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Syngas value chain in Rotterdam HIC

Deliverable 3: Staircase assessment by external stakeholders

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Contents

Introduction – A strategic syngas value chain assessment

As the chemical industry transitions toward circular and renewable carbon, syngas emerges as a uniquely versatile building block for what comes next. Produced from waste, biomass, or CO_2, and convertible into chemicals, fuels, and other hydrocarbon products, syngas connects diverse feedstocks to a wide range of valuable outputs — making it a natural focal point for large-scale circular carbon development.

The Rotterdam Harbor Industrial Cluster (HIC) is uniquely positioned to lead this development. Its logistical reach across roads, rails and waterways, its access to large volumes of renewable power, and its role as a hub for international trade flows of feedstocks and products give the Rotterdam HIC the foundations to develop syngas value chains at meaningful scale — supplying both chemicals and fuels to the Antwerp-Rotterdam-Rhein-Ruhr Area (ARRRA) super-cluster and the greater Western European hinterland.

This study was initiated by the Province of Zuid-Holland (PZH), team Sustainable Harbor, Industry and Maritime Industry. PZH asked itself: "What can we do to stimulate the development of circular and renewable carbon investments in the Rotterdam Harbor Industrial Cluster?" To answer this, PZH commissioned Tekenkamer van de Industrie (TvdI) and Sproule ERCE to conduct a strategic exploration of how the transition toward circular carbon can move forward — assessing what syngas value chain development in the Rotterdam HIC could look like at different scales, what it requires, and what it means for the existing industrial ecosystem, infrastructure, and investment climate.

To structure this exploration, first archetypes of syngas value chains were developed to understand value chain requirements and conversion efficiency. Based on these archetypes three versions were made of development pathways for a syngas value chain with the aim to increase scale and allow the Rotterdam HIC to continue to play its critical role. These versions are deliberately polarized to surface the impact of starting with a different approach. For all three versions, as scale increases the complexities grow: from the challenge of supporting many independent projects, to coordinating the large-scale systemic transformation of the industrial cluster itself. The nature of the assets, the infrastructure demands, and critically, the focus of leadership all shift — from individual project developers to regional and ultimately national governance. And they differ markedly in their contribution to sustainability and strategic autonomy, making scale a strategic choice.

The exploration is structured across four deliverables and summarized in a whitepaper. Together they take the reader from the fundamentals of syngas value chains, through a scaling assessment, to a stakeholder landscape and a decision-based roadmap — building a coherent picture of what it takes to go from ambition to action. At its core, the study asks which scale is needed, and what it would take for the Rotterdam HIC to supply the hinterland and achieve our goals of CO_2 neutrality, circularity and strategic autonomy — creating a diversified circular carbon portfolio that secures the region's long-term industrial position.

Introduction – the stakeholder landscape framework

In this deliverable we take a close look at the stakeholder landscape connected to the syngas value chain. For syngas value chains to emerge and grow, it is important that key stakeholders who have influence on the development of these value chains, are aligned in their support for the development. To break this down in a structured way, we look at the stakeholder field at three levels, schematically shown in figure 1. We recognize three levels:

1. **Industrial assets:** the core of the value chain is shaped by the assets that form the value chain, from feedstock to products. This domain contains all primary elements – sourcing by suppliers, pretreatments, conversion and separations, and delivery to customers, including assets that deal with utilities, waste and byproducts.
2. **Infrastructure:** Industrial sites are connected with their environment, their suppliers and their customers via various shapes of infrastructure. These need to be in place at the right time and capacity to support operations.
3. **Investment climate:** The more generic term investment climate is often considered as an abstract notion of things that need to be in place for economic activity. From syngas value chain perspective, this domain covers all immaterial elements necessary for safe, clean, sustainable and supported industrial operations.

When there is support missing from any of these three elements, successful delivery of novel value chains is very difficult, if not impossible. Alignment of the stakeholders across these levels, as well as in time, is crucial. Therefore, we will first take a close look at what are the key elements in each category and which typical stakeholders are covering these areas. From this first overview we map the stakeholders that were interviewed and review their ideas and viewpoints in the stakeholder analysis. Finally, we report the feedback of stakeholders on the syngas staircase in a stakeholder workshop held on January 15, 2026, at the Province of Zuid Holland, The Hague.

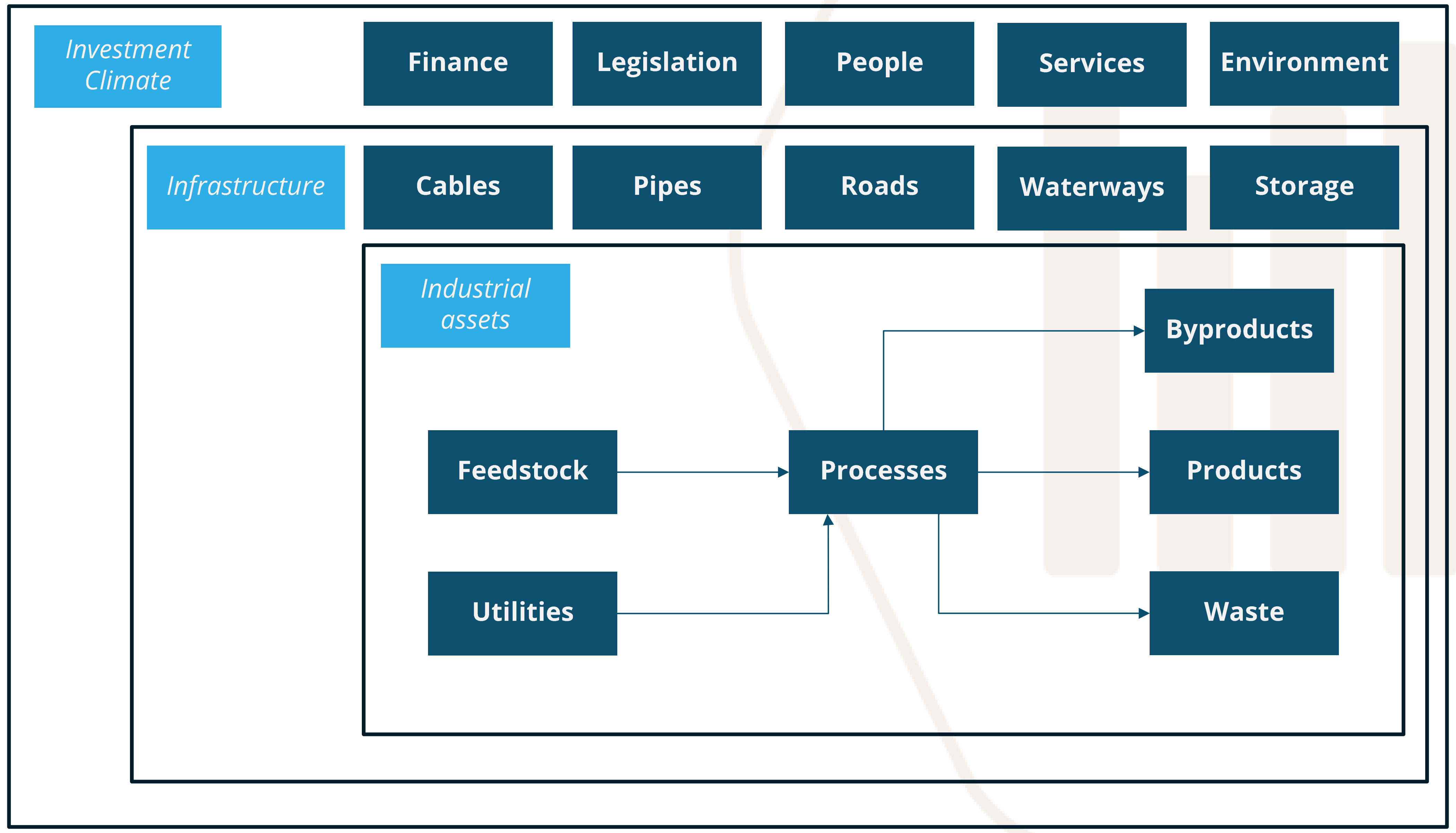

Figure 1: General 3-level framework for the stakeholder landscape for industrial assets – assets, infra and investment climate

Stakeholder landscape – organizations across three levels (1/2)

Types of actions and operations

When we review the stakeholder landscape, segmented across the three levels indicated, we find that we engage with very different types of companies and organizations:

1. At the core, at the **industrial assets**, we encounter all companies that develop, build and operate the assets in the core of the value chain. Of course, it depends on the scope and specific choices, but it contains all entities that are necessary to build and operate a full supply chain, from feedstocks and utilities to delivery of products and management of waste and side streams. These kind of parties are plotted in the center of figure 2.
2. In the next circle we identify all parties that are providing **infrastructure** and infrastructure services to operate the assets, securing to bring utilities to the site, and enable transport of feedstocks, goods and wastes to and from the site. From gas and power supply to roads, storages, waterways and more.
3. In the third circle, **the Investment Climate**, we identify typically parties that set rules and control them (governments and authorities), but the scope is much wider, as for development you need skilled people, funding, supporting services to help you develop and operate the assets. And in the end, you also need your societal support, so even the general public is part of this domain.

For the stakeholder assessment on development of syngas value chains, we have selected approximately 20 stakeholders that were interviewed for this project, selected from these different categories.

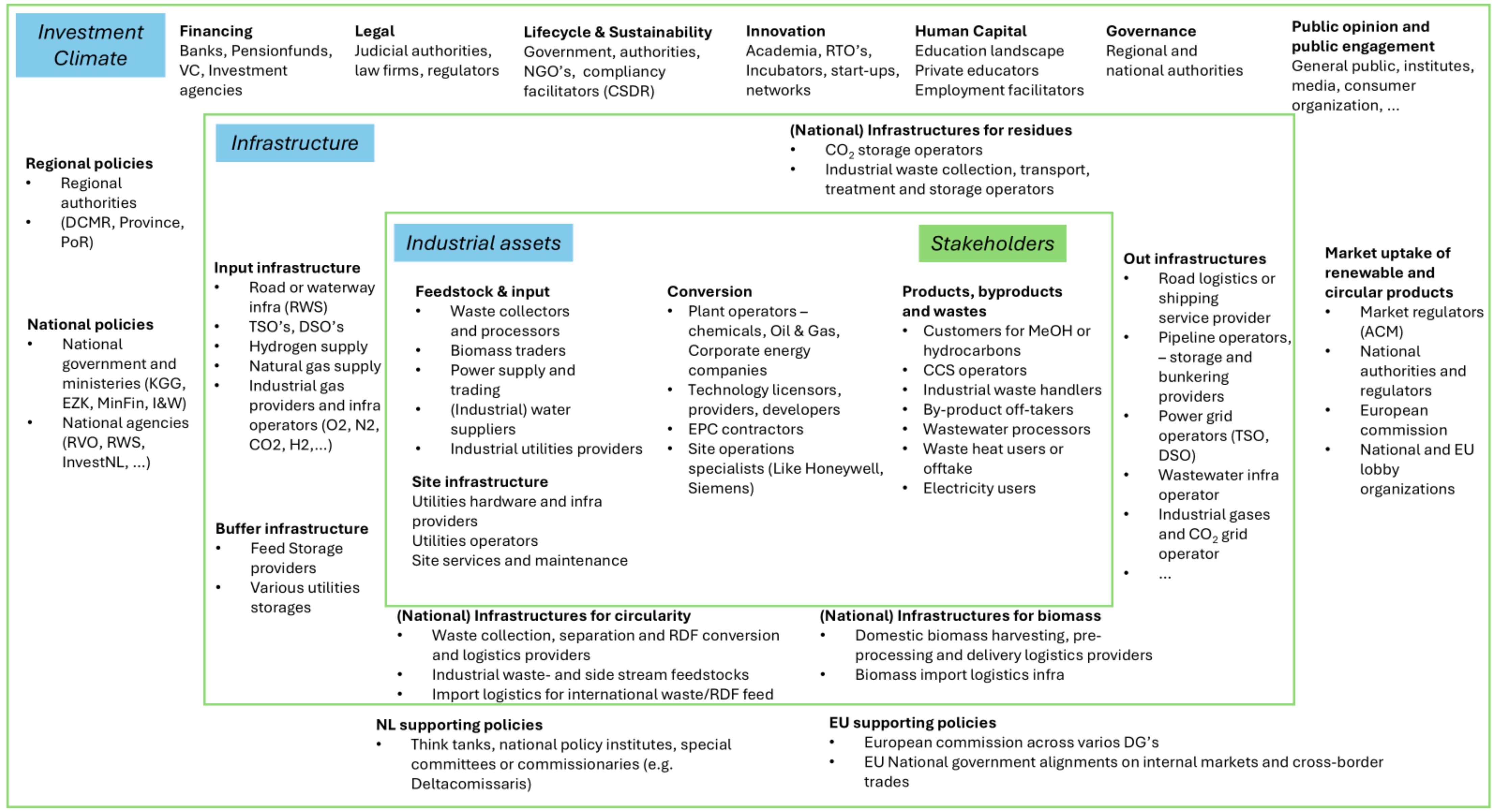

Figure 2: Stakeholder types across the 3-level framework. Next page give a full-page overview for better readability.

The types of organizations across three levels (2/2)

Investment Climate

Financing
Banks, Pensionfunds, VC, Investment agencies

Legal
Judicial authorities, law firms, regulators

Lifecycle & Sustainability
Government, authorities, NGO's, compliancy facilitators (CSDR)

Innovation
Academia, RTO's, Incubators, start-ups, networks

Human Capital
Education landscape
Private educators
Employment facilitators

Governance
Regional and national authorities

Public opinion and public engagement
General public, institutes, media, consumer organization, …

Regional policies
- Regional authorities
- (DCMR, Province, PoR)

National policies
- National government and ministeries (KGG, EZK, MinFin, I&W)
- National agencies (RVO, RWS, InvestNL, …)

Market uptake of renewable and circular products
- Market regulators (ACM)
- National authorities and regulators
- European commission
- National and EU lobby organizations

NL supporting policies
- Think tanks, national policy institutes, special committees or commissionaries (e.g. Deltacomissaris)

EU supporting policies
- European commission across varios DG's
- EU National government alignments on internal markets and cross-border trades

Infrastructure

(National) Infrastructures for residues
- CO_2 storage operators
- Industrial waste collection, transport, treatment and storage operators

Input infrastructure
- Road or waterway infra (RWS)
- TSO's, DSO's
- Hydrogen supply
- Natural gas supply
- Industrial gas providers and infra operators (O2, N2, CO2, H2,…)

Buffer infrastructure
- Feed Storage providers
- Various utilities storages

Out infrastructures
- Road logistics or shipping service provider
- Pipeline operators, – storage and bunkering providers
- Power grid operators (TSO, DSO)
- Wastewater infra operator
- Industrial gases and CO_2 grid operator
- …

(National) Infrastructures for circularity
- Waste collection, separation and RDF conversion and logistics providers
- Industrial waste- and side stream feedstocks
- Import logistics for international waste/RDF feed

(National) Infrastructures for biomass
- Domestic biomass harvesting, pre-processing and delivery logistics providers
- Biomass import logistics infra

Industrial assets

Stakeholders

Feedstock & input
- Waste collectors and processors
- Biomass traders
- Power supply and trading
- (Industrial) water suppliers
- Industrial utilities providers

Site infrastructure
Utilities hardware and infra providers
Utilities operators
Site services and maintenance

Conversion
- Plant operators – chemicals, Oil & Gas, Corporate energy companies
- Technology licensors, providers, developers
- EPC contractors
- Site operations specialists (Like Honeywell, Siemens)

Products, byproducts and wastes
- Customers for MeOH or hydrocarbons
- CCS operators
- Industrial waste handlers
- By-product off-takers
- Wastewater processors
- Waste heat users or offtake
- Electricity users

Stakeholder interviews – approach

Stakeholders

For this project, a longlist of stakeholders was set up for interviewing. The aim of the interviews was:

1. To get a basic insight in lessons learned from past projects that aimed to develop syngas value chains;
2. To understand where current technology developments are heading, and what challenges and solutions are encountered in this area;
3. To get a general understanding of how syngas value chain development is perceived currently across stakeholders; and
4. learn what issues and choices are encountered across the stakeholders.

To address these areas of interest, a mixed set of experts and leaders in various segments of the value chain at asset level were selected, two parties that categorize as infrastructure were interviewed, and a number of parties in the investment climate, from national policy makers to innovation support organizations and networks. All interviewed people, their organization and roles are presented in Appendix 1A. Their comments and feedback is considered to reflect their personal view on the field of syngas value chains and not taken as reflecting their company's position on the matter.

Interviews

The interviews were held in the period of October to December 2025. Most of the interviews were recorded and transcribed. Analysis across the interviews was done using the AI tool Claude Sonnet 4.5 from Anthropic, to facilitate cross-interview strategic analysis.

From the analysis we present in this report learnings on:

- The general state of progress of syngas value chain developments
- Key challenges and hurdles encountered in developing syngas value chains.
- A diversity of views on scale-up of syngas value chains as expressed by the interviewees.
- The views and perceptions on circularity and sustainability of syngas-based value chains for fuels and chemicals.
- The impact of regulations on value chain development

Interviews were automatically transcribed using Fireflies.AI. Recording and transcription and presentation of their names in this report is done with consent of the interviewees. The analysis is presented in non-attributable form and presents overarching insights, views and opinions, challenges, and learnings.

Views on syngas value chain development
Technology and readiness

Gasification technology for waste and biomass has a long development history. The general assessment across interviewees is that core gasification processes are at high technology readiness levels and ready for commercial deployment. Pre-treatment of feedstocks (torrefaction for biomass, RDF production for waste) is considered essential for stable operation. Syngas-to-methanol conversion is well understood and commercially available at smaller scales. Fischer-Tropsch synthesis is seen as viable mostly at large scale.

Several technology approaches are in active development in the Netherlands, each reflecting a different scaling philosophy. Gidara Energy's HTW fluidized bed technology operates at lower temperatures with long residence times, handling all conversion including tar management in a single reactor step. The HTW design has over a decade of commercial-scale operational history on lignite in Germany, later extended to waste fractions and municipal solid waste.

For biomass, torrefaction can be used as a pre-processing step to create a coal-like feedstock suitable for entrained flow gasification, the only gasification technology proven at megaton scale. Torrefaction removes moisture and volatiles, which improves gasifier stability but reduces the carbon available for conversion. DOPS has developed a novel batch-fed modular gasifier designed for factory-built replication at 100 kton scale, targeting a wide range of feedstocks including organic waste, sludge and potentially even composite materials such as wind turbine rotor blades.

Views on scaling differ. Some interviewees point to persistent challenges with feedstock variability, ash behavior and process stability when moving from demonstration to industrial scale. Others point to specific design choices and project experience that address these issues. The general view is that larger plants will use multiple gasifiers feeding into shared downstream conversion, giving robustness through redundancy while purification and synthesis benefit from economies of scale. Several developers position their technology as a platform with the ability to produce methanol, electricity, hydrogen or carbon products depending on market conditions.

No commercial-scale plant for waste or biomass-to-methanol has yet been built and operated continuously in Europe. The experience with Enerkem showed that the road from technology to stable commercial operation is hard. Their acquisition by Repsol and the subsequent FID for a 240 kton methanol plant in Spain shows that a major industrial player with strong engineering capacity is willing to invest in making this work. Past Dutch experience also showed that projects can fail for many reasons beyond technology, including logistics, management and financing. First-of-a-kind industrial demonstration is still seen as a necessary step across the sector. Technology archetypes are described in Deliverable 1.

Views on syngas value chain development
Industrial Assets (1/5)

The Asset perspective
From the Asset perspective we look at the elements needed to build a value chain, from feedstocks to product. From the interviews a good perspective can be obtained on the state of development of the field. We summarize the key observations.

Technology
The core technology for gasification has a long history, various processing technologies have been developed and matured, and the general opinion is that the technology for waste and biomass gasification is at high TRL levels. However, implementation is not straightforward, because gasification of waste and biomass means processing highly variable feedstocks with a high degree of impurities and variable content. Pre-processing of feedstocks is important to homogenize the feed, and downstream purifications are important for delivering a controlled syngas quality. Depending on choice of product this still leaves many choices to be made for system design. On the one hand there is a general opinion that the technology can perform and is ready for larger-scale roll-out. At the same time, because of the limitations in the technology, innovation in the core technology is still ongoing.

Biomass gasification
The general opinion is that for stable operation of the gasification process torrefaction is important. This produces hard coal and removes volatile components that form tars and potential for fouling. The hard biochar is gasified, and this should give a stable, high-throughput process. The light fraction from the torrefaction process is burned and provides heat that can be used directly in the plant (e.g. for drying) or it can be used to generate heat. A downside is that this reduces carbon efficiency of the process. This route is being developed by Perpetual Next.

Waste gasification
Waste is first transformed to RDF – Refused Derived Fuel. These are pellets that have a fairly homogeneous composition and a high carbon content. In the RDF production about half of the waste stream is captured as feedstock and half is rejected and still available for waste incineration. Current main use of RDF is in cement production. There is an RDF market in Europe for this purpose.
On the stability and operations of waste gasification views vary. There have been several attempts for the Enerkem process to operate, in The Netherlands and Canada, but a stable long-term running process has not been demonstrated yet. The opinion was shared that this is only due to lack of business case, and not so much due to technology issues. Enerkem is now acquired by Repsol, and new process development is ongoing in Spain.

Gasification Innovations
Two innovative companies approach the market with very distinctive new gasification technology:

- **DOPS** develops a gasification unit where the carbon-rich gas that emerges when feedstocks are initially heated are kept in the gasification chamber and passes through a moving bed of gasifying material. In this way the gaseous flow is thermally decomposed which removes the risks of tar formation and fouling and gives a stable and very flexible process. The outlook is that the DOPS process can handle a wide range of feedstocks. The gas that is generated can partially be used to provide heat to the process, or can be used to generate power, thus giving the potential to produce multiple products. A first demonstration plant is in development.

- **SCW - Supercritical water gasification** uses high-pressure high-temperature water to gasify streams that are wet in nature. This prevents or reduces the need to dry the feedstock and gives very controlled gasification conditions. Product mix contains a high degree of methane and is seen as a route to produce green gas. The technology is at a demonstration scale and SCW is looking at for example gasification of wet feedstocks from water treatment residues, but also from industrial waste streams that are otherwise hard to process.

Views on syngas value chain development Industrial Assets (2/5)

Investa Innovation Park setting

The Investa Innovation Park in Alkmaar has been created to provide an environment for piloting research and innovation and carry out scale-up to first (pre-)commercial scale operations. DOPS and SCW are both operational in this park and SCW has scaled units on site while DOPS is currently carrying out small-scale pilot tests and developing a first of a kind 100 kton/yr demonstration plant. There are a number of advantages of the Investa setup. Firstly, it aims to create an innovation ecosystem where technology development and scale-up comes together, and parties learn together. Permitting is arranged as the park is covered by the local Bergermeer UGS permits. There is also the HVC waste processing facilty, who can provide feedstocks and give development support. Investa provides a valuable and lively ecosystem for first-of-a-kind scale-up projects.

Scaling strategies

To reach large volumes, scale-up of the technology is necessary. The general view is that the gasification step has a productivity rate that is determined by the characteristics of the specific type of gasification process and this has certain scale limitations. Therefore, scaling of a gasification plant will typically consist numbering up by using multiple gasifiers to produce the syngas. Upstream pre-treatment and downstream purification and conversion may lend itself better for economies of scale and syngas is typically aggregated, treated and converted in one larger-scale process unit or train to the target product. Having multiple gasification units gives a certain degree of robustness and flexibility to the system for operations and maintenance cycles that may be needed for stable long-term operations. Across the different technologies, scale-up strategies depend on technology maturity and capabilities of the project developer or asset owner-operator.

Full scale and modular projects – past and present developments

In The Netherlands gasification has been applied since long times. Originally for city gas, with introduction of the Haber-Bosch process it served for production of ammonia and fertilizers at DSM and at Yara Sluiskil. Cokes gasification was replaced by natural gas with the development of the Groningen gas field. Later gasification was applied for electricity production from coal in Buggenum, Limburg, at the Willem-Alexander centrale. It was seen as a cleaner route to use coal for power generation than direct incineration, with the potential for pre-combustion CCS and biomass gasification. Operational experience has learned that stable large-scale operation of gasification was not without operational difficulties. One major initiative for gasification-based chemicals was the Waste-to-Chemicals project, aimed at producing methanol from waste, later shifting its focus to fuels from waste. This project was supported by a strong industry consortium, but for various reasons not brought to completion.

Several full-scale projects are currently in development in The Netherlands. For routes from biomass, Perpetual Next currently develops projects at a scale of 100 kton C/yr, with locations in Moerdijk and Delfzijl. The full-scale plant is aimed to deliver 220 kton/yr methanol and has feedstock requirements of 1.2 Mton/year for this production rate. Losses come from drying and losing light fractions in torrefaction, and process efficiencies of gasification and methanol synthesis.

For routes from waste Gidara is developing the AMA project to convert 360 kton/yr (biogenic) waste into 90 kton/yr bio-methanol, but current status is unclear; RWE is developing the FUREC project in Limburg. The FUREC project aims to convert 700 kton/yr municipal solid waste and produce 50 kton/yr hydrogen for the Chemelot site, with the potential to produce syngas carbon products at a later stage or after further scaling. The hydrogen will be used by OCI at Chemelot to produce ammonia and reduces natural gas intake by 280 million cubic meters.

Views on syngas value chain development Industrial Assets (3/5)

Value Chain

For syngas from waste and biomass fully new value chains need to be built up. Parties were interviewed with different roles in the value chains that need to be developed.

Feedstocks – Waste Sector

In NL we collect and process approximately 8 million tons of municipal waste and 80 million tons of construction waste per year. Municipal waste is incinerated and generates electricity and heat that is supplied to urban use and to industry. The waste is considered approximately 40% biogenic (e.g. from wood). Across the sector, as most waste is being processed, at this moment relatively small amounts of waste are available for gasification. There are different options to do this. Aggregating waste from several waste collectors could lead to sufficiently large volumes with a robust supply to run one or more smaller gasification processors (100 ktC/yr range) across The Netherlands. A different approach is the FUREC route, where all waste from the Province Limburg is collected centrally, pre-processed into RDF, where the reject fraction still goes to the incinerator, but the RDF gets gasified centrally bij RWE. When scaling up the use of domestic waste to Mton/yr ranges, this will lead to such high volumes of waste that it asks for restructuring of the waste sector and/or securing RDF imports from abroad, in Europe or overseas. In many European countries waste is still dumped in landfills, so potentially the import can be organized to substantial volumes, but if gasification of waste to hydrocarbons and methanol becomes attractive, also regional processors may decide to step in.

Feedstocks – Biomass

Biomass in The Netherlands today mostly has commercial applications. Wood for energy use, both from domestic and imported origin, is pelletized and used for home use or for industrial use for heat or power generation. Even though bio-economy has received much attention and seen with much potential, there is relatively little conversion of biomass to industrial products and fuels. For setting up new value chains wood, residue wood and other biomass that can qualify will be partly domestically produced and partly imported. Perpetual Next has been setting up operations in Estonia and may combine nationally produced biomass with imported streams for their gasification projects.

Products

Methanol was produced in The Netherlands by BioMCN (now owned by Methanex) when we produced gas from Groningen. With the downturn of gas and commissioning of large-scale overseas methanol production facilities the methanol used these days is imported. There are some small-scale Methanol developments in The Netherlands planned (e.g. by DOPS) and projects aim to come on stream in the next years. In Europe there are multiple projects that aim at eMethanol and eSAF at 50 to 100 kiloton scale. These various smaller sources provide Methanol feedstock as fuel, or feedstock for further processing. There are initiatives in the Rotterdam HIC for Methanol-to-Olefins (Blue Circle) and Methanol-to-SAF (Power2X) who aim to come onstream by the end of the decade.

Hydrocarbons are obviously currently produced through refining of crude oil. Biodiesel is produced mainly by Neste, from hydrotreated vegetable oils. No substantial synthetic fuel production from waste or biomass is currently taking place in the National market. Synthetic fuels through syngas are produced through Fischer-Tropsch in very large volumes by Shell at its Pearl site in Qatar and by Sasol in South-Africa.

Hydrogen

Views on syngas value chain development Industrial Assets (4/5)

Hydrogen

Hydrogen is a key molecule for the syngas value chain. It is a crucial component for the conversion of syngas to final products. Hydrogen is also produced during gasification, but the resulting syngas is not rich enough in H_2 to directly support synthesis of methanol or hydrocarbons. Hydrogen can be recovered from syngas by 'shifting' the gas with the water-gas shift reaction: syngas is combined with steam to produce CO_2 and H_2, where the H_2 can be separated off while the CO_2 is emitted or stored. To bring syngas to the right composition for methanol or hydrocarbon synthesis, additional hydrogen needs to be supplied from elsewhere. This hydrogen can come from different sources, each with different implications for scale, sustainability and the stakeholders involved. The following four production routes are relevant for the Rotterdam HIC, each with players and projects on the ground.

From waste and biomass, hydrogen can be produced via gasification and water-gas shift, either as the main product of the plant or as an intermediate that is recombined with the remaining syngas for methanol or hydrocarbon synthesis. The clearest current example of the first case is the FUREC project by RWE in Limburg, converting 700 kton/yr of municipal solid waste into 50 kton/yr of hydrogen for ammonia synthesis by OCI at Chemelot, reducing its natural gas intake by 280 million cubic meters. When no external hydrogen sources are available for syngas upgrading and onward synthesis, the syngas is split in two parts, and one part is shifted to produce hydrogen, which is then added back to the remaining syngas to reach the right composition for synthesis. This route is often preferred for pragmatic reasons as it avoids the need to source hydrogen externally, but it emits CO_2 and reduces the carbon yield of the chain.

External hydrogen can be sourced from electrolysis powered by renewable electricity. In Deliverable 2 it was shown that this requires large additional investments, as the hydrogen volumes needed for syngas are substantial. In the Rotterdam HIC, electrolysis capacity is starting to come online. Shell's Holland Hydrogen 1, a 200 MW electrolyzer on the Maasvlakte powered by the Hollandse Kust Noord offshore wind farm, is being built to supply its Pernis operations, with start-up expected in late 2026. Air Liquide's ELYgator reached FID in 2025 on a 200 MW electrolyzer at the same Maasvlakte conversion park, operational by end-2027. A wider project pipeline is in development in Rotterdam, although several face significant uncertainty in their realization. Scaling volumes and managing costs, both technology costs and system costs such as grid fees, are the binding constraints. If syngas routes can scale in the Rotterdam HIC, they offer sustained demand for green hydrogen produced from offshore wind, with an onward perspective on green products for end markets. Institutional support and demand-side applications at scale are both needed to pull this growth forward, and syngas value chains are one of the few applications with the volume potential to play that role.

Blue hydrogen from steam methane reforming (SMR) or autothermal reforming (ATR) with carbon capture and storage is the pragmatic near-term option. In the Rotterdam HIC, Air Liquide and Air Products both operate SMR and ATR capacity in the Botlek area, supplying hydrogen to refineries and chemical operators. Both companies have taken FID on retrofitting carbon capture to their existing hydrogen plants, connecting to Porthos for permanent storage in depleted North Sea gas fields, with operations starting in 2026. Together they will form one of the largest concentrations of blue hydrogen production capacity in Europe.

Views on syngas value chain development Industrial Assets (5/5)

Finally, hydrogen can also be imported. The Port of Rotterdam positions itself as the entry point for Northwest European hydrogen imports, with a 2030 target of 4.6 Mton/yr. Ammonia is the dominant carrier under development, with LOHC and liquid hydrogen also in early stages. Multiple ammonia import and cracking projects are in development on the Maasvlakte and in Europoort. A 2023 Fluor study commissioned by the Port of Rotterdam and industry partners concluded that a central 1 Mt/yr ammonia cracker was technically and economically feasible. Subsequent cracking operations are to be developed on individual terminal sites rather than on a centralized hub.

Currently there is one operating ammonia terminal in the Rotterdam HIC (formerly OCI's, now AGROFERT as of March 2026), with FID taken for a phased expansion to 2 Mton/yr throughput. Most other projects remain pre-FID; a March 2026 port consultation found that nine companies plan terminals but the majority target operations after 2030, with FID stalled by demand uncertainty.

On the supply side, first commercial green hydrogen derivative shipments are emerging. Chinese green ammonia exports started in Q4 2025 at landed costs in Europe under CBAM approaching grey parity. Saudi NEOM (1.2 Mton/yr) is now expected to start production from 2027, with most volume routed to fertilizer markets. Indian and Spanish projects are linked to Rotterdam through Port-led corridor agreements. The US Gulf export pipeline that was envisaged under the Biden administration has largely been abandoned. Across origins, blue ammonia to supply hydrogen through cracking is the weakest hydrogen route. Upstream methane losses, CO_2 captured at production, and with cumulative round-trip energy losses before recombination with carbon make this very inefficient in terms of energy and carbon use, although near-term economics may override the energetic and carbon-efficiency merit order. Imported ammonia molecules from various sources will compete predominantly with global demand for fertilizer and possibly with shipping fuel demand before reaching syngas applications.

System Integration and Flexibility

Industrial transformation needs room to maneuver, with hybridization options across assets and commodities to absorb variability in technology, markets, and supply. Syngas value chains offer a unique proposition on integration and flexibility. They touch all other commodity flows in the cluster: feedstocks in, power, natural gas, hydrogen, CO2, and products out. This makes them a system integration point. Spanning multiple inputs and outputs, the value chain can respond to variability across these commodities. Hydrogen is the clearest illustration.

Green hydrogen from electrolysis must follow the variability of renewable power supply. When offshore wind turns down, hydrogen can be supplemented via blue hydrogen from SMR/ATR with CCS. The two can operate as a swing pair: electrolyzers lead when renewable power is abundant, SMR/ATR ramps when it is scarce.

The dynamic response to variable power propagates also to other commodities like natural gas, CO_2 to storage, and hydrogen distribution to off-takers. If need be, syngas can also be used to produce hydrogen. Via water-gas shift, gasifier output can be routed to H2 when other supply is constrained and demand is high, temporarily turning down methanol or hydrocarbon synthesis while shifting to (biogenic) hydrogen and CO_2 output. The gasifier becomes a lever in the dynamic behavior of the entire cluster.

This variable property may reduce the need for H_2 storage or enables alternative storage (e.g. storing light hydrocarbons or methane in gas fields when electrolyzes run).

Infrastructure plans should reflect this combined-utilization logic to enable systemic dynamics. Flexible operation at this scale, across multiple parties and commodity networks, needs a high-order coordinating market-maker to align operating regimes, contracts, and infrastructure access across the participating asset owners and network operators.

Views on syngas value chain development
Infrastructure and connectivity (1/3)

The Infrastructure perspective

Infrastructure is the key enabler of industry operating in a cluster. It provides critical utilities through cables and pipe networks, and it connects the cluster through waterways and roads. The infrastructure serves the exchange between value chain partners within the cluster, just as much as it serves the interconnection of the cluster over large distances, connecting for example large volumes of offshore wind power to the cluster, and making the Rotterdam HIC a key node in the larger ARRRA setting. The pace and direction of development of infrastructure is crucial for the timely transformation of the cluster.

Public and public-private utility infrastructures

The main public utility infrastructure consists of the power grid, gas and hydrogen network, CO_2 network, and industrial heat network. The power grid is managed by Tennet for transmission, handling the long-distance interconnections, landing of offshore power and connecting to the largest power users in industry. The distribution is managed by Stedin, who operates an extensive grid from 150 kV downward to most of the users in the Rotterdam HIC.

The gas grid is managed as well at two levels, by Gasunie for long-distance transmission and delivery to large industrial users. Regional distribution to consumers and smaller industries is done by Stedin. Furthermore, a local hydrogen network backbone is developed by Gasunie where the Rotterdam part between the Maasvlakte and Pernis is the first stretch, which at later stage will be connected to a national grid that expands to Chemelot and other regions across The Netherlands.

There are two main initiatives for CO_2 infrastructure: Porthos with a planned capacity of 2,5 Mton/yr with capability to expand the volume up to 10 Mton/yr and storage volume around 37 Mton CO_2, and Aramis as a second development, starting at 5 Mton/yr and capacity capable to handle up to 22 Mton/yr and total volume of 400 Mton CO_2. These infrastructures are publicly owned. Porthos is managed by the Port of Rotterdam, Gasunie and EBN, while Aramis was initiated as a public-private partnership in a consortium of Gasunie, EBN, Shell and TotalEnergies. In 2025 Shell and TotalEnergies withdrew from the pipeline investment, making it now fully publicly owned. Shell and TotalEnergies are still involved in supporting the development with technical expertise.

Finally, there is the Botlek Steam Network, operated by NetVerder (subsidiary of Stedin group). It connects waste incinerator AVR and Cabot as suppliers providing heat to among others LyondellBasell, Air Liquide, Huntsman and Lanxess, with potential for future expansion.

For long-range interconnections of public utilities there is the Delta-Rhine-Corridor (DRC) being planned, managed by Gasunie and OGE, while Shell and BASF are involved as prospective customers and technical partners. It aims to secure cross-border long-range transport between Rotterdam and Chemelot, and further on to the Ruhr area. While initially it was geared towards hydrocarbons, and while also ammonia and HVDC were considered as part of the scope, it is currently officially focused on hydrogen and CO2 only, with later expansions to other utilities still being possible. In addition, also a separate CO2 connection to Antwerp is planned via Zeeland through the Delta Schelde CO2nnection, in development under Gasunie and Fluxys (Belgian TSO).

With most of these utility infrastructures the PoR has served various supportive roles, as initiator, facilitator, allocator of space and infrastructure program manager. Its core role is that of enabler and facilitator, as also confirmed in various conversations.

Public infrastructure development is typically done on a first-come-first-serve basis. The pace of infrastructure development is often seen as a key bottleneck in transition of industry, and focused development requires a high degree of coordination. For progress on the transformation of the industry in the Port area there are further initiatives started under the national program for the Cluster Energy Strategy, where a role for the cluster coordinator and the data safe house have been developed over time. These aim to accelerate debottlenecking infrastructure development in support of industrial transition.

Views on syngas value chain development
Infrastructure and connectivity (2/3)

Product pipeline and industrial gas networks

Besides utility networks the Rotterdam HIC is also highly connected with private networks that support exchange within the port as well as between the port and other clusters. These networks mostly transport bulk products between various operators.

Within the port we see three different categories. First, there are industrial gases networks operated by Air Liquide and Air Products for transport of nitrogen, hydrogen, oxygen and CO, embedded in the cluster and serving refineries and chemical plants. These companies often combine production and infrastructure operations and play a role as private system integrator. Air Liquide for example provides hydrogen by production and distribution. The company operates ATR/SMR capacity and develops a 200 MW electrolyzer plant (FID taken in 2025) for green hydrogen production. Air Products operates similar hydrogen production and distribution assets in the port area, serving a partly overlapping customer base. These existing private gas networks and production assets form a natural interface for future syngas value chain integration.

Second, a notable example of shared product infrastructure is the Multicore pipeline system, a joint venture of the Port of Rotterdam (75%) and Vopak (25%). It consists of a bundle of four pipelines running from Pernis through the main industrial areas to the Maasvlakte, transporting a diverse mix of chemical products and gases. Multicore operates on a leasing model, allowing companies to transport products via pipeline without owning the infrastructure. Users include ExxonMobil Chemical, Air Products, Shin-Etsu and Shell Chemicals among others. As an open-access shared pipeline with public majority ownership, it is one of the few existing models in the port where product infrastructure operates on a utility-like principle.

Third, there is the combining of public and private infrastructure. Refineries currently use their residual gases for furnace firing, for which they have internal gas infrastructure. The H-Vision concept is implemented through SMR operators that are now retrofitting with CCS. These are used to convert the gas streams into hydrogen with CO2 captured for storage via Porthos. The hydrogen is then fed back to the refineries for low-carbon heating, tying existing SMRs into both public utilities and private product infrastructure.

Long-range interconnections exist between the Rotterdam HIC and other industrial clusters to transport crude oil and products. For crude oil there is the Rotterdam-Rhine pipeline to inland refineries in Germany, and the Rotterdam-Antwerp pipeline between the two ports. For ethylene and propylene there are privately operated networks connecting cracker-operating companies between them and to downstream operators in Rotterdam, Moerdijk, Zeeland, Chemelot, and outside The Netherlands to Antwerp and into Germany.

Liquids bulk storage and terminals

The Rotterdam port area has over 30 million cubic meters of tank storage capacity for liquid bulk, operated by independent terminal companies including Vopak, Chane, Rubis, Odfjell, and others, handling crude oil, oil products, chemicals, biofuels and edible oils. For LNG, the GATE terminal on the Maasvlakte is a joint venture of Gasunie and Vopak with a capacity of 16 bcm/yr. For ammonia, AGROFERT (formerly OCI) operates an import terminal, while the ACE Terminal (Gasunie and Vopak) is in development for green ammonia as a hydrogen carrier. A new CO_2 terminal, CO2next, is being developed by Gasunie, Vopak, Shell and TotalEnergies at the Maasvlakte to receive liquid CO_2 by ship and connect it to the Aramis pipeline, with initial capacity of around 5 Mton/yr. Methanol is currently imported and distributed through existing tank terminal infrastructure. As syngas value chains develop, methanol storage and bunkering infrastructure will become increasingly relevant, as methanol is the most likely first product from gasification routes.

Solid bulk

For solid bulk, terminals such as EBS (European Bulk Services, part of HES International) already handle biomass and wood pellets at scale for the European energy and heating market, with dedicated storage facilities. No dedicated import infrastructure for waste or RDF currently exists in Rotterdam. At Mton scale gasification, new handling and storage capacity for these feedstocks would need to be developed.

Views on syngas value chain development Infrastructure and connectivity (3/3)

Syngas ring main – a new shared infrastructure concept

Syngas and gasification have a long history in the Rotterdam HIC. Coal gasification was first studied in the context of new coal-fired power plants in the early 2000s, with pre-combustion CCS as the rationale. In the same period, TU Delft conducted infrastructure studies on syngas under the Next Generation Infrastructures program. The syngas ring main concept was proposed around 2005 by Rein Willems, then President of Shell Nederland, as a shared pipeline network for the port area. None of these were realized. The ring main concept has been revived in the current context of waste and biomass gasification.

The core idea of the ring main is a shared syngas pipeline network where multiple gasifiers feed in and multiple off-takers draw from. This decouples individual project economics from system economics: each project does not need to secure its own full downstream value chain. The logic is comparable to existing shared networks in the HIC such as the Botlek Steam Network and the industrial gas pipelines operated by Air Liquide and Air Products. Multiple gasifiers feeding a shared network also provide redundancy and flexibility for operations and maintenance.

Operational syngas capacity already exists in the port. Shell Pernis owns a residue gasifier with a capacity to produce on the order of 100-200 kton/yr of syngas. It was commissioned in 1997 and is used internally for hydrogen production for the hydrocracker. These assets are fully amortized and have marginal operating costs. They form a natural anchor supplier for any future ring main, providing baseload volumes around which other gasifiers and off-takers can develop.

Several conditions that were absent in earlier attempts are now materializing. CO2 infrastructure is being built through Porthos and Aramis. Product mandates under RED III and the eSAF regulation create demand pull. Refineries undergoing electrification may free up residual gas streams and potentially space. Together these create a setting in which a shared syngas infrastructure could become viable.

A ring main would shift the investment logic from bilateral offtake contracts per individual project to a shared network allowing flexible routing of syngas to methanol, Fischer-Tropsch, hydrogen via water-gas shift or other products depending on market conditions. This is the infrastructure equivalent of market formation.

Who builds, owns and operates such a network remains an open question. No existing operator or governance model has been identified. The pattern observed across other port infrastructure, where large-scale utility systems gravitate toward public or public-private ownership, suggests a similar model may apply. No interviewee offered a concrete answer, but the need for coordination was consistently flagged. Infrastructure requirements at different scales are described in Deliverable 2.

Views on syngas value chain development Investment Climate (1/4)

Scoping the Investment Climate
The investment climate covers the immaterial conditions that enable industrial investment. Figure 2 mapped this domain broadly, covering financing, legal, innovation, human capital, public engagement, governance and more. Each of these dimensions matters for syngas value chain development and operations. In this deliverable we narrow the focus to the governance and policy axis, where stakeholder interviews and the workshop converged most strongly: the parties that set, interpret, and implement the rules under which investments are made, and the leadership needed to align action across them. Financing, human capital, and the wider societal dimensions are recognized but treated in less depth.

Regulation and governance are the public-sector levers for steering industrial transition. Each governance level signals to the adjacent levels what is important and what is needed: regional authorities are close to the operations and follow progress on the ground. National government sets national priorities and policies. These need to comply with the European Commission policy frameworks that shape the space within which all of this operates. The alignment on priorities is distributed across these stakeholders and asks for alignment to secure a guided and coordinated transformation, which is a major tension point.

European level. The current Commission has framed its agenda around prosperity, security, and democracy, with competitiveness and strategic autonomy as overarching themes following the Draghi report. Security has risen in priority alongside the green transition, with energy security, critical raw materials, and industrial sovereignty drawing significant attention. The Clean Industrial Deal is the main vehicle through which decarbonisation and competitiveness are being brought together. For syngas value chain development, this means the rules around feedstocks, CO2 cost, renewable mandates, circular economy criteria, and permissible funding are spread across several DGs and have to be navigated together.

The relevant policy areas are split across several Directorates-General. DG CLIMA covers carbon pricing and CO2 transport and storage; DG ENER covers renewable energy and hydrogen market rules; DG ENV covers waste, circular economy and bioeconomy; DG GROW covers industrial strategy and the Clean Industrial Deal; DG COMP covers state aid.

National level. At national level, the Klimaat en Groene Groei (KGG) portfolio is now held under the Ministry of Economic Affairs and Climate Policy (Ministerie van Economische Zaken en Klimaat) and includes the Circular economy policy. The Ministries of Finance and of Infrastructure and Water Management retain supporting roles. Executive agencies RVO and InvestNL administer funding instruments. ACM oversees market formation and competition. EBN is the state-owned company under EZK mandate holding the State's interest in subsurface energy activities and is increasingly involved in Rotterdam HIC (CO_2) infrastructure development.
The national level translates EU frameworks into national policy, sets the funding envelope through SDE++ and innovation programmes, and supports tailored arrangements such as maatwerkafspraken with individual industrial sites. Coordination of industrial decarbonisation runs through the Nationaal Programma Verduurzaming Industrie (NPVI), with the minister for KGG as steering group chair.

Regional Level. At regional level, the Province of Zuid-Holland, the Municipality of Rotterdam, and the Port of Rotterdam each have specific responsibilities. The Province is the competent authority for permitting, supervision and enforcement of high-risk industrial sites, including all Seveso installations in the port area. These tasks are executed on its behalf by DCMR Milieudienst Rijnmond, the joint omgevingsdienst of the Province and thirteen Rijnmond municipalities. DCMR handles permitting and supervision in the port. The Province also leads on spatial planning for the region and convenes industry on transition topics. The Municipality of Rotterdam is the competent authority for non-Seveso activities within its territory, with DCMR acting on its behalf, and is majority shareholder of the Port (70.8%), with the State holding the remaining 29.2%.

Views on syngas value chain development Investment Climate (2/4)

Regional Level (continued). The Port of Rotterdam Authority is manager, operator and developer of the port and industrial area. As port authority it carries the nautical management task under covenant with the State. As infrastructure party it develops and maintains port roads, rail, inland waterway connections, and underground pipelines, and plays a leading role in major port-area infrastructure programs including Porthos, the hydrogen backbone interfaces, and ammonia corridors. As landlord it allocates land through long-term sub-leases and selects which activities establish where. Port land is mostly owned by the Municipality with the Port holding the perpetual ground lease; land reclaimed at Maasvlakte 2 is owned by the State.
Two joint instruments steer regional development. The Havenvisie 2050, initiated by the Port of Rotterdam and the Rotterdam Municipality. Key stakeholders were consulted in the process (Province of Zuid Holland, the State (I&W, EZ, KGG, VRO), Deltalinqs, and DCMR). The vision was adopted by the Rotterdam municipal council in December 2025 and provides the long-range compass: climate-neutral, circular, agile and resilient by 2050. The NOVEX Rotterdamse haven program translates this into a spatial execution agenda for 2025-2050, with the same regional partners plus several national ministries. A follow-on investment agenda will link financing to the agreed projects.

Fragmentation across and within pillars. Each governance level is internally organized in pillars or directorates with their own mandates:

- **European level.** The Clean Industrial Deal is jointly owned by five DGs whose briefs intersect on carbon pricing, renewable energy, waste and circular economy, industrial strategy, and state aid.
- **National level.** Under the Jetten government climate, energy, industrial policy, and circular economy are located within a single ministry, which reduces fragmentation in one direction while concentrating it internally; infrastructure and water remain in a separate ministry.
- **Regional level.** With three governing bodies responsibilities are separated but touching each other. The Havenvisie 2050 and the NOVEX Rotterdamse haven program operate with overlapping but not identical partner constellations, alongside the separate competent authorities for permitting.

Each pillar covers its own priorities consistently, although even within pillars often responsibilities are distributed again in sub-pillars. The resulting stack of frameworks makes integrating across domains difficult for novel value chains like syngas, spanning multiple pillars by design. Progress requires alignment with many stakeholders across different domains and jurisdictions, making developing novel extended industrial activity highly complicated.

Non-governing bodies active across the domains

Across the policy and governance landscape, non-governing bodies play supporting roles in shaping conditions for syngas value chain development:

- **Sector associations**: VNCI (chemical industry), VEMOBIN (Dutch refineries and (sustainable) fuel suppliers, and EV mobility), Deltalinqs (Rotterdam port industry)
- **Knowledge and innovation networks**: ISPT (process industry innovation platform), TNO (applied research), Erasmus University and TU Delft (academic research)
- **Regional economic development**: Economic Board Zuid-Holland (regional innovation agenda and investment promotion), InnovationQuarter (regional development agency, investment and scale-up support)

Views on syngas value chain development Investment Climate (3/4)

Investment climate as stakeholders see it
Across the interviews, stakeholders describe the investment climate for syngas value chains as a field of conditions that must align. Few cite economics or technology as the binding constraint. What recurs is a set of observations about the rules, the governance, the time horizon, and the role of public actors; what stakeholders see as the conditions under which they are being asked to commit capital and what they see as missing for those conditions to hold. The reflections below are grouped into three areas: the regulatory environment, the coordination environment, and the temporal and political environment.

Regulatory environment
Fragmentation and the space to experiment. Stakeholders across the panel describe the regulatory environment as fragmented rather than hostile — published intent (CMP, RED III, PPWR, CBAM) does not yet translate into operational rules investors can plan against. The RED III treatment of syngas, end-of-waste status, mass-balance acceptance, and the absence of demand-side instruments are each cited as live obstacles.
Within this picture two postures emerge. One stance is to wait for clarity before committing capital – everything must be clear before you move. The other, articulated most directly from corporate side, argues that concrete projects are themselves the instrument through which regulation gets fixed, and calls for sandbox-style space to experiment and learn with first-of-kind configurations under interim rules. This asks for active partnership from government to walk along and act to solve problems as we go.

Policy levers recognized but not yet built. Demand creation is described as the missing piece across the panel. Stakeholders point to a populated list of possible instruments such as the CBAM treatment of circular products, blending mandates, public procurement, BTW exemption on circular intermediates, a circular levy on virgin material, anchor offtake contracts, mass-balance pragmatism, regulatory sandbox designation. The list is well-developed in stakeholder thinking but national policy intent has not yet hardened into operational instruments. The Critical Chemicals Alliance, the Actieplan Aanbod Duurzame Koolstof and the CMP are named as vehicles through which this is being worked out. Stakeholders indicate that the instruments needed to close the business case are visible and broadly agreed on, but not yet in force. This leaves investors either to wait or to move ahead and carry the policy risk. But investors will not commit at scale on the latter basis. The call across the panel is for pace: for government to bring policy instruments into force on a timeline that matches the investment decisions and FIDs the private sector is now preparing.

Coordination environment
Governance gap behind the dissolution of collective action. A consistent pattern surfaces across interviews: in transition planning collective concepts emerge, attract initial interest, then dissolve into bilateral deals. Stakeholders do not describe an absence of coordination so much as the absence of a framework that holds collective action together once it forms. Large-scale capex-intensive collective development requires disciplined sequencing (demand first, then supply, then infrastructure, then technology), together with governance, criteria for participation, and joint decision-making in planning and execution.

First-cluster or minimal viable system definition as a live question. How to transform the Rotterdam HIC, within a national ambition of 20 Mton/yr sustainable carbon across pyrolysis, gasification, bio-refining, biopolymer and methanol routes, is an open question. The syngas project is welcome input to that allocation. To shape an initial syngas value chain, ideas on a syngas ecosystem were proposed suggesting to start with two anchor offtakers, three anchor suppliers, modular gasification trains in the 100–300 kton range feeding a shared syngas backbone, and with participation limited to parties willing to commit capital, knowledge and effort. The open question is if such an initial system is technically and economically viable to stably operate, if it passes as a minimal viable system.

Views on syngas value chain development Investment Climate (4/4)

Coordination environment (continued)
The role of Province Zuid Holland: under-defined, with more potential than is currently harvested. The role of Province Zuid Holland in transition planning and coordination is not formally articulated in the eyes of stakeholders, and views range across the spectrum from pure facilitator to active coordinator and protection negotiator. The interviews suggest the formal mandate is light enough that the Province has considerable latitude, acting in roles as facilitator, landowner, permit authority, convener, public co-investor in shared infrastructure, or as negotiator of protection mechanisms with national government. The variation in stakeholder expectations points to a potential that is not currently being captured rather than to a contested role.

Temporal and political environment
Dealing with timeliness and the need for resilience against political volatility. The investment climate is shaped by mismatches between project cycles, corporate strategy cycles, and policy cycles, and by the volatility of policy and the nature of politics itself. Stakeholders cite concrete instances where regulatory shifts mid-project collapsed the business case: projects whose feedstock contracts and offtake mandates did not arrive in time to hold corporate commitment, projects where the policy route they were built on was changed after FID, recent decisions to divest assets that depended on conditions that never fully formed.
Political polarization is described as a structural source of risk: in the absence of binding instruments, policy can swing with each coalition, and market actors will follow the cheapest source rather than honor sustainability commitments. At the same time, broader strategic markers (the Draghi and Wennink reports and strategic autonomy debates) are described as signals that the political moment for industrial decarbonization investment is opening.
The call across the panel is for instruments that are robust to political instability. Binding mandates, sandbox space, anchored demand, coordinated decision-making, structured with sufficient durability to survive coalition cycles. And by analogy there is the ask to create long-mandate roles like the Deltacommissaris, to make sure the moment is created and captured.

Views on syngas value chain development

In summary: clear interest needs conditions to align before commitment

- **Industrial assets: the technology is ready, the value chains need to be built.** Gasification of waste and biomass is at high technology readiness levels and stakeholders consider it ready for commercial deployment. No large plant in Europe has yet reached stable long-term operation so a scale-up path is considered important. Interviewees attribute this more to incomplete value chains and business cases than to a lack of technological performance, the technology itself is considered proven.

- **Infrastructure: the ring main concept comes from industry and has a history.** Rein Willems-, then President of Shell Nederland, proposed a shared syngas network for the port area around 2005, and gasification developers have revived the concept today. A shared network decouples individual project economics from system economics, so that no single project needs to secure its own full downstream chain. In this way infrastructure can help to stage and segment value chain development and de-risk investments.

- **Investment climate: companies wait for conditions to align before they commit.** Stakeholders name two missing elements: demand-creation, with rules that are broadly agreed but not yet in force, and a governance framework that coordinates collective development once it takes shape. The coordinating role to organize the system build-out receives less attention as there is a strong belief that development must come from market initiative alone. Political volatility adds risk to both.

Conclusion. The syngas ring main is a systemic answer to a system question in an exploratory phase and companies show clear interest. To reach a point where private parties can answer the question whether they will invest requires further development of the concept into a concrete plan. The central question for the follow-up exploration is under which conditions companies will invest.

Stakeholder workshop to reflect on the syngas staircase Future Triangles (1/2)

Stakeholder workshop and futures triangles
Workshop intent. The workshop on 15 January 2026 at the Provinciehuis in Den Haag brought together stakeholders from across government, the port, industry, and knowledge institutes to reflect on the staircase framework developed in deliverables D1 and D2. The aim was twofold: to test the version logic against stakeholder views on the long-term development of the Rotterdam HIC, and to surface where the cluster stands on the questions of sustainable carbon, circularity, and strategic autonomy.

Triangles as lead-in. Before the workshop, participants were asked to complete a futures triangle. The triangle is a strategic foresight method to map three forces acting on any transition: the pull of the future as a guiding image, the push of the present as the forces currently moving change forward, and the weight of the past as the structural barriers holding it back. Nine participants returned a completed triangle. The purpose was first to give participants time to form their own position and surface the implicit assumptions about the future may unfold. Figure 3 shows the setup of the triangle.

Pull of the future. Across the submissions a coherent image emerges. Rotterdam HIC is seen as a sustainable molecule hub for North-West Europe, anchored in circular and renewable carbon, contributing to a competitive Dutch and European base industry, and supporting strategic autonomy. Variation is in framing rather than in direction. Technology developers articulate a paradigm shift, moving from a refining-based industry to a synthesis-based industry, which builds products up from single-carbon building blocks from waste, biomass, and CO_2 and syngas is the platform of a new system paradigm. National and regional government emphasize strategic relevance and the retention of a strong base industry on Dutch soil. The Port frames the cluster as positioned between geopolitical superpowers and obliged to find a distinct sustainable identity. All submissions share large-scale infrastructures, feedstock imports and local and regional integration with downstream value chains as building blocks of a future position of the Rotterdam HIC.

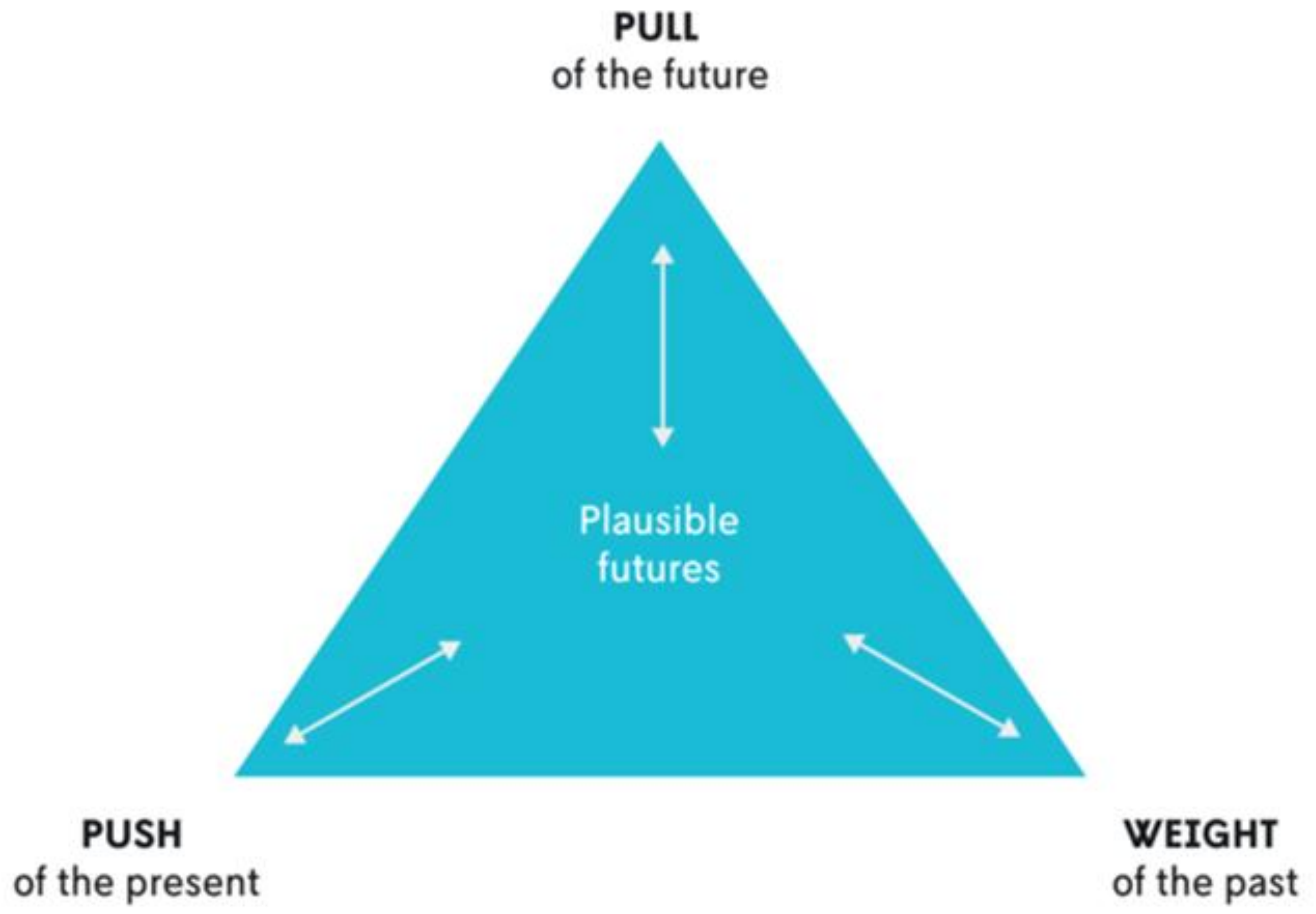

Figure 3: Setup of the future triangle, aiming to uncover plausible futures. (Source: How Can We Predict Plausible Futures? — Futures Platform)

Stakeholder workshop to reflect on the syngas staircase Future Triangles (2/2)

Push of the present. Submissions converge on the forces currently working with the transition. Climate awareness is intensifying, even where political momentum is volatile. Geopolitical pressure is driving the strategic autonomy agenda, with the Draghi and Wennink reports named as recent markers in multiple submissions. The EU policy stack is maturing, with CBAM, the Clean Industrial Deal, the Critical Chemicals Act, RED III, and circular economy targets all cited as active drivers. Technology readiness is improving across gasification, electrolysis, and chemical recycling. The first electrolyzers coming on stream are noted as a tangible signal that the energy transition is moving from announcement to operation. The shared framing is that the present contains the ingredients for the transition, but that these ingredients are unevenly developed and not yet aligned into operational instruments.

Weight of the past. This is where stakeholder convergence is strongest. Submissions name a consistent set of structural barriers: long-term contracts and sweated fossil assets, underpriced fossil energy without true pricing, fragmented and slow EU regulation, infrastructure designed for fossil flows, shareholder short-termism and limited risk appetite, scarce space in the HIC, political volatility, a shortage of practically skilled technical labor, and linear economic logic that still dominates investment decisions. Where the pull and push descriptions vary in emphasis, the weights are described in remarkably similar terms across government, port, and industry contributors.

Tensions across submissions. Two open debates surface. The first is who funds the transition: industry views diverge on whether consumers, producers, or the state should carry the cost, with submissions ranging from explicit calls for consumer-funded transition to explicit rejection of the customer as the primary driver of change. The second is the balance between specialization and base-volume production: whether the Dutch industrial base should focus on niche, high-value products in which it can lead globally or maintain sufficient volume in base chemicals to underpin strategic autonomy. These tensions are not blockers but mark where decisions still need to be made.

Implications for the workshop. The triangles confirmed that stakeholders broadly agree on the direction of travel and on the weights that hold the transition back. The harder questions are about pace, sequencing, and the design of the value chain. The workshop sessions that followed were structured to take this agreement as a starting point and to explore where stakeholders would land on the three development versions of the staircase.

Stakeholder workshop to reflect on the syngas staircase Workshop Approach

Setup and participants. The workshop brought together approximately 20 participants from across the stakeholder landscape introduced in the previous chapters: technology developers, plant operators, port and infrastructure parties, financiers, knowledge institutes, and government at national and regional level. The day was held under Chatham House rules and is reported here in non-attributable form.

Structure of the day. The day opened with a plenary session covering the findings from the futures triangles, the staircase framework with its three versions, and the external driving forces developed for the project. The plenary also presented a structured set of ten decisions distilled from the interviews and the staircase development. These are decisions that need to be made to develop a value chain and for which the answer differs by scale. These are points where stakeholder views had diverged on technology route, scale strategy, product choice, feedstock, infrastructure ownership, regulatory priority, and the role of the Province and other governing bodies. These ten decisions formed the working material for the breakouts.

Three parallel groups, two stages. Participants were divided into three working groups, each assigned one version of the staircase: V1 Circular Carbon Niche, V2 Industrial Scale, V3 Renewable Carbon Megahub. Each group worked through two consecutive stages. In the first stage, the group developed its position on the ten decisions for its assigned version: where to land on each open question, working systematically across the asset, infrastructure, and investment-climate levels of the stakeholder framework. In the second stage, the group stress-tested its version against external driving forces that put stress on the value chain as time unfolds. The driving forces are

- Multipolarity and Struggling Superpowers
- Energy Transition and Climate Change
- EU Internal Dynamics

Each of these dimensions can accelerate developments or hamper successful deployment. The participants were asked to reason through the risks that they give, what does this version look like under pressure of the driving forces, where does it hold, where does it strain, and what does it ask from the Rotterdam HIC and from public actors to secure progress. And aiming to surface unexpected truths that may surface from the assessment.

Plenary confrontation. The day closed with a plenary session in which each group reported back, followed by cross-group dialogue to surface where versions converged, where they diverged, and where the driving forces put fundamentally different pressures on the three development paths.

Reporting in this deliverable. The findings are reported one version at a time. For each version we present the position the group developed on the key decisions, followed by how the version held up under the scenarios. After the three version reports, a synthesis section draws the lines across the three.

Stakeholder workshop to reflect on the syngas staircase Version 1 – Circular Carbon Niche

Decisions made by the group. The group was asked to develop value chains of plants of 100–200 kton/yr renewable carbon each. They agreed this implied ten to twenty distributed circular carbon plants producing methanol at a total scale of around 1.5–2 Mton/yr of carbon by 2040. Feedstock is diversified across plastic waste, biomass, and municipal waste, sourced locally and regionally. They concluded this captures about 10% of anticipated circular carbon demand. Across the three levels the following picture emerged:

- At asset level, the group landed on a portfolio of gasification technologies to match feedstock type, with methanol as the primary product to decouple production from offtake. Hydrogen supply needed to upgrade the syngas for methanol synthesis raised a challenge. Self-produced hydrogen consumes part of the carbon and emits CO_2, reducing carbon yield. Local electrolysis carries large capital cost, depends on grid capacity and/or is intermittent, requiring hydrogen storage potentially leading to siting constraints. A third route connecting to a hydrogen grid helps but is not in place soon. No route resolves the tension, and the choice cascades into site selection, energy infrastructure, and project economics.
- At infrastructure level, the group asked national and regional government to designate ten to twenty suitable sites, with methanol moved to Rotterdam by road, rail, or barge and CO_2 captured on site for storage via Porthos or equivalent.
- At investment-climate level, the group flagged municipal waste contracts, often locked into incineration for around thirty years, as a critical barrier to feedstock access, and pointed to a provincial coordinator role across sites and a public de-risker role for first movers.

A central finding emerged: Version 1 appeared to ask for more public orchestration than a centralized one. It requires location designation across multiple jurisdictions, feedstock allocation against incumbents, infrastructure coordination, and sustained political support over time to come to operation. “Market-driven, small-scale" turns out to be a misnomer at execution, coined the coordination paradox. The version reads as incremental on paper but demands extensive public sector coordination in practice.

Stress test against the driving forces. Under multipolarity and struggling superpowers, the feedstock diversification across plastic, biomass, and municipal waste gives a resilience advantage if global trade fragments. But as Version 1 produces only a limited share of the carbon need, Rotterdam necessarily becomes a sustainable carbon product import port. The group viewed a minimal share of 20–30% domestic production as the minimum to reach a meaningful contribution to strategic autonomy and noted that Version 1 sits well below this. Assessing the contribution to energy transition and climate change it was acknowledged that Version 1 gives a modest contribution and is climate-compatible rather than climate-transformative. The modular design does carry optionality: if a climate shock opens a political window, proven 100–200 kton/yr units can be replicated. Under EU internal dynamics, Version 1 cannot close its business case without an EU-wide instrument that levels the cost gap between circular and fossil-baseline carbon. EU policy is moving in Version 1's direction (CBAM, the Clean Industrial Deal, RED III, circular economy mandates), but without a cost-leveling instrument, no commodity buyer pays the premium that circular methanol requires at the volumes needed. The instrument must apply EU-wide. If only the Netherlands imposes it, fossil-baseline product flows in from other member states and the Dutch circular volume will not emerge.

Unexpected truth and closing observation. The unexpected truth surfaced by the V1 group is the coordination paradox: the pathway that looks like the easiest first step demands sustained public coordination across many fronts while remaining too small to anchor either strategic autonomy or material climate impact. A second observation followed: Version 1 lacks a politically durable narrative. The climate story is too small to count, the autonomy story is contradicted by the import position the version itself produces, and "portfolio of experiments" is not inspirational at political level. Version 1 reads as conditionally viable: a learning platform and logistics positioning if the cost-leveling instrument arrives, and a stalled set of pilots if it does not. The group therefore positioned V1 as a necessary first phase on the way to a larger scale, not as an endpoint.

Stakeholder workshop to reflect on the syngas staircase Version 2 – Industrial Scale

Decisions made by the group. The group developed large-scale centralized chains of 1 Mton/yr or more renewable carbon per cluster. Moerdijk and the Rotterdam HIC were both considered. Feedstock is mixed waste and biomass, with cross-border import necessary at this scale. Methanol and chemicals are the primary outputs. One cluster captures around ten percent of HIC carbon demand. The following picture emerged:

- At asset level, the group chose proven gasification technology over experimental, given chemical-industry risk appetite at this scale. Development is facilitated where waste processing, chemical offtakers, deep-sea port access, and CCS proximity are already co-located. AVR transformation from incineration to gasification was seen as a specific enabling step, with heat output retained for district-heating networks. The cluster requires syngas piping between sub-facilities and offtakers; the group held different views on whether this stays local to the cluster or extends into the broader ring main concept. A joint-venture consortium was assumed throughout.
- At infrastructure level, syngas distribution within the cluster is new shared infrastructure, with Port of Rotterdam or an equivalent operator as natural network developer. CCS via Porthos or equivalent is essential, with cluster scale justifying dedicated connections. Deep-sea port capacity is needed for biomass import.
- At investment-climate level, refining assets face ETS allowances phase out and carbon prices ramp up through the mid-2030s, hampering investments. Version 2's key challenge the emerges: how to keep investment flowing into transition assets that tie into fossil assets while downward pressures mount on all sides. Safeguarding via a book-and-claim credit system was considered a possible mechanism. Cluster-scale orchestration was another important precondition with FUREC given as example: provincial coordination, a clear industrial lead, and support for first movers. The group agreed that the Province can convene and create conditions while a long-horizon infrastructure operator like Port of Rotterdam should take the lead.

Version 2 was seen as an economically rational pathway: scale efficiency, infrastructure leverage, proven technology. But investments must hold for fifteen years, and most conditions sit outside regional control, raising tension on alignment and synchronization.

Stress test against the driving forces. Under multipolarity and struggling superpowers, cross-border feedstock dependency becomes a vulnerability: domestic supply covers only a fraction, and the rest must come from elsewhere. If trade fragments, the cluster cannot run at design scale. A multipolar world makes strategic autonomy a durable political argument which may help sustain the policy commitments Version 2 needs. An ARRRA-scale coalition of the willing was identified as a fallback if EU-wide coordination does not materialize. This remains viable when ambition reduces but loses the European-market scale that makes the economics work. The contribution to energy transition and climate change was seen as meaningful but not transformative. The same ETS phase-down that closes the fossil-baseline investment window also opens space for Version 2, but only if circular capacity is in operation as that pressure builds. Sequencing matters. Under EU internal dynamics, Version 2 is most exposed. Cluster economics require an EU-wide demand-creating instrument with a continuous and predictable growth path, avoiding boom-bust investment cycles incompatible with cluster-scale capex development. A Dutch-only mandate creates competitive disadvantage, instruments must apply EU-wide.

Unexpected truth and closing observation. The unexpected truth surfaced by the Version 2 group is that the most efficient pathway is also the most fragile one. Concentration brings cost advantage and risk at the same time: a single cluster requires policy, feedstock, infrastructure, and offtake to align and hold over a long horizon. A first cluster is achievable with FUREC as useful template; replication depends on conditions outside regional control. Version 2 brings a politically durable narrative: a strategic position in the European industrial transition, reduced dependency on volatile global markets and an anchored future role for the HIC. But that narrative only works if framed at European scale. Framed nationally, Version 2 cannot deliver what it promises; the European-level commitment to match is essential.

Stakeholder workshop to reflect on the syngas staircase Version 3 – Renewable Carbon Megahub

Decisions made by the group. The Version 3 group developed an infrastructure-based ecosystem across the HIC with 10 to 20 Mton/yr of carbon throughput. Feedstocks combine European domestic and imported waste, biomass, and torrefied pellets. Products span fuels, methanol, and chemicals, with the multi-outlet character treated as a core design feature. At full scale it supplies the HIC carbon demand and gives the cluster a credible role in European basic chemicals and synthetic fuels for the coming decades. The following picture emerged:

- At the asset level, the group saw two to three large gasification sites feeding a shared syngas backbone. Products feed into the Rotterdam refineries, engaging as active participants during the transition. Existing refinery hydrogen and conversion capacity acts as buffer while circular feedstocks scale up. The resulting hybrid fossil-and-circular system is a deliberate way to manage disconnects in time and space: rather than shutting one site down before the next is built, the system allows gradual clearing and redeployment of space as the system develops.
- At the infrastructure level, the group identified a syngas ring main with central quality specifications, a parallel hydrogen network for ratio adjustment, integration with Porthos for CO2 management, and waterborne feedstock logistics through the port as the four pillars of the system. A dedicated (public or private) network operator is considered a requirement, and its absence flagged as a gap to be filled.
- At the investment-climate level, the group concluded that the system cannot be built by market coordination alone. Upfront public infrastructure investment, sustained over a multi-decade horizon, is the precondition; the group described this explicitly as a new Delta Works in scale and political character, requiring cross-party consensus and a dedicated Deltacommissaris for industrial transition as necessary authority.

The central finding the group converged on is that Version 3 offers a robust design but rests on fragile prerequisites to get started. The integration that gives the system its resilience (multiple feedstocks and products, hybrid fossil and circular operation, cross-utility integration), creates coordination demands that exceed what existing institutions provide. The leadership question recurred without resolution: the Port has the operational profile but a commercial mandate, the Province has convening capacity but not the scale, the national government has the scale but does not hold the in-house capacity it had in the original Delta Works era, and industry consortia run into a racing-to-be-second dynamic to survive market mechanisms that do not resolve.

Stress test against the driving forces. Under multipolarity and struggling superpowers, the scale gives Rotterdam genuine European strategic relevance rather than symbolic capacity, and the combined hybrid design provides a real fallback if circular feedstock flows are disrupted; the import dependency at megaton scale is acknowledged and partly absorbed by sourcing across a European catchment rather than globally. Under energy transition and climate change, the system delivers transformational rather than incremental emissions displacement at the HIC level, and the hybrid capability lets the circular share rise or fall with policy stringency without stranding the infrastructure. Under EU internal dynamics, the picture is different: viability depends on European manufacturing remaining competitive enough to absorb the chemicals and fuels produced. It must be built on EU-level instruments that create a level playing field, and on political durability across multiple election cycles. The group judged the first two outside its control and the third uncertain in the current climate.

Unexpected truth and closing observation. The unexpected truth surfaced by the group was that the baseline alternative, a slow withering of the existing cluster under absent reinvestment, is worse on climate, safety, and economic grounds than the managed transition that Version 3 describes. There is no status quo fallback, but only a choice between a managed or an unmanaged decline. The closing observation is that even if Rotterdam does not capture the full ambition locally, demonstrating that a megaton circular carbon system can be built and operated has European value in its own right; the cluster's role as proof of concept can also inspire other regions to replicate the approach.

Stakeholder workshop to reflect on the syngas staircase
Comparison and Conclusion

Cross-version reflection

"The small-scale, distributed, market-driven approach turned out to require more government coordination, not less. We were shocked that it came out this way."— insight on Version 1.

"At minimum you need a national government that says: we need this." — insight on Version 3

Each version surfaced a different limit. Version 1's distributed approach ran into the coordination paradox: numbering-up a small-scale, market-driven design produced more government coordination demands, not less, surprising the group that built it. Version 2's business logic stood up, but the concentrated megaton execution carries political risk that the design itself cannot absorb. Viability requires policy and market conditions to hold up through a long build-out without guarantees. Version 3's hybrid, multi-feed, multi-product architecture is the one design that absorbs that risk once it stands, because the system itself carries flexibility. The baseline requirement is that it demands national-level political leadership declaring the strategic need, shaped in government-based coordination for the large-scale development. The Version 3 ambition is the crucial start point if we want to seriously reach our strategic autonomy and climate targets, it sets the essential conditions for long-term viability and engages possible version 1 and 2 scale developments into a learning ecosystem.

Syngas as paradigm shift

"Ten megaton is bizarrely large, and still only a fifth of what the Rotterdam port handles today." — observation on scale

"Having such a roundabout in this region is a golden development for the future." — observation on syngas as platform

The workshop demonstrated that syngas is a key value chain, not a residual waste and biomass valorization route. Applied at the scale Version 3 describes, syngas becomes the platform that shifts the cluster from a refining-based industry that sorts multi-carbon chains out of fossil sources, to a synthesis-based industry that builds products from C1 building blocks (CO, CO2, methanol) derived from waste, biomass, and renewables. This reframing, which surfaced in the futures triangles and recurred in the workshop discussions, changes what Rotterdam is doing rather than just what it processes. A megaton syngas backbone in the HIC is a fifth of current port conversion. It carries the cluster's role into a post-refining future where fuel demand ultimately will decline, and anchors sustainable fuels, methanol, and high-value chemistry production on a shared infrastructure. The European logic follows: Rotterdam serves the largest manufacturing economy on the continent, and that economy needs a credible carbon platform to continue operating.

Staircase reflection

"The future of the Rotterdam port is visible here." — observation on what the workshop made visible

"This is not a five-year project, but a thirty-year project." — observation on timeline horizon

The three versions were deliberately polarized to isolate the effect of development scale on reaching the capacity that the Rotterdam HIC requires. Each group worked its own version in isolation through the morning design session and the afternoon stress test, with no cross-version comparison until the plenary. The staircase reading emerged when the three tracks were presented side-by-side. Each version's limitations fed into the next version's logic. The side-by-side comparison culminated in the recognition that V3-level ambition is where the value chain needs to land: a high ambition that must be set from the start, with V1 and V2 carrying the building blocks toward it. The 30-year horizon that comes with that ambition emerged in the plenary evaluated and accepted without argument. What we set out to test, whether the three-tier staircase frames the syngas value chain in the right way, was confirmed by the workshop. Participants embraced the framing, and the side-by-side comparison produced new strategic insights for all.

Appendix A – Stakeholders involved in the syngas value chain project

The following stakeholders from across the asset, infrastructure, and investment climate layers of the syngas value chain were involved in this work, through interviews, the futures triangle exercise, the stakeholder workshop on 15 January 2026, and on reviewing draft versions and providing feedback of the final position paper:

Asset layer
Arjan van Vliet (Shell)
Benny Bakker (DOPS)
Ellis Huijsmans (Perpetual Next)
Jacob Rookmaaker (RWE)
Marthien van Eersel (Ortessa)
Melle Nieuwhof (Nobian)
Michiel Spits (DOPS)
Reinier Grimbergen (Blue Circle)
Wim de Jong (Twence)
Wouter Meiring (Shell)

Infrastructure layer
Esther van Soest-Vercammen (EBN)
Wilco van der Lans (Port of Rotterdam)

Investment climate layer
Astrid Garretsen (Economic Board Zuid-Holland)
Eline van Krimpen (Deltalinqs)
Els Boesveld (Provincie Zuid-Holland)
Geoffrey Schouten (ISPT)
Irene ten Dam (ISPT)
Kees Biesheuvel (ISPT)
Markus Flick (InnovationQuarter)
Martijn Reubzaet (Ministerie van Infrastructuur en Waterstaat)
Peter Simoes (Investa)
Rob Stevens (Ammonia Energy Association, ISPT)
Ronald Korstanje (ISPT)
Sander Kes (Ministerie van Economische Zaken en Klimaat)

Colophon

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