feedstock transition must already be built. Also, the present arrangements in the HIC have been optimized over decades. The exchange of flows between sites contributes not only to energy/feedstock efficiency and carbon efficiency, but also to spatial efficiency.

Third, the interviews confirmed that value chains can be organized in a variety of ways. Some parts of the value chains could be set up in the HIC, while other parts could be organized elsewhere. As such, there are options to develop either a larger or smaller portion in Rotterdam. Because decision-making power in this respect resides in a wider societal, economic and political context, the outcomes do not depend exclusively on the preferences of Rotterdam site executives. No generic expectation for one arrangement or another was heard in the interviews.

The presence of considerable uncertainty confirms that a scenario approach is an appropriate method for exploring future land use. For this research project, the insights gained from the interviews were mirrored against the Wuppertal pathways. This effort led to the conclusion that the pathways could be enriched with insights particularly relevant for a spatial analysis. More specifically, uncertainties affecting demand for hectares in the HIC could be explored in three dimensions (see Figure 7).

Figure 7. Three uncertainties will determine demand for hectares for the energy and feedstock transition

The first dimension represents the dominant technologies. To this end, the insights from the 2016 Wuppertal analysis are largely adequate, although for the years leading up to 2030 the pathways can be updated, based on new insights. Suggestions for such an update are provided in this report. Additionally, from the interviews with high-level professionals, it became clear that a business as usual pathway is not anticipated. A widespread concern was observed regarding 'impracticable ambitions', a potential pathway that places demands on business activities in the HIC within a political-regulatory-societal framework that does not allow for these very same demands to be met.

The second dimension represents the nature of the process of change in the HIC. At one extreme, this dimension is illustrated by clear, facilitating and consistent public policies as well as a strong willingness among companies to invest and cooperate. The other extreme is characterized by ambiguous, erratic and inconsistent policies, coinciding with companies avoiding or delaying investments. The process of change could thus be coherent or incoherent, which is to suggest that either much or little renewal could take place on the existing industrial sites, impacting demand for hectares.

The third dimension represents the future of international trade and markets. The context of international trade and markets could either be characterized by relatively unbounded global trade or by a more strategic EU economy. Political choices for a more strategic economy could impact the number of hectares required for a range of production, conversion, storage and transport capacities. Yet the extent of this impact is unknown, since in the past decades a relatively strong belief in unbounded global trade was dominant.

Based on the presented analysis, this report recommends five priority areas for future Port dialogues:

- Recognize the existence of a looming spatial challenge that already plays a role at some individual sites and is expected to become more pronounced in the post-2030 period, in part because the energy and feedstock transition will progress in an asymmetrical manner. Regular meetings that constructively address these issues based on updated research findings can help remedy some of the uncertainties.
- Highlight examples of how existing plants and sites in the Port contribute to a space-efficient transition. The transition could greatly gain from focusing on what brings the stakeholders in the HIC together rather than what divides them.
- Acknowledge that the transition is part of a dynamic process of industrial change by taking a forward-looking perspective, accepting the present and being discrete when echoing results of back casted scenarios. The three dimensions of uncertainty presented in the report can serve as a basis for such repeated forward-looking assessments.
- Embed future (modelling-based) results of land use assessments in a wider set of narratives of Port development, and avoid the potential alienation of stakeholders by presenting (quantitative) assessments as isolated facts, inattentive to the wider discourse and the onsite developments.
- Weigh the costs and benefits of the dynamic process of energy and feedstock transition on existing sites as opposed to developing new sites.

The interviews conducted as part of this study confirm that the energy and feedstock transition will lead to substantial changes in the Port of Rotterdam and its industrial cluster. They furthermore make clear that 'business as usual' is not anticipated by the companies. It is important to emphasize once again that this expectation far from guarantees the achievement of the desired degree of industrial renewal in the HIC. The widely shared view is that it is imperative to avoid 'impracticable ambitions' and to make sure that the political, regulatory and societal framework in the run-up to 2030 supports the transition ambitions.

-Appendix-
Terminology

The interviews confirmed that some of the terminology used in the energy and feedstock transition discourse in the Port of Rotterdam is being used differently and perhaps ambiguously by the different companies. The words 'greenfield' (development), 'brownfield' (development), and 'infrastructure' are used differently and can lead to some confusion, because they have a different meaning for one party than for another, resulting in different interpretations of statements and views. In the 17 interviews, field experts were asked how they use the three terms.

Greenfield and brownfield

While the concepts 'greenfield' and 'brownfield' have different meanings in specific sectors and industries, the definitions according to Cambridge dictionary are shown in Table 4.

Table 4. Greenfield and brownfield according to the Cambridge dictionary

greenfield	• adjective [before noun] UK /ˈgriːn.fiːld/ us /griːn.fiːld/ • used to refer to land that has not yet been built on, or buildings built on land that had never been used before for building: "a greenfield site"
brownfield	• adjective [before noun] UK /ˈbraʊn.fiːld/ us /ˈbraʊn.fiːld/ • used to refer to an area of land in a town or city that was previously used for industry and where new buildings can be built: "Planners are committed to developing the city's brownfield sites before granting permission to build on the rural outskirts."

The interviews confirmed that there is no general agreement on how to use the terminology consistently. Four causes appear to play a role. First, the defining factor differs from one party to the other. No agreement exists over whether the status of the land is key for choosing either term, or whether it is instead the degree to which the new (industrial) activity is integrated with existing (industrial) processes and activities. For example, one party may consider a plot of land brownfield because it is surrounded by installations that provide excellent integration with existing systems and does not require any dedicated systems for heat generation, feedstock or demi-water. Another party may consider the same piece of land greenfield, since as the land itself is free of buildings. A fair amount of agreement is present only in some cases. For instance, when no integration is planned and no pre-existing installations need to be decommissioned, the proposed development is often considered greenfield.

Second, the concepts are dynamic in nature. Pre-used plots can be rehabilitated. In that process, different actors have different roles and perspectives. If a plot of land is to be re-used for a development by an actor which itself is doing some kind of rehabilitation first, then that actor is likely to consider it a brownfield development. However, if a third party rehabilitates the plot, over time it provides room for a greenfield development. Meanwhile, it should be kept in mind that the defining factor of integration with existing processes and activities can blur this picture.

Third, the use of the terms depends on a company's perspective. A piece of land can be greenfield for a grid company because there is no connection yet with its grid, while it is brownfield for a refinery because there are integration possibilities for a refinery. The fact that both companies may play a role in such a development makes both company perspectives relevant.

Finally, the level of analysis is a cause of confusion. For example, from a global or European level of analysis, it can be concluded that every additional development in the Rotterdam HIC is brownfield, since it will practically always build on existing practices and processes in the cluster. In contrast, a new development outside any existing cluster in an emerging country which cannot benefit from or be integrated with existing activities is more likely regarded greenfield. However, from the Rotterdam level of analysis, both greenfield and brownfield developments can take place.

Infrastructure

Also, the term 'infrastructure' has different meanings for different stakeholders. The definition according to Cambridge dictionary is shown in Table 5.

Table 5. Infrastructure according to the Cambridge dictionary

infrastructure	• noun [C usually singular] UK /ˈɪn.frəˌstrʌk.tʃər/ us /ˈɪn.frəˌstrʌk.tʃɚ/ • the basic systems and services, such as transport and power supplies, that a country or organization uses in order to work effectively: o "The war has badly damaged the country's infrastructure"; "It is a long-term task to rebuild the infrastructure of a war-torn country such as Angola"; "The industry was accused of having invested little in workers, plant or infrastructure"; "The minister is responsible for the country's transport infrastructure"; "More money is needed to maintain the city's infrastructure"; "Improvements are being made to the region's decrepit infrastructure".

The interviews again confirmed that there is no general agreement on how to exactly use the term consistently. Five factors appear to play a role. First, the company perspective determines the meaning attached to the term. Companies agree that many assets can be seen as infrastructure. However, when asked for concrete examples they are more likely to refer to what is closely related to their primary business activities. This is part of the natural human tendency to relate more to whatever is closer in time, space or ownership, a phenomenon known as 'proximity bias'.

Second, the assumed system boundary contributes to confusion. Some companies refer to infrastructure as all systems that they need for their primary business activities coming from offsite (outside of the company's battery limits, outside the company gates). They may use the word 'utilities' to refer to the same type of systems when these are situated onsite.

Third, some companies consider themselves 'infrastructure companies'. As a consequence, the company gates distinction does not always apply. For example, a tank storage company considers itself to be an infrastructure company. Its onsite facilities can be seen as infrastructure. The role a company plays is thus also a consideration.

Fourth, the level of analysis can determine what is included in the word 'infrastructure'. An observer at the HIC level may focus on specific elements in the cluster, such as pipelines and cables. At the same time, an observer at the European level may consider the HIC as a whole as relevant infrastructure for Northwest Europe.

Finally, physical items as well as immaterial factors can facilitate companies in carrying out their primary business activities. Both are sometimes referred to as infrastructure. Immaterial infrastructure can include knowledge infrastructure, financial infrastructure or ICT infrastructure (services offered by universities, R&D centres, training institutions, banks, insurers, accountancy firms, information and communication service providers, etc.).

Many factors contribute to confusion surrounding the use of the terms 'brownfield', 'greenfield' and 'infrastructure'. The HIC harbours multiple companies, each employing a multitude of individuals. It is impossible to agree on a strictly defined terminology. Researchers, policy makers and business professionals engaging with each other in energy and feedstock transition discourses are therefore recommended to aim for clarification through an 'add and ask' approach. 'Add' refers to giving more context when using the words, and 'ask' refers to asking more context whenever the words are being communicated.

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DO YOU HAVE
ANY QUESTIONS?

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