Final version - MARCH 2026

Syngas value chain in Rotterdam HIC

Deliverable 2: Syngas Staircase

Produced by:
Tjerk Hassing, Andreas ten Cate,
Michael Tan, Mirre Stevens – TvdI

Tijs Beek – Sproule ERCE

TEKENKAMER VAN
DE INDUSTRIE
Transparantie in complexiteit

Deliverable version review history

Title	Syngas value chain in Rotterdam HIC Deliverable 2: Syngas Staircase
Authors	Tjerk Hassing – Tekenkamer van de Industrie – tjerk.hassing@tvdi.eu Andreas ten Cate – Tekenkamer van de Industrie – andreas.tencate@tvdi.eu
TvdI Internal review and versions	Full draft version release to client for review – v1.0 – March 10 2026 Internal review of V1.0 – March 10 2026
External review	V1.0 review – Els Boesveld – Provincie Zuid Holland – March 2026
Status	Final
Publication status	Internal PZH and TvdI and partners

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.

Deliverable 2 – The Syngas Staircase

The Rotterdam HIC currently converts around 50 Mton/yr of crude oil (approximately 40 Mton/yr carbon); in a clean and circular future this is expected to reduce to 15-20 Mton/yr carbon. Meeting even a meaningful share of this future demand through circular and renewable carbon is the scale challenge this deliverable works from. Carbon mass is used as the key metric throughout — it is the fundamental factor connecting feedstocks, conversion processes and products across the value chain.

To explore this challenge, the deliverable introduces a staircase of versions — from small and distributed to cluster-wide transformation. Each version is internally consistent, representing a distinct development pathway with its own implications for assets, infrastructure and investment climate. Together they span the range of what is possible, from a first meaningful step to a full strategic response.

The versions are screened against key drivers — cost, time, intrusiveness and impact — giving the reader a comparative view of what each version demands and delivers. This screening is performed both for a single implementation and for replication across the cluster, since reaching a meaningful share of the 15-20 Mton/yr goal requires multiple projects at scale. It is at the replication level that the true strategic implications become visible.

By holding the versions deliberately apart, the analysis surfaces what scale truly changes: who leads, what infrastructure is needed, and how each version contributes differently to sustainability and strategic autonomy. This makes the staircase the natural starting point for ordering the decisions that need to be made to bring any of these versions alive.

Deliverable 2 builds directly on the archetype value chains established in Deliverable 1, which provides the process fundamentals and feedstock bandwidths that underpin the version sketches. Its outputs feed directly into Deliverable 3, which maps the stakeholder landscape across the three domains, and Deliverable 4, which translates the version logic into a decision-based roadmap.

For the cost and space indications, this study only provides order of magnitude numbers, as no actual cost or space estimates have been made. The indications that are provided relate to the carbon conversion plants, and do not include related hydrogen or power generation. Furthermore, cost and space scaling benefits have not been applied in this report – while larger capacity plants come with lower costs or space per kt of product, larger scale versions also require more (new) infrastructure and land provision, and they come with different risks, they require different finance models with related cost of capital. Scaling and also technical development may well still be beneficial for costs and total space, but overall impact for the large scale versions has not been demonstrated.

Scope: Feedstock & Processes

The feedstocks and processes underpinning this study are covered in depth in Deliverable 1. The key reference data for what follows are summarized in Tables 1 and 2. The scope covers the following:

Feedstocks

Municipal Solid Waste (MSW) and RDF — the higher-carbon fraction of household waste, available domestically and importable at scale
Plastic — non-recyclable fraction directed to gasification
Biomass — domestic and imported, the largest available carbon source
CO_2 —via reverse water gas shift, requiring hydrogen at significant scale

Conversion routes

Gasification — converts waste, plastic or biomass into syngas, the central building block of the value chain
Syngas to methanol — converts syngas into methanol, the most direct product route and the basis for further upgrading
Methanol to olefins / fuels — upgrades methanol into circular chemicals and fuels for the existing market
Syngas to Fischer-Tropsch — converts syngas directly into naphtha, diesel and jet fuel via synthetic crude processing
Electrolysis — produces the green hydrogen needed to drive gasification at scale

Existing assets such as naphtha crackers and refineries are retained where they can be integrated into the circular carbon value chain.

Table 1: Overview of relevant feedstock volumes in Netherlands and Europe

Feedstock type	Feedstock / C [Mton/yr]			H_2 demand [Mton H_2/Mton C]	Alternative use
	NL	NL/B/D	Europe		
MSW	7 / 0.9	37 / 4.9	107 / 14.3	0.2 (44)	Heat/power
Plastic	2 / 1.0	8 / 4.0	43 / 21.5	~0 (~0)	Partially recycling, rest heat/power
Biomass	7 / 1.3	52 / 10.0	358 / 68.8	0.3 (50)	Building material, heat/power
CO2 (rWGS or hydrogenation)	-	-	-	0.5 (102)	CCUS, green houses

Table 2: Overview of relevant processes[1]

Process Step	TRL	Feedstock rate [Mton feed / Mton C]	Acreage [ha/(Mton C/y)]	*Costs [€/Mton C]*
Gasification (from waste; plastic; biomass)	7-9	7.5; 2.0; 5.2	160	Up to 5bln€
CO2 to syngas or to methanol	6-9	3.7	40	
Syngas to methanol	9	0.96	40	
Methanol to Olefins	8-9	0.81	25	Up to 5bln€
Fischer-Tropsch (Syngas to Naphtha or fuels)	9	0.88	120	
Electrolysis	9	250kt to support 1Mt C from gasification	50 (20 ha/GW)	Up to 10bln€
Imports of fuels, feeds; Import of methanol	-		5; 25	

[1] Carbon feedstock transition of the petrochemical industry under spatial limitations, Ten Cate et al., ISPT (2025).

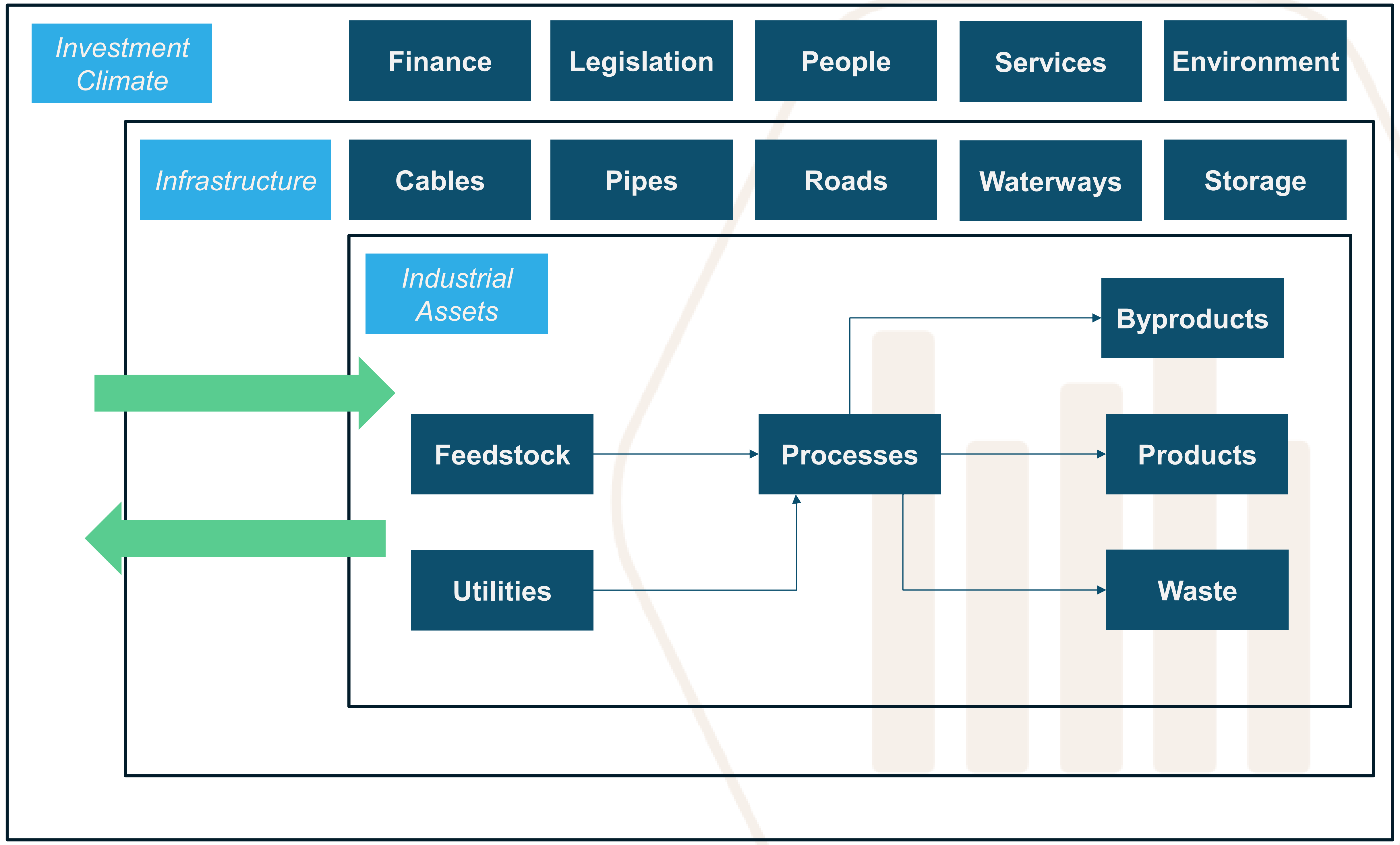
Who acts?

Realizing a syngas value chain at any scale requires decisions across three levels — assets, infrastructure and investment climate. But decisions do not make themselves: behind each level sits a distinct set of actors, with different interests, different mandates and different time horizons.

- At **Asset level**, project developers, asset owners and technology providers drive the physical investments — deciding where to build, what to produce, and how to secure feedstock and offtake.
- At the **infrastructure level**, port authorities, grid operators and logistics providers shape the conditions in which those investments can function — deciding how to organize space, utilities and connectivity.
- At the **investment climate** level, national and regional authorities, financial institutions and European regulators set the rules, the incentives and the ambition — deciding how to create markets, de-risk investment and align regulation.

The same actors appear across all versions of the staircase — but their roles, their influence and the order in which they must act may differ fundamentally depending on the path chosen. Surfacing those differences is one of the central purposes of this exploration.
The two arrows in figure 1 carry the central message: if these actors are not aligned, nothing gets built. The key stakeholder categories are shown on the next slide in more detail.

Figure 1: Typical decision topics across the Asset, Infrastructure and Investment Climate levels. A long list of typical decisions is shown on the next page.



Actor landscape overview

Figure 2: Long list of typical decision topics across the Asset, Infrastructure and Investment Climate levels

Investment Climate

Finance **Legislation** **Lifecycle & Sustainability, Environment** **Innovation** **Human Capital** **Governance** **Public opinion and public engagement**

Regional policies
- Permits
- Enforcement and inspections
- Space allocation
- Integration support
- Development support

National policies
- Support for circularity and supply of feeds
- Subsidy schemes for development and deployment
- EU-alignment for level playing field
- Harmonization of split-incentives
  - biomass for power & feedstock
  - waste incineration and CCS or circularity?
- De-risking investment, coordination and execution support

Infrastructure

Input infrastructure
- Road or waterway transport services for feed supply
- Power supply
- Water supply
- Hydrogen supply
- Gas supply
- Oxygen

Buffer infrastructure
- Feed Storage
- Various utilities storages

National supply infrastructures
- Hydrogen backbone, supply & storage
- Renewable power production, transmission, distribution and backup

(National) Infrastructures for residues
- CO_2 storage infrastructure
- Collect, transport and store residual waste streams

Industrial Assets

Feedstock & input
- Biomass or waste feed
- Electricity
- Hydrogen
- Water
- Gas
- Oxygen or air
- Heat

Site infrastructure

Requires on-site logistics and infra depending on integration and layout

On-site storages for feeds, by-products, wastes and products

Conversion
- Pretreatment or intake of pre-treated feedstock
- Oxygen production
- Hydrogen production
- Syngas production
- Product synthesis
- Power generation
- Heat production
- Water extraction
- Water conditioning
- Wastewater treatment

Products, byproducts and wastes
- MeOH or hydrocarbons
- CO2
- Unusable fraction from pre-treatment
- Solid residues from gasification
- Wastewater
- Waste heat
- Electricity

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

* future of AVIs is a major decision point: combust or recycle

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

Out infrastructures
- Road or waterway transport for solid wastes and by-products
- Product outlet infra – storage and tanking, road, ship or pipeline to customers, bunkering infrastructure
- Power delivery
- Wastewater outlet to central treatment or to surface water after on-site treatment
- Product outlet infra
- CO_2 outlet infra

Market uptake of renewable and circular products
- Balanced approach to negative emissions, renewable fuels and circular use of carbon
- Demand creation support with balanced mandates (RED III, ReFuelEU, PPWR, etc)
- EU-wide level playing field
- Protection for international competition (CBAM and more)

NL supporting policies
- Long-term vision on use of oil and gas in a responsible manner

EU supporting policies
- Coherent approach to use of carbon
- Support for circularity in EU-wide framework
- International alignment on renewable feedstock trades (waste & bio)

Versions to build the Staircase (1)

Maximum target setting (largest, Version 3)

For the Syngas Staircase in the Rotterdam HIC, we first turn to what a maximum version looks like, i.e. what it takes to fulfil the maximum goal of circular carbon in the HIC context. The HIC currently handles up to 200 million tons of crude oil and oil products per year, of which up to 50 million tons is processed in its' refineries. The remainder is transshipped to the hinterland. For the maximum version we refer to the Sustainable Industry Lab (SIL) in figure 3, suggesting a reducing demand for Dutch use in the coming decades. The current conversion is ~40million ton of Carbon per year (Mton C/yr). This may reduce to 15-20 Mton C/yr. For a Rotterdam HIC target, the following assumptions are made:

- 20Mt total sustainable Carbon
- Up to 75% of sustainable carbon through syngas route, while the remaining 25% is achieved through other contributors such as mechanical and chemical recycling, pyrolysis, HVO
- 2/3 of the Syngas route to be achieved in Rotterdam, the remaining 1/3 in other locations in the Netherlands

➢ **10Mton/yr of circular carbon** through syngas/methanol would then be a relevant high Version for sketching and screening purposes.

Actual future demand for fuels and/or chemicals in the European Union is uncertain. The exact future scale of alternative (mechanical and chemical) sustainable carbon routes is also unknown. Still, it is possible to state that affordable and secure fossil free, circular carbon fuels and products in Europe by 2040 will require a syngas route in the Rotterdam HIC with an 10Mton/yr order of magnitude size.

Replacing all this carbon requires a complete transition of the HIC. This Version has a major impact on current refineries, requires massive supplies of feedstock, hydrogen, power and space and integration. This high version matches the scale of the (other) transformations indicated in the Draghi[3] report for Europe, as well at the recent and Wennink Report[4] for NL.

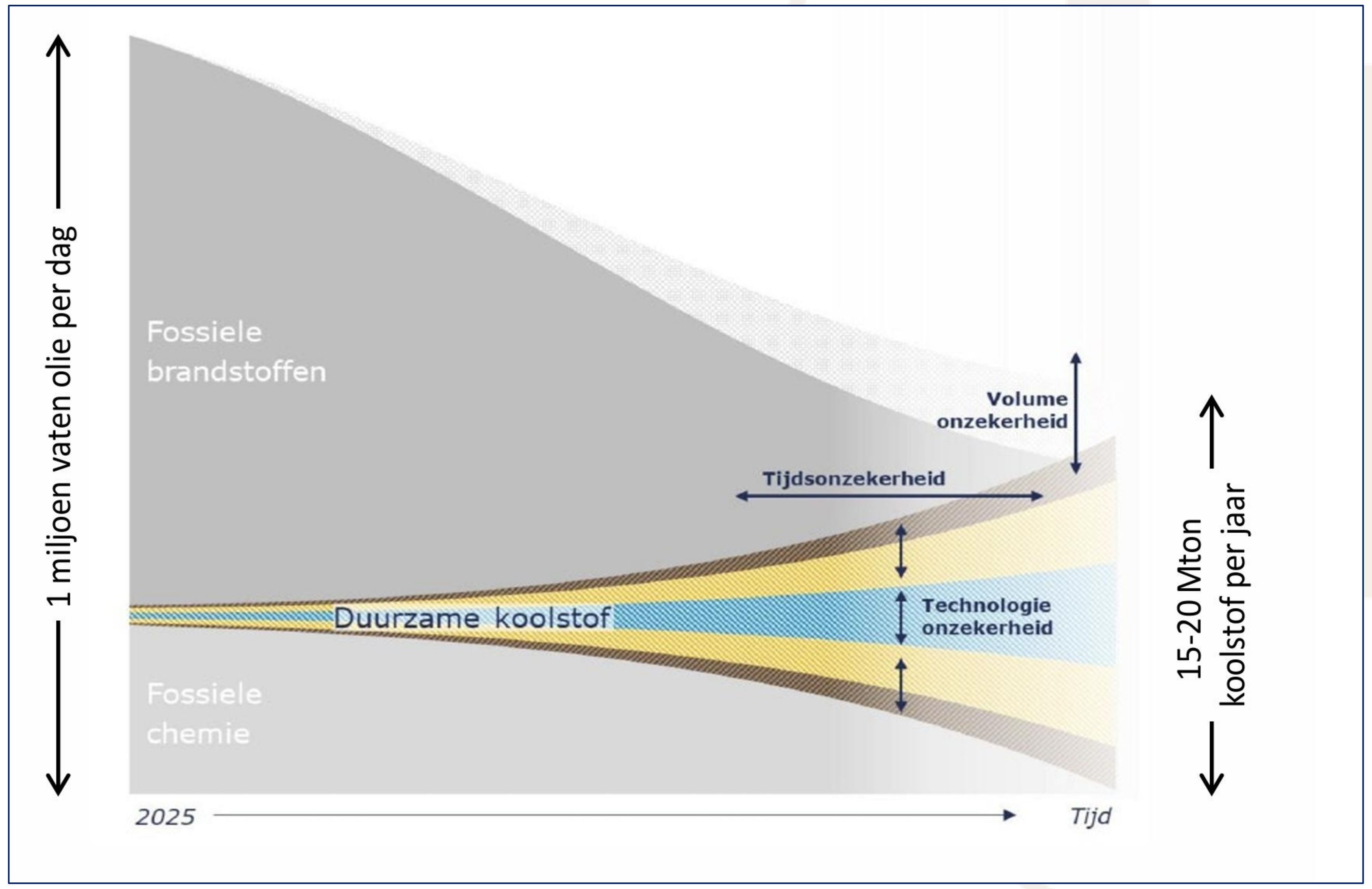


Figure 3: 15-20Mton per year of carbon is still required by 2050[2].

[2] 2. Toekomst van een duurzame Koolstofchemie – Sustainable Industry Lab (2025)

[3] 3. The Draghi report on EU competitiveness

[4] 4. Rapport Wennink - De route naar toekomstige welvaart

Versions to build the Staircase (2)

Minimum target setting (Version 1)

For a minimum target we look at what is happening already today on circular carbon Syngas processing. For waste or biomass to syngas conversion a recent initiative that didn't got built was the Waste to Chemicals plant, planned next to the AVR in Rotterdam. New projects are currently under development with a capacity typically around 200-250kton/yr of Syngas / Methanol, i.e. ~0.1Mton C/yr. This is small compared to the ultimate goal of 10Mton C/yr but when replicated many times could still deliver scale.

➢ **0.1Mton/yr of circular carbon** is chosen as a relevant minimum Version for sketching and screening, and consideration of replication potential

To reach volume many of these projects need to materialize. These already need support from and put stress on investment climate parties such as authorities, as each requires permits, space, financial support and more. This type plants would be new-built, focus on producing methanol, and have limited integration with the HIC or with each other. They are opportunistically started by individual companies and project developers, aimed at supplying a niche market, possibly co-located with feedstock suppliers (waste companies) or downstream processors.

Intermediate version (Version 2)

The aim of the study is to assess how we can reach 1Mton C/yr scale. A single site processing at this scale is appropriate intermediate version for the Staircase, as it is very different from Versions 1 and 3.

➢ **1Mton/yr of circular carbon** provides a relevant mid-point for sketching and screening purposes

1Mton Projects are characterized by transformation of and integration with existing assets. Infrastructure must be adequate. For multiplication assessment, with 4 refineries currently in the Rotterdam HIC, it is assumed that up to 4 of these projects may be placed at or near the refineries, while some may appear also outside the HIC.

Version 0 – Do nothing

For comparison, also a situation of inaction is included. This Version 0 is for Rotterdam HIC referred to in the recent SIL report[5] as the "Wegkwijnscenario" (Languish scenario).

Table 3: Selected Versions to test implementation and effect

#	Target [Mton C/yr]	Version	Expected Impact (green, autonomy)
0	0	"Wegkwijnen" (Do nothing)	Slow languishing of HIC carbon conversion industry
1	0.1 (0.1-1.0)	Circular carbon niche	Very limited impact
2	1 (1-4)	Industrial scale	Supports circular products
3	10	Transformation	Significant role in green EU vision

---

5. Hulp bij systeempijn – Sustainable Industry Lab (2025)

Versions to build the Staircase (3)

With an expected total of 15-20Mton C per year, the mix of where this carbon is coming from depends on the willingness and investment efforts in circular carbon via syngas, other renewable carbon routes, imported products, and finally, remaining crude imports. Figure 4 shows how a balance of domestic production, product import and residual crude use may look in the different versions along the staircase.

Figure 4: Indicative distributions for total 15-20Mton/yr carbon feedstock along the staircase from Version 0 to Version 3.

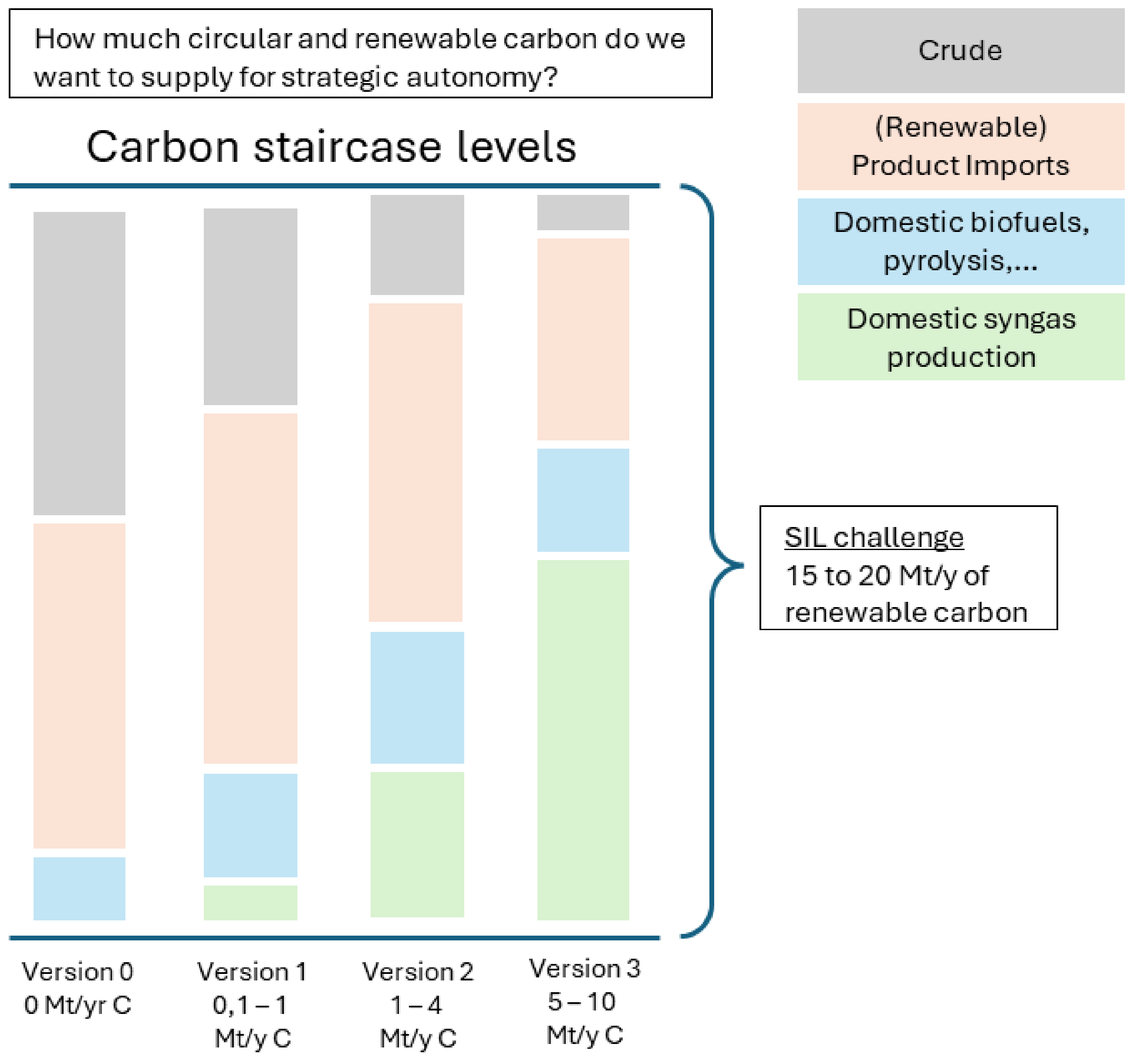
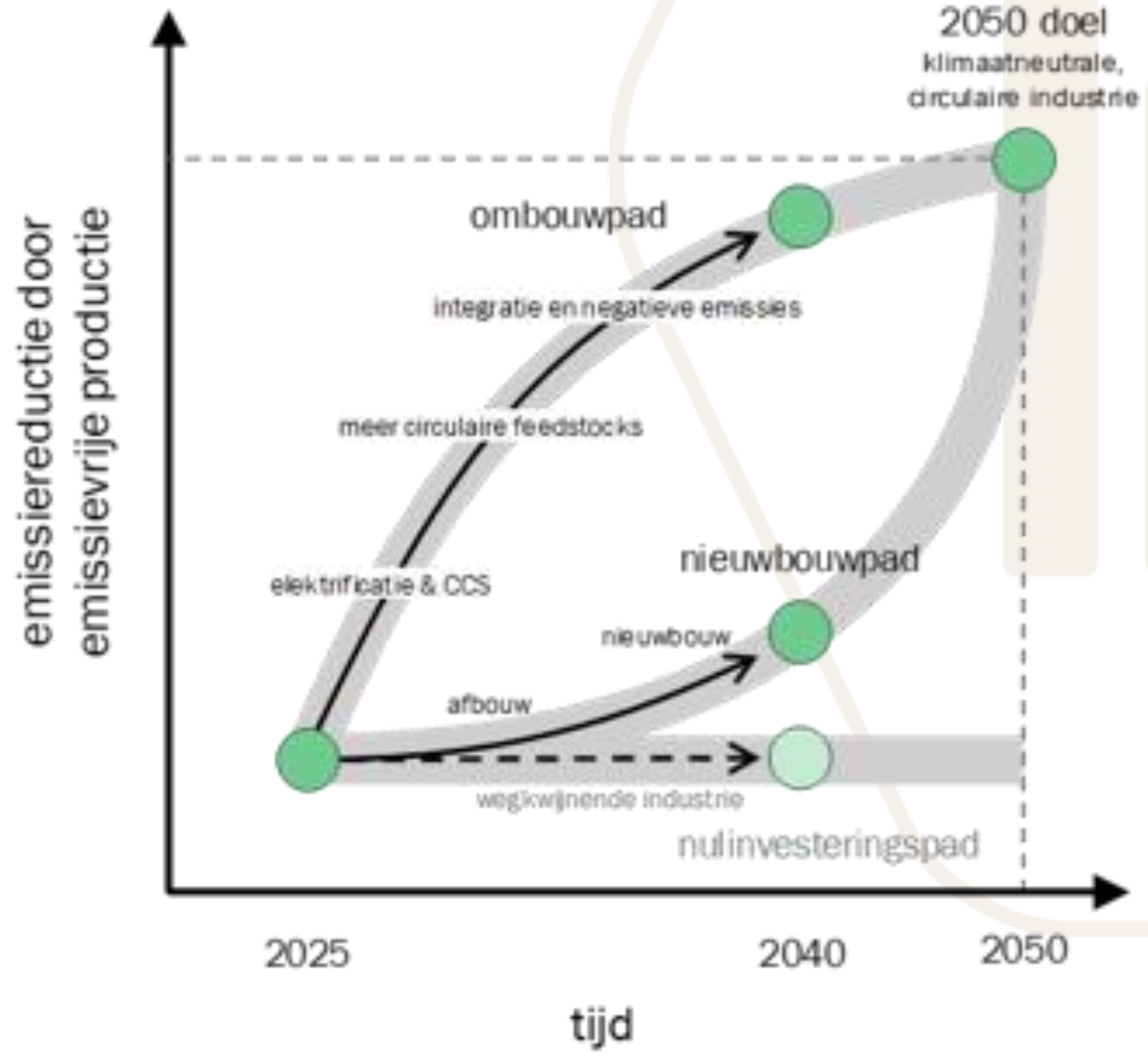


Figure 5 indicates how staircase versions can be related to the transition path towards our 2050 goals. Version 0 is the path of decay, when investments halt. Increasing scale from Version 1 to Version 3 shows how we can climb towards our goal with growing scale. New built value chain assets integrate with existing refineries and industry, enabling a steady transition. A scrap & build pathway (nieuwbouwpad), implies re-imagining the port from scratch, and clearing the port to build new large-scale operations. This leads to long periods without domestic industry, as this takes a prohibitive long time. This is not further detailed in this project.

Figure 5: Different goals and routes come with different impact [5].



Version sketching and screening

In this deliverable, for each of the selected Staircase versions, a vision is presented for understanding the Version better: What does it take to realize this Version, how could it be implemented and which parties would be involved? This provides a basis for understanding which decisions need to be made, when and by whom. Subsequently, it is possible to assess the Version on both project implementation metrics, as well as on goals and other value screening factors.

Project implementation metrics include indicative costs, time, space and constraints, infrastructure.

The goals and value screening factors, as presented and described in the main position paper, are:

- ETS1 CO_2 emissions, refer 2030 NL ambition
- Circular Production, refer 2040 NL ambition
- Domestic Chemicals Production by 2040
- Total Investment 2025-2040

Remaining fossil & non-fossil carbon imports, as indicator for the resulting (lack of) NL/EU autonomy

Sketching and screening in this deliverable is designed to reveal the relationship between scale and systemic change. Reaching meaningful scale in circular carbon development inevitably requires more than adding new plants to an existing system — at some point, the system itself changes. This transition from changing the existing system to changing the system itself is a threshold that not every version can meet as it builds out over time. What differs between versions is how far they can drive systemic change, determined by the scale they target. Version 1 can initiate change but not transform the system. Version 2 reaches significant impact but at the cost of disruption. Version 3, targeting full ecosystem scale, is the version that can drive systemic change all the way through by design.

System change is experienced already today, as all key organizations are in a permanent state of reorganization. This implies not only a change of physical assets but also changes the organizations themselves across the full stakeholder landscape, shifting focus from support to development.

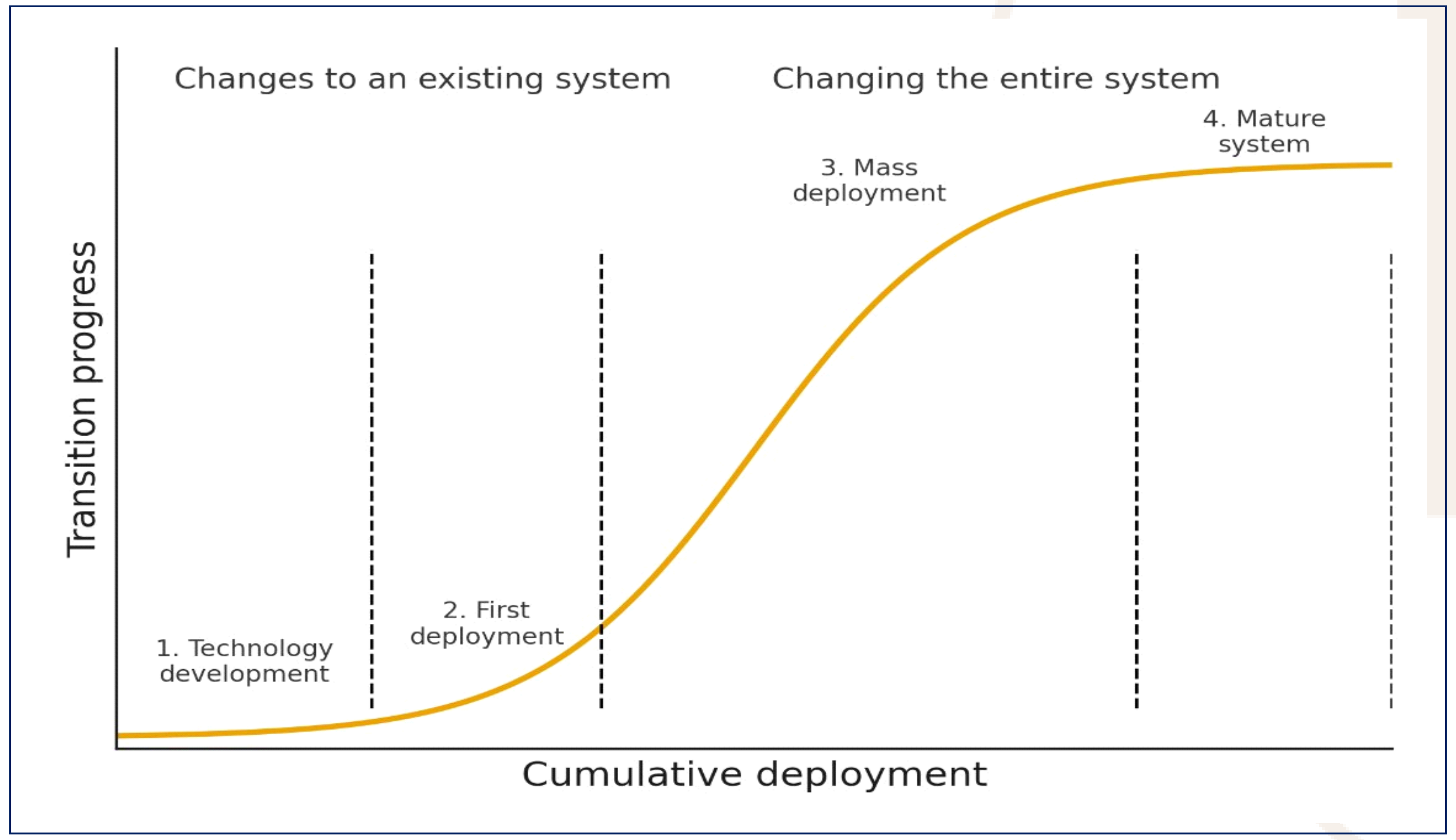


Figure 6: Changing characteristics as transition progresses from incremental change to systemic transformation.

Version 0 – Do nothing (*Wegkwijnen, Languish*)

When faced with deep uncertainty, it is understandable that decision-makers gravitate toward a "do nothing" position but, waiting is itself a strategic, albeit often implicit choice, with long-term consequences.

In the short term, this pathway is not primarily driven by the physical impacts of climate change as these are largely locked in by past and current emissions. Instead, the near-term pressures on the Harbor Industrial Complex (HIC) arise from increasingly stringent EU and Dutch policy frameworks, geopolitical tension, and volatile energy markets.

It is inevitable that the EU will continue to pursue its decarbonization ambition. It is equally inevitable that the current policy framework requires refinement as the wishful "change it all at once" or "let's go to north Sweden" ideas preached by some in practice create a highly uncertain investment climate. Consequently, demand for traditional fossil-based products likely persists beyond current policy trajectories.

In such conditions, asset owners rationally delay or avoid long-term investments and continue to operate for as long as they remain technically and economically viable, sweating the assets. Attention shifts toward short-term value preservation, assets change hands to lower-cost operators and emissions continue as long as possible, while asset condition gradually deteriorates.

A critical risk of the do-nothing pathway is the assumption that lost production in the HIC will be seamlessly replaced elsewhere and emissions will go down. There is little evidence that alternative hubs, inside or outside Europe, are currently investing at scale in low-emission, circular carbon value chains capable of delivering the scale of the HIC, especially when considering the total volume of carbon that passes through the HIC. Ultimately, imports of green fuels or molecules face the same policy, financing, and infrastructure uncertainties as projects within the EU.

Because the HIC functions as a foundational node for downstream industries in the European hinterland, a delayed or unmanaged decline would have consequences far beyond the port itself. Downstream industries depend on the availability of basic chemicals, fuels, and intermediates to enable their own transitions. If the HIC does not evolve, it becomes increasingly difficult for the broader industrial ecosystem to decarbonize. In practice, decline in local conversion of fossil fuels would likely be replaced with imports of those same fossil fuels.

Version 1 – Circular carbon niche

Characteristics

- Plants with a typical size of ~0.1Mton carbon per year
- For achieving significant total volumes, many of these (relatively) small plants would be required, distributed across the HIC or wider area

Version 1 – What it could look like (1)

Installation

Version 1 involves the installation of multiple plants converting about 100kton C/yr each. Several companies are already aiming for this type and size of plant in The Netherlands or other countries in Europe. They can be developed opportunistically in locations where there is space close to affordable feedstock, and/or where the gasification product can be further processed or transported. An example is the previously planned Waste to Chemicals plant, next to the AVR in the Rotterdam HIC.

Feed & Products

An example feedstock for a 100kton C/yr plant is ~250kton/yr of RDF, based on ~700kton/yr of MSW. This is some 10% of the available MSW in The Netherlands, e.g. waste as collected in the Province of Zuid Holland. Another plant could use e.g. ~500kton/yr of biomass. For reference, this equals 20% of the imported wood pellets in the Netherlands in 2022[6].

Such a plant can convert 100kton/yr of carbon, which corresponds with 220kton/yr of syngas or methanol. The methanol can be used to replace imported (grey) methanol, which is used directly or as feedstock for other products. Alternatively, at the same location, a new methanol-to-X plant can be built to use the methanol for the production of olefins or naphtha, and keep the carbon fully controlled for a niche circular products market.

Infra & Other needs

Both feedstock and product volumes can be transported by inland shipping but are also small enough to be trucked if the plant cannot be co-located with a feedstock provider. As *order of magnitude*, 500kton/yr of biomass requires ~60 truck loads per day. The methanol another 45 trucks per day. In many places this is a significant impact. In addition, there will be a need for significant infrastructure for steady hydrogen supply.

The space required for such a plant depends on the existing infrastructure, feedstock and products. Producing 220kton of methanol requires roughly 8-16ha. The WtC location could do with as little as 6ha, co-siting with AVR. Multiple locations could probably be found across the Rotterdam HIC area.

External hydrogen supply

A single Version 1 plant requires around 25kton of hydrogen per year — already more than the planned output of Holland Hydrogen 1. Generating the equivalent green hydrogen would demand around 250MW of electrolysis capacity and 30-40 offshore wind turbines. For a plant of this scale, that is not a self-evident addition.

No hydrogen network exists to draw from. Each plant must secure its own supply independently. Plants that can connect to port infrastructure or an existing import terminal have a clear advantage — those opportunities go first.

As more Version 1 plants are realized, accessible supply points are taken. Later plants face longer logistics chains, less supply certainty and higher cost. Hydrogen remains a fragmented challenge — solved plant by plant, never systematically.

[6] National solid biomass balance; production and consumption - CBS (2022)

Version 1 – What it could look like (2)

Waste to Chemicals — a Version 1 example

A concrete example of a Version 1 plant is the Waste to Chemicals (WtC) plant that was planned next to the AVR in Rotterdam. The asset owner was a consortium of large companies with Enerkem as technology provider. The plan was to split available MSW into an RDF stream and a rest stream handled by the AVR, producing methanol to be trucked out or piped to an adjacent client. The plant was never built.

The planned space requirement was only 6ha, made possible by cooperation with the AVR and access to local hydrogen supply. Without this co-location, or with a different feedstock and no local hydrogen available, the required space and supply complexity would be significantly larger.

Site ecosystem

Version 1 plants are largely stand-alone, with little synergy between them. Integration with other assets happens through shared infrastructure — power, heat, CO_2 and storage. A mini-ecosystem forms naturally when a plant is co-located with its feedstock provider or a downstream off-taker, as in the WtC-AVR example.

Investment, technology and timeline

The capital investment order of magnitude for a feedstock to methanol plant is up to 0.5bln€, with first-of-a-kind plants potentially exceeding this. When Methanol to Olefins or Naphtha facilities are included, the investment increases to 0.5-1bln€ cost range. The Enerkem technology had not been fully proven at this scale, making it a first-of-a-kind globally.

A plant of this type can be developed in a few years, including permitting, engineering and construction. No special materials or equipment are required, though technology selection follows from feedstock and product choices.

Figure 7: Visualization of Version 1, shown as the example of the Waste to Chemicals project at the AVR.

Version 1 – What it could look like (3)

Execution

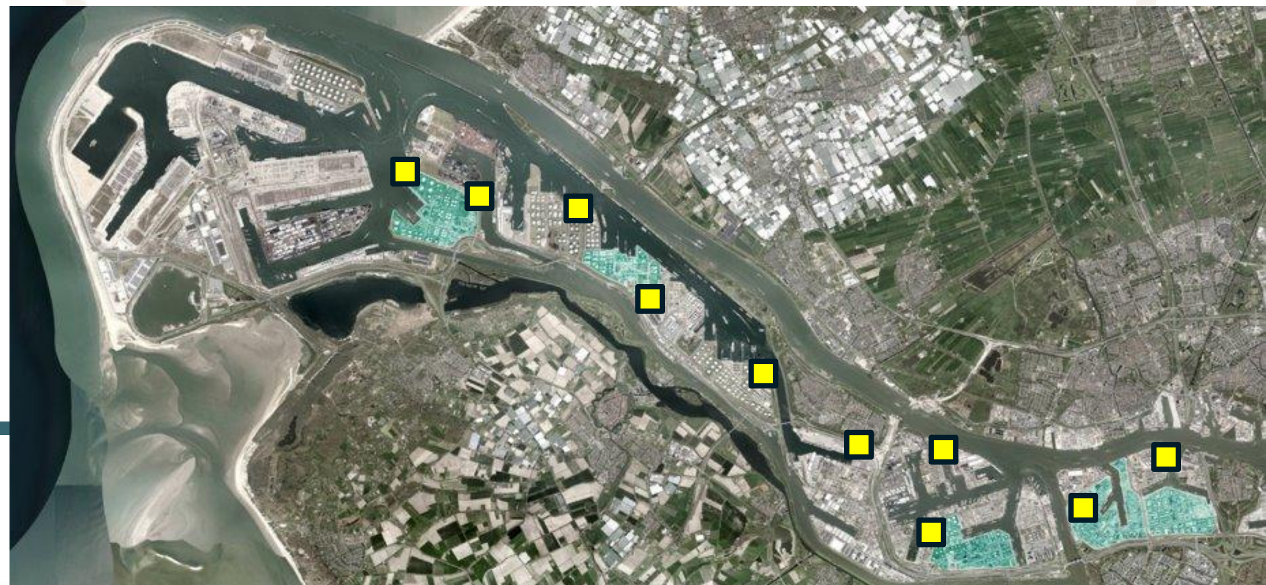
Version 1 is the smallest of the envisaged versions, but it should not be considered small and easy. A project like this still requires all the permits and will find hurdles for finance because it is just a niche player. If directly linked to an existing asset for feedstock such as waste, it will have dependencies and may find reluctance to change the currently working system. Moreover, even when aiming to locate this in small, available spots to fit in and minimize investment, it may still prove difficult to find space. The Version 1 type project will likely be driven by an asset owner or project developer. It cannot rely yet on existing infrastructure for hydrogen supply, if it can even get the supply secured at all. Despite its size, realizing such plant may still take years if not supported by infrastructure and investment climate players, or if the goals are not fully agreed by all these players. The previously planned Waste to Chemicals project besides the Rotterdam AVR is unfortunately an example of a project that was stopped.

Multiplication

Difficulties start to shift and increase when realizing more of these projects. While co-siting as much as possible with existing facilities, these attractive opportunities will quickly run out. This is known as creaming of an asset – the best options are taken first, while the harder opportunities are left. They will require access to imported feedstock and will have to fight even harder for infrastructure and hydrogen, permits may get trickier. Investment climate players, including authorities, may go through a learning curve, and start supporting the several Version 1 asset projects with efforts for combined infrastructure, access to funding, and facilitate procedures or even market creation. But even with such joint efforts, the system will likely remain fragmented as sites are scattered across the country. While the first asset should be doable, with the right intentions and support, subsequent projects quickly grow harder. It is difficult to indicate a maximum number of Version 1, but more than 10 is not likely. With individual owners, projects, infra, possibly trucking requirement, securing funding and permits all involved, the failure rate of attempted projects may be high.

Impact

The great thing about Version 1 is that it feels very doable. A single company can carry it, and it solves a local waste issue at the same time. Parties can indicate they are on the right track, while not doing much more. However, one Version 1 project of 0.1Mton C/yr represents only 1% of the 10Mton/yr goal to meet by 2050. If 10 projects are managed, this means 10% of this goal. The other 90% of the HIC carbon will remain non-circular, i.e. will remain the same as the Version 0.
The (felt) perspective to act, needed to move forward, may become a blocker for more impact.



Version 1 – Asset process archetype

Figure 8: Asset process archetypes of Version 1, showing selection points for feed and products.

Version 1 – Characteristics & Screening

Implementation

Version 1 concerns the installation of 1 or more small plants converting 100kton C/yr each. Key characteristics are the following:

Target capacity	*0.1Mton C/yr (or smaller)*
Replicability in HIC	*10x → 1Mton C/yr*
Feedstock	*Waste or plastic or biomass* *Multiple plants will need multiple feeds*
Process & Product	*Simplest is methanol, unless regulation demands fully circular products*
Implementation	*Local, new-built or co-located on existing site. Near feedstock. Needs connection to hydrogen.*
Integration	*Only locally, no ecosystem, limited synergies*
Space	*Feedstock to Methanol: ~10ha (excl hydrogen)*
Time (minimum)	*< 5 years from agreed scope to start-up*
Costs, finance	*0.5bln€ each (order of magnitude) for feedstock to methanol only); 1bln€ when including methanol to products facilities. Excl hydrogen.*

Screening

This version may have its main benefit in providing value to a waste stream rather than a large contribution to a circular carbon industry. A single plant corresponds to 1% of the 10Mt target. If installed 10x*, this becomes 10%.

Impact of:	*1 Plant*	*10 Plants**
ETS1 CO_2 emissions (2030)	*Minimal*	*Some*
Circular Production (2040)	*Minimal*	*Some*
Domestic Chemicals (2040)	*Minimal*	*Some*
Investment (2025-2040)	*Relevant*	*Significant*
Strategic autonomy	*None*	*Minimal*

Additional value, pros and cons:

Perspective to Act	*Good*	*Quickly getting hard*
Effective as temporary step	*Limited, no easy upscaling later*	

** Actual maximum number of plants and pace of realization to be assessed*

Version 2 – Industrial scale

Characteristics

- Plants with a typical size of ~1Mton carbon per year
- For achieving significant total volumes, several of these (relatively) large plants would be required, across the HIC or wider area.
- Plants are mostly independent, but would benefit if sooner or later connected or cooperating

170ha,
RDF + biomass to circular products
(1Mton C/yr)

Version 2 – What it could look like (1)

Installation

Version 2 plants have a capacity of (up to) 1Mton/yr of carbon each, aiming to (partially) replace the fossil crude feed of refineries. This size operation involves transforming one or more existing refineries, using part of the space that may come available as fuel demand reduces over time. This is an industrial first-of-a-kind at the capacity of 10 plants of Version 1. At this scale, space must be made available to place the new-built facilities, infra, logistics, feedstock storage and treatment and for lay-down during execution. Scaling benefits lead to less total space than for 10 0.1Mton/yr plants, but it lacks the opportunity-driven co-location benefits with existing feedstock providers of Version 1. If new, large-scale waste handling facilities are built co-location may become an option. The products can be fed directly into larger plants for further processing. An example location could be at one or between two existing refineries. This immediately surfaces a fundamental challenge: integrating such a large new operation into a refinery means simultaneously running it and rebuilding it. This makes that Version 2 inherently risks destabilizing key facilities in the cluster from the outset.

Feed & Products

An example feedstock for a 1Mton C/yr plant could be a combination of 1Mt/y RDF (3Mton/yr of MSW), and 2.5Mton/yr of biomass. For reference, this would be almost half of the total Dutch municipal waste, plus the total currently imported biomass in The Netherlands. A second plant would need an additional 5Mton/yr of biomass and/or substantial MSW or RDF imports from other countries. A version 2 plant is sized to convert 1Mton/yr of carbon, which corresponds with 2.2Mton/yr of syngas or methanol. This can still replace non-circular methanol. If the aim is to achieve circularity, then new methanol-to-olefins or methanol-to-chemical facilities are required as well. This becomes more relevant in case of multiple Version 2 plants. Direct production of hydrocarbons through Fischer-Tropsch processing is also an option, but it needs to be investigated at what capacity this becomes more advantageous than methanol routes.

Infra & Other needs

Feedstock as well as product volumes become too large to be trucked easily. Trucking may still be part of the (RDF) transport, however, ideally most of the feedstock is shipped (inland as well as overseas).

Depending on the feedstock mix the plant will contain multiple gasifiers, with pre-processing and downstream treatment. The syngas is collected in a site-based syngas network and fed to one or more methanol or Fischer-Tropsch plants (FT). Methanol is transported by pipelines to storage and further processing. If needed, part of the methanol can still be trucked. In case of FT conversion, hydrocarbons will be processed in the downstream remaining refinery assets.

Version 2 – What it could look like (2)

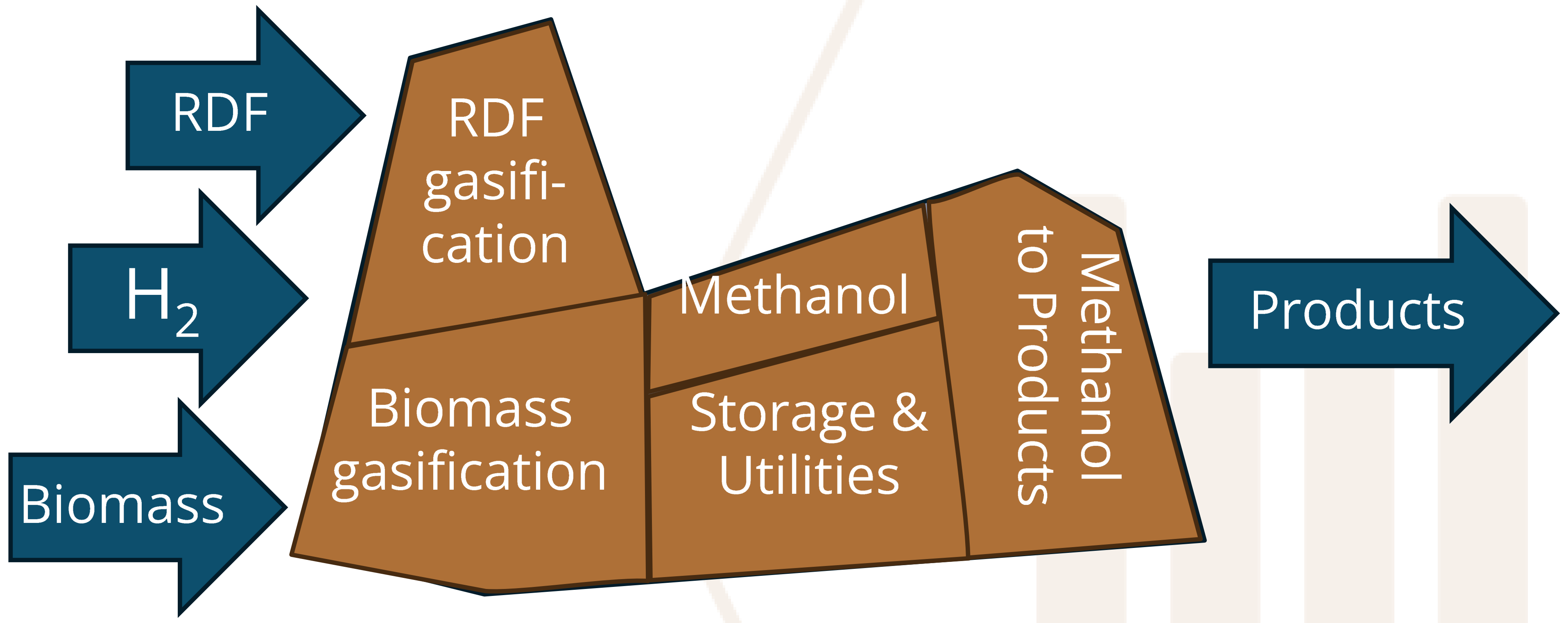
Space

The required space for such a plant depends on the infrastructure, feedstock and the end products. To create 2.2Mton/yr of syngas and methanol from RDF or biomass requires about 80-160ha, following the indicative acreage/Mt approach shown in Table 3 of Deliverable 1. For the methanol to products an additional 25ha is needed for that same capacity, or for Fischer-Tropsch facilities that would be 120ha. With these large area requirements, a 1Mt plant would nearly require the space of a complete refinery to build all the facilities from feedstock to end olefins, chemicals or fuels. If this same space is re-used for the new facilities, this can only be done after taking the old facilities out of services, i.e. when they are no longer required for the overall HIC capacity.

External hydrogen supply

The indicated space requirement is excluding hydrogen generation and infrastructure. For 2.2Mton of methanol, some 250kton of hydrogen is needed. This is 11x the production from Holland Hydrogen 1 – demanding approximately 2,2 GW electrolysis capacity. The equivalent power demand would need about 140-200 offshore windmills.

Figure 9: Visualization of Version 2, shown as an implementation of the process archetype from feedstock to product, following the methanol route. The 1Mton C/yr plant could be located at one of the refineries, when its current production is first diverted to other refineries.



Version 2 – What it could look like (3)

Ecosystem

Version 2 plants are initially mostly self-sustaining, but they do not operate in isolation. Dependencies on utilities, hydrogen supply and logistics connect each plant to the wider HIC, and cooperation between plants — supplying methanol or FT oil to remaining refineries — becomes a natural feature of the system as it builds out.

Coordination

Effective coordination between plants is essential from the start. Asset owners must jointly decide which refinery converts when, how remaining production is redistributed while conversion is underway, how feedstock is allocated between plants as volumes grow, and where products go when the host refinery no longer exists. This is best organized through a Joint Venture structure. However, JVs carry a structural risk: partners that start aligned can become dysfunctional as incentives diverge over time. Moreover, the locus of coordination shifts with scale — JV 1 and 2 can largely be driven by asset owners together, but JV 3 and 4 start requiring HIC-level and potentially national-level coordination to resolve hydrogen supply, space sequencing and market creation.

Multiplication

Version 2 at scale means not one refinery conversion but three or four — near-simultaneously across the HIC. Each plant takes 5-10 years to realize; to reach 3-4 plants before 2040, they must run in parallel. As multiple JVs build out, they will compete with each other — for feedstock, hydrogen, offtake markets and investment capital. JV 1 and 2 may be achievable; JV 3 and 4 face an order of magnitude greater challenge. The building blocks of Version 2 are simply too large to remove without systemic risk to the cluster — if one refinery is taken out and rebuilt, the remaining three must absorb its function, and the risk of discontinuity grows with each iteration.

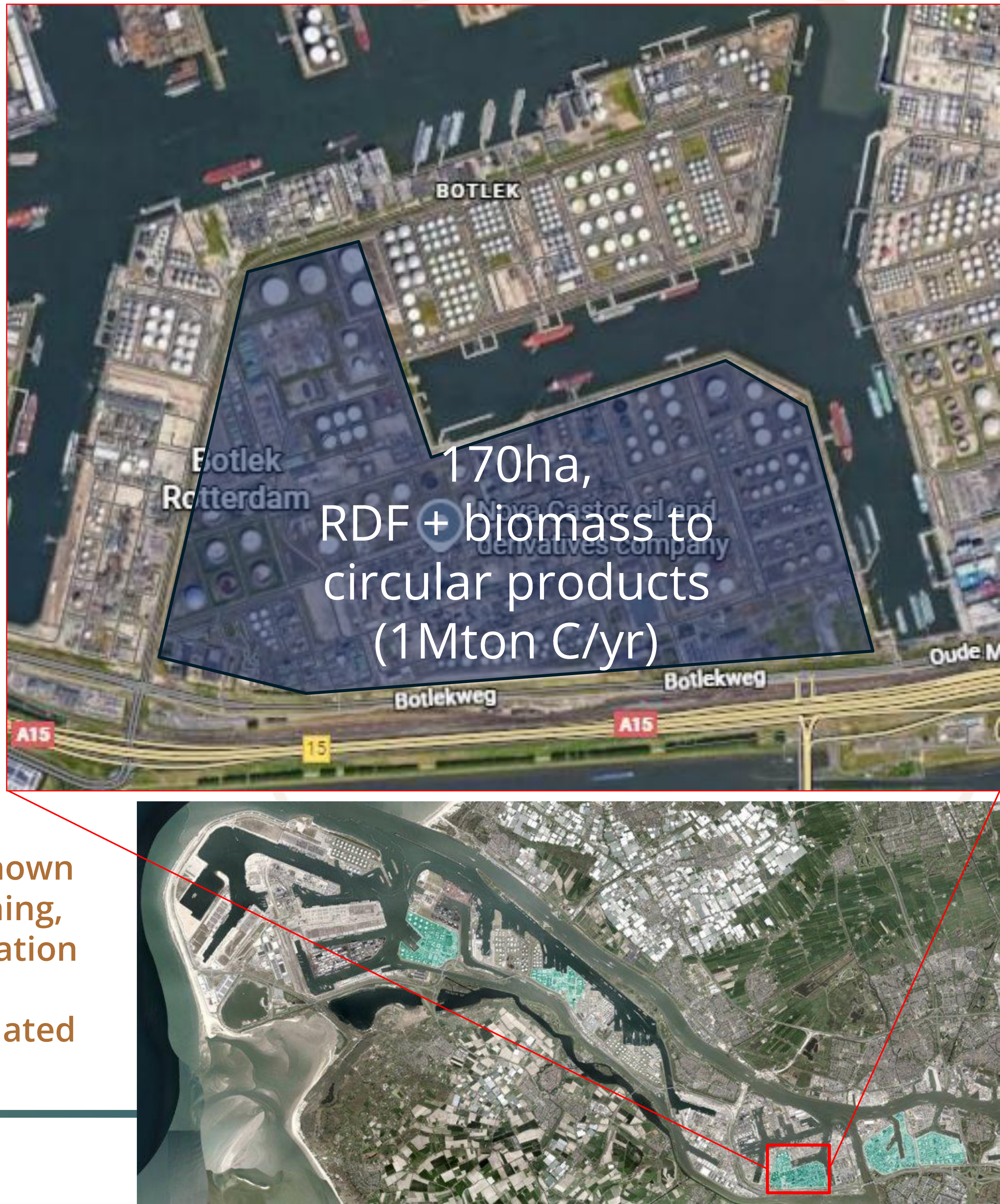


Figure 10: Visualization of Version 2, shown as the example of a mostly self-sustaining, feedstock-to-product facility at the location of one of the current refineries.
The shown location is arbitrary, not related to any project plans.

Version 2 – What it could look like (4)

Execution challenges

In this report, we call Version 2 is an "industrial size" plant. It is however a project of a scale that has not yet been realized for circular carbon anywhere in the world. This doesn't mean it cannot be done, with the support of current asset owners, HIC, authorities and other relevant stakeholders. The asset owners together can deliver a proposition for financial institutes that is investable, authorities of all levels, including EU, can see how serious the proposal is, and can support with regulation to steer market creation for circular carbon products, or they can adjust current demands on when products can be called green or circular on paper. However, the above listing indirectly highlights the risks and challenges of executing a project at this scale. The cooperation may not work, the required timelines may not add-up, requiring space earlier than it is available, or the market creation is ineffective, jeopardizing very large investments.

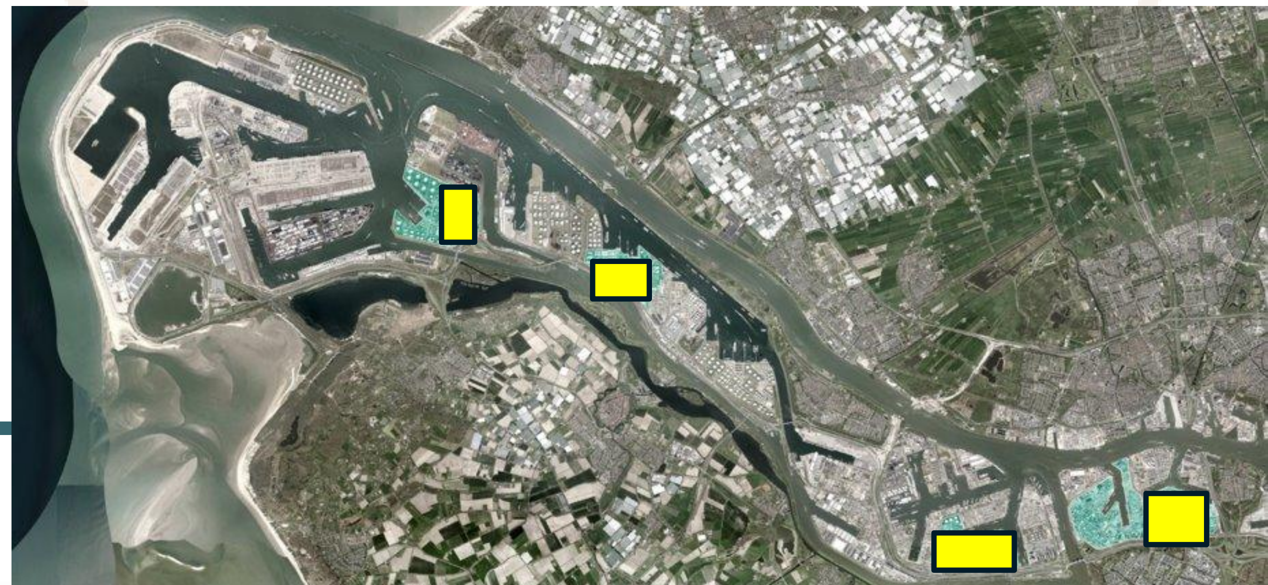
Feedstocks

An additional challenge is the organization of the feedstock. Preference would be to use the lowest-value of feedstock, i.e. RDF and non-recyclable plastic. Collecting and handling RDF and plastic in the amounts needed for 1 or several Mton C/yr requires not only a logistic challenge, but also additional legislation and political hurdles to be taken. When taking in large volumes of biomass, the challenge is to ensure that only suitable materials from agriculture or dedicated forestry are used, not valuable natural resources.

Impact

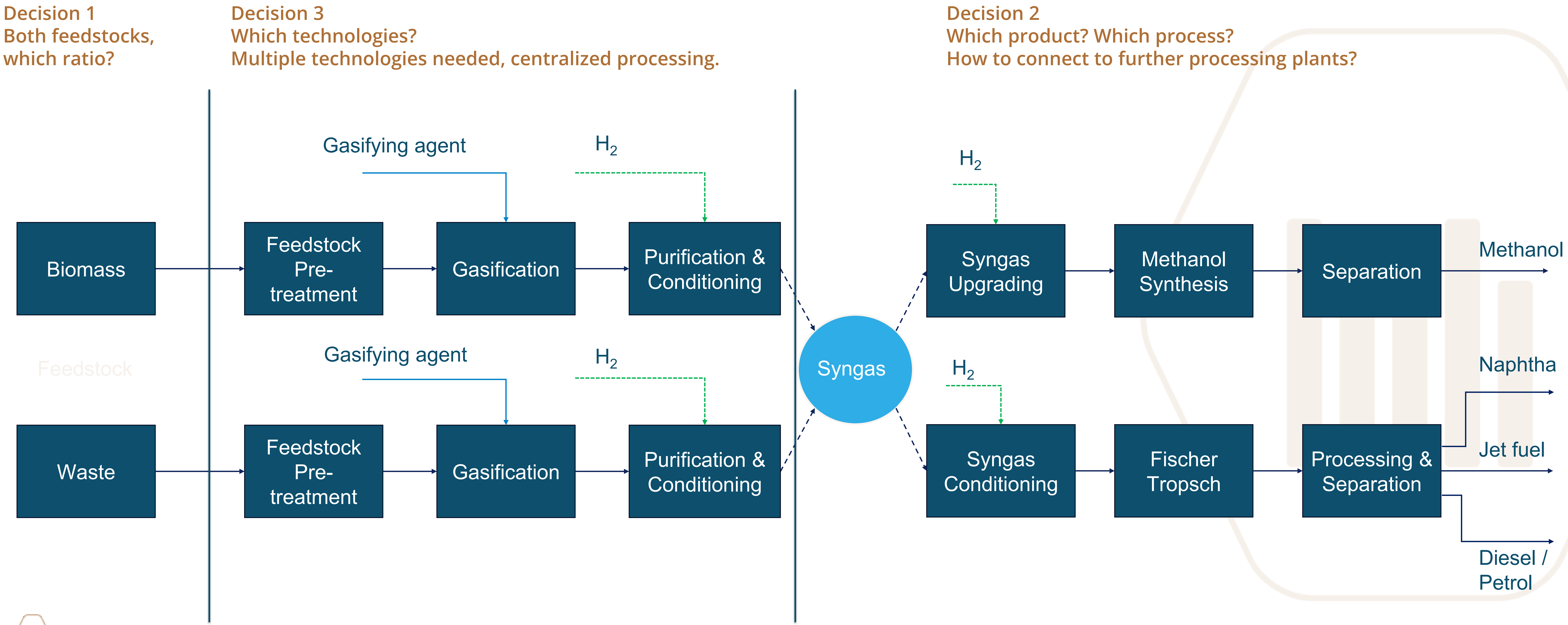
If stakeholders are joined in a coalition of the willing, and market creation can be realized, 1 or more of these industry size plants seem feasible, even though not proven. This reasonable perspective to act is an important factor to be able to actually bring those same joined forces together. For this, direction and coordination are needed.

Each Version 2 plant realizes 10% of the 10Mton/yr circular carbon target. Three or four of these plants, if feasible, can therefore present a significant change for the HIC. Still, this means that 60-70% of the carbon conversion is not yet circular, with the remaining risks of the Version 0 *wegkwijnscenario*. With 60-70% of carbon conversion remaining non-circular, Version 2 alone seems insufficient to achieve strategic autonomy. It is a meaningful contribution — but not a complete answer.



Version 2 – Asset process archetype

Figure 11: Asset process archetypes of Version 2 showing the dual-feedstock and dual product decision points in the integrated value chain.



Version 2 – Characteristics & Screening

Implementation

Version 2 involved the installation of 1 or more large plants converting 1Mton C/yr each. Although this size industry exists from coal or gas conversion, it has not been built before for circular carbon creation.

Target capacity	*1Mton C/yr (or smaller)*
Replicability in HIC	*2-4x → 2-3Mton C/yr*
Feedstock	*Mainly biomass, first plant can also use RDF*
Process & Product	*Simplest is methanol, but with multiple plants, also Methanol to X and/or FT is assumed*
Implementation	*Large scale conversion of existing refineries. Needs access to large scale hydrogen.*
Integration	*At least locally, but ideally with ecosystem and synergies between plants, pipe connections*
Space, Time	*100-200ha each depending on products. 5-10 years.*
Costs, finance	*5-10bln€ each, order of magnitude, depending on included facilities and end products (methanol or other), excluding costs if hydrogen*

Screening

This Version starts to significantly contribute to a more circular carbon industry (10% or target 10Mton/yr each), besides providing a value solution for all available waste. Potential for ultimately 3-4 such plants is assumed*.

Impact of	*1 Plant*	*3-4 Plants**
ETS1 CO2 emissions (2030)	*Relevant*	*Significant*
Circular Production (2040)	*Relevant*	*Significant*
Domestic Chemicals (2040)	*Significant*	*Most*
Investment (2025-2040)	*Relevant*	*Significant*
Strategic autonomy	*Minimal*	*Some*

Additional value, pros and cons:

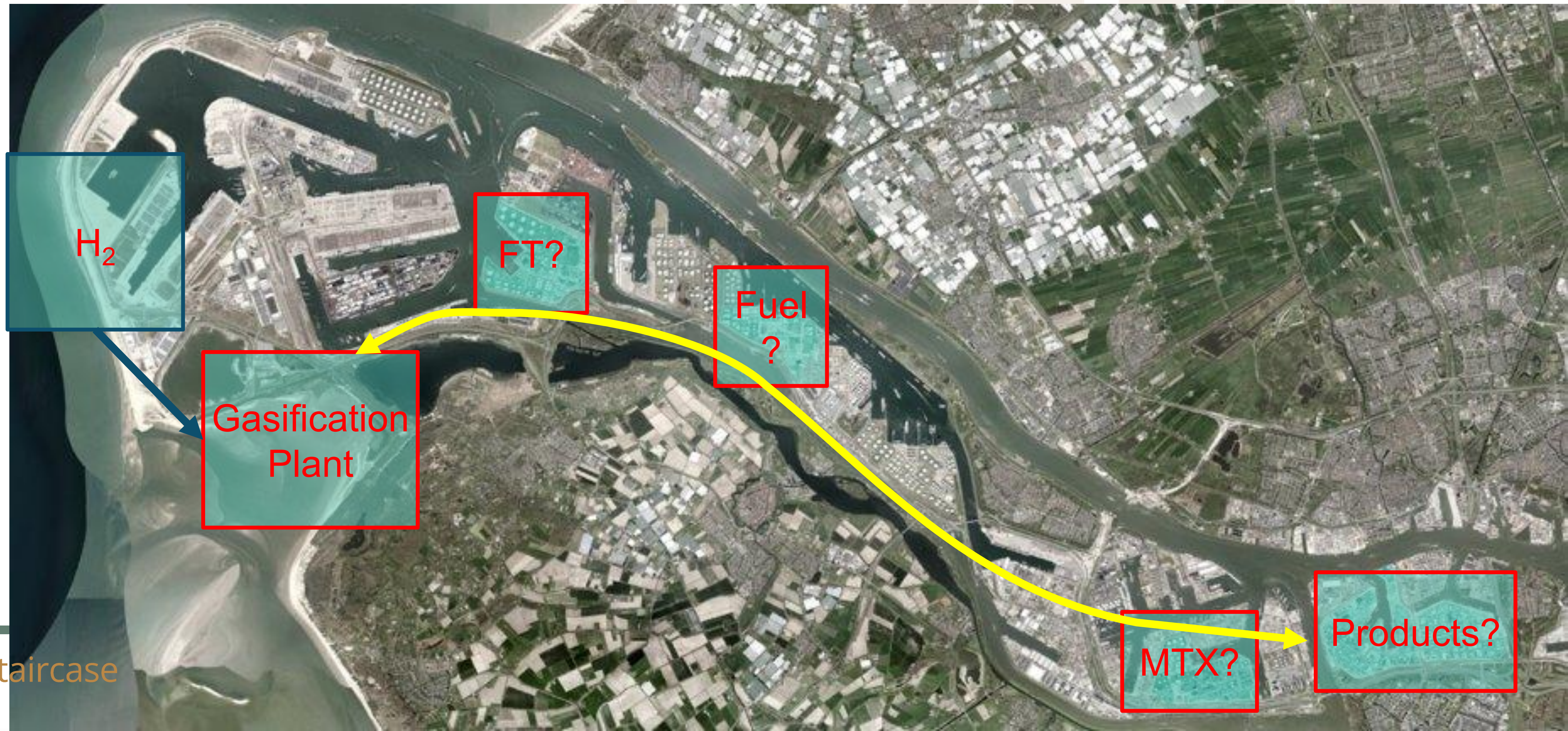
Perspective to Act	*Feasible*	*Hard*
Effective as temporary step	*Limited, no easy upscaling later*	

** Actual maximum number of plants and pace of realization to be assessed*

Version 3 – Renewable Carbon Megahub

Characteristics

- New ecosystem of cooperating, connected plants, with an overall target capacity of ~10Mton of circular carbon per year.
- High level of direction to gradually re-shape the HIC with the new ecosystem in mind from the start.
- Specialized activities, all connected through shared infrastructure. Area(s) for generating hydrogen, for gasification of waste and biomass to produce syngas, and areas to produce chemicals, olefins and fuels through applicable processes. Syngas shall be distributed as a utility. Value chain elements support each other, but can also grow separately, with import to handle any disbalance.
- An good mix of technologies for the expected product needs shall be designed from the start, and scheduled appropriately to distribute resources, finance and space, and mimic the simultaneous reduced carbon product volumes and existing production facilities.



Version 3 – What it could look like (1)

Installation

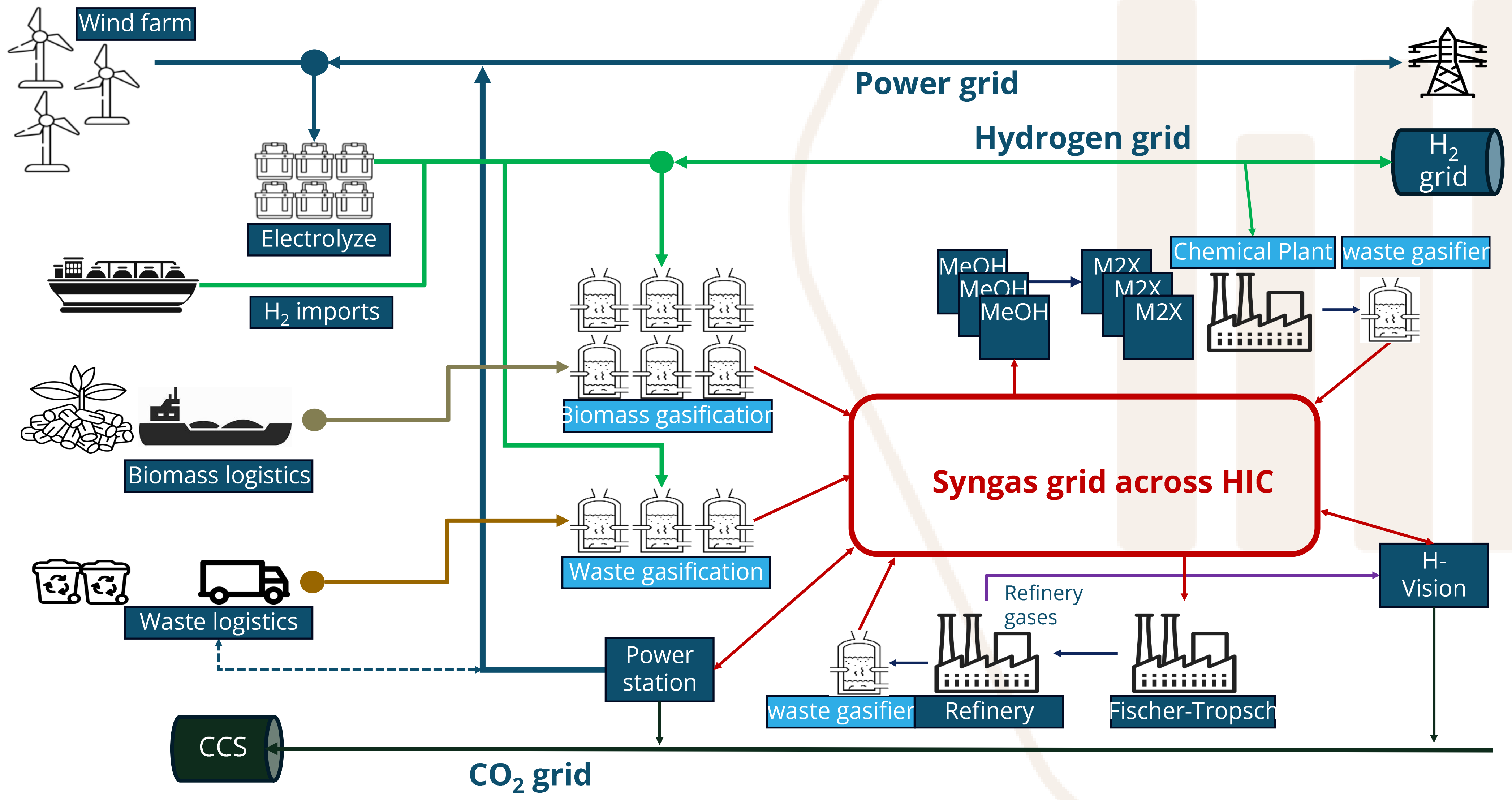
Version 3 is built around a master plan — an agreed picture of what the full ecosystem can look like when complete transformation to 10Mton C/yr is reached, used to guide every installation decision from the first day. This upfront investment in planning and alignment is not a delay: it is what allows the system to grow continuously without the discontinuity risks that come with building large, standalone blocks. Go slow in the beginning to go fast in the end — this is front-end loading by design.

Within that master plan, capacity is installed gradually. Designated areas across the HIC are assigned to specific functions — gasification, hydrogen generation, syngas distribution, methanol synthesis, FT processing, product upgrading — and filled out over time as space becomes available and investment follows. Most elements scale modularly. FT plants typically require minimum scale to be economic and are planned from the start but likely built later in the sequence.

Crucially, the master plan identifies existing sites where units may turn down over time. If the right incentives are in place to decommission these units and add new functionality in their place, space becomes available in a natural flow — and the system can evolve organically rather than requiring forced, disruptive clearance.

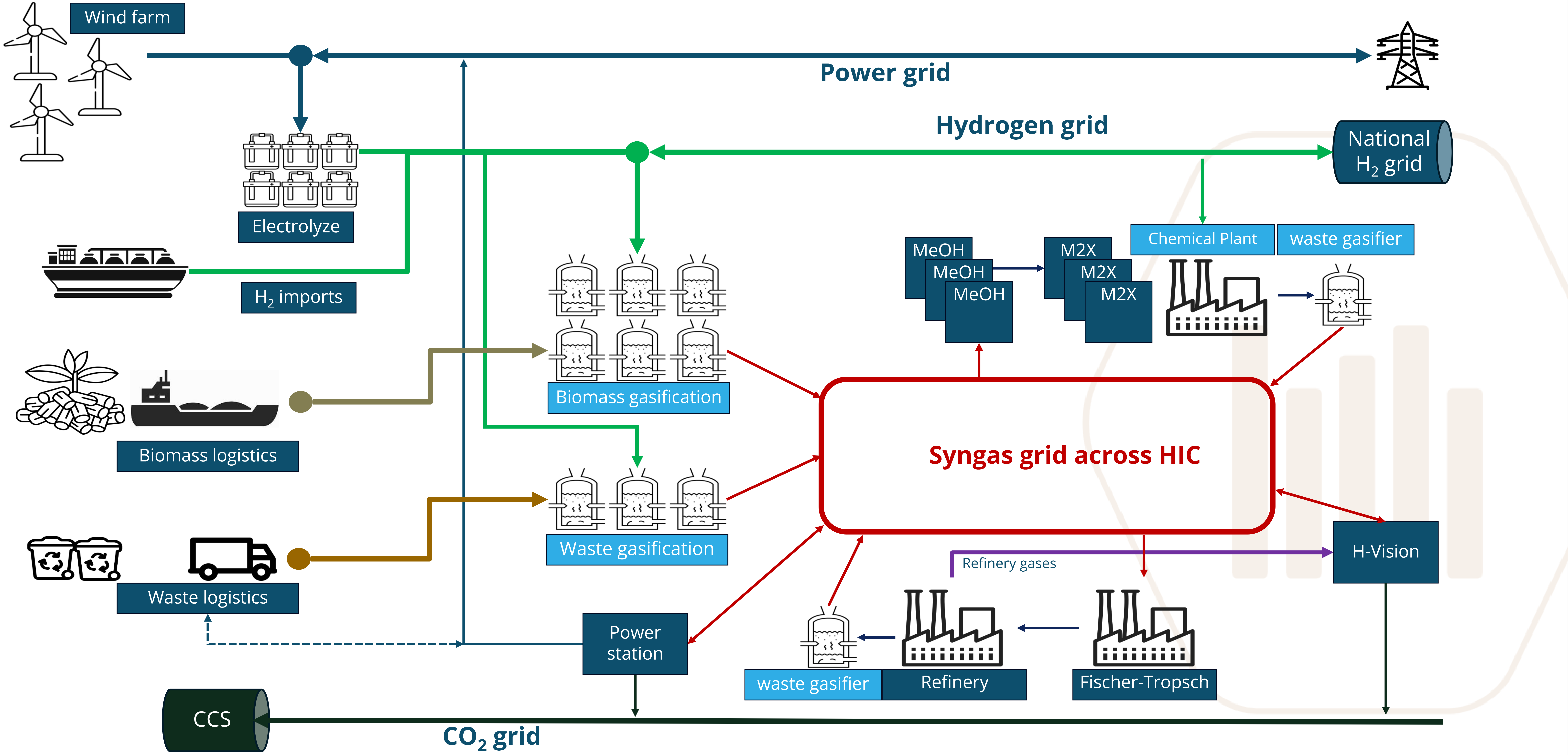
The syngas grid is the first critical piece of infrastructure. It is what connects the distributed plants into one functioning system, and it needs to be initiated early — even before full capacity is in place. Import facilities for hydrogen and methanol bridge the gap during build-out, keeping the ecosystem supplied while domestic capacity grows. The distributed ecosystem this enables is shown in Figure 12.

Figure 12: Schematic of the distributed ecosystem, with locations where separate functionalities can be developed gradually and to some extent independently over time, while contributing to the overall master plan. (See next page for an enlarged version).



Version 3 – Distributed ecosystem

Figure 12 (enlarged): Schematic of the distributed ecosystem, with locations where separate functionalities can be developed gradually and to some extent independently over time, while contributing to the overall master plan.



TEKENKAMER VAN DE INDUSTRIE

Version 3 – What it could look like (2)

Feeds

Feeding 10Mton/yr of carbon requires all available sources — waste, RDF and biomass combined. Running on biomass alone requires 50Mton/yr, around 10-15% of total expected solid biomass in Europe, so diversification of feedstock is essential. At this scale, the majority of domestic waste is absorbed into the system — requiring a fundamental rethink of how waste is handled in the Netherlands. Beyond domestic volumes, cross-border waste imports and substantial biomass supply are needed, drawing on EU and global biomass trades. This diversification of feedstock across domestic, European and global sources is not just a logistics challenge — it is the foundation of strategic autonomy and supply resilience for the circular carbon system. If carbon turns out to become scarce, CO_2 via reverse water gas shift offers a last resort option — but requires hydrogen and power at a scale and cost not foreseeable before 2040. Products are made in specialized plants, each optimized for its part of the value chain.

Products

Version 3 produces the full range of circular carbon products — chemicals, olefins, fuels and naphtha — from a set of specialized downstream plants, each optimized for its part of the value chain. Rather than integrating all processing steps on one site as in Version 2, downstream integration in Version 3 is distributed: methanol-to-X and Fischer-Tropsch facilities connect into the syngas grid and feed into existing refinery back-ends and cracker complexes where these remain operational. This distributed downstream integration is what allows the system to grow incrementally while maintaining product supply continuity throughout the transition.

Infra & Other needs

An extensive syngas pipeline grid is the physical backbone of the Version 3 ecosystem, schematically in figure 13 — distributing syngas across the HIC to gasification clusters, methanol synthesis, Fischer-Tropsch and product plants. Beyond syngas, all commodity utilities must be developed or expanded at current or larger scale: power, CO_2, heat, water and wastewater. Port infrastructure — storage, pre-treatment and import terminals — must be developed in parallel to handle the scale of incoming feedstock and outgoing products. All new facilities together will likely require space beyond the combined footprint of the existing refineries — the full transformation may require additional area around the HIC or an additional Maasvlakte.

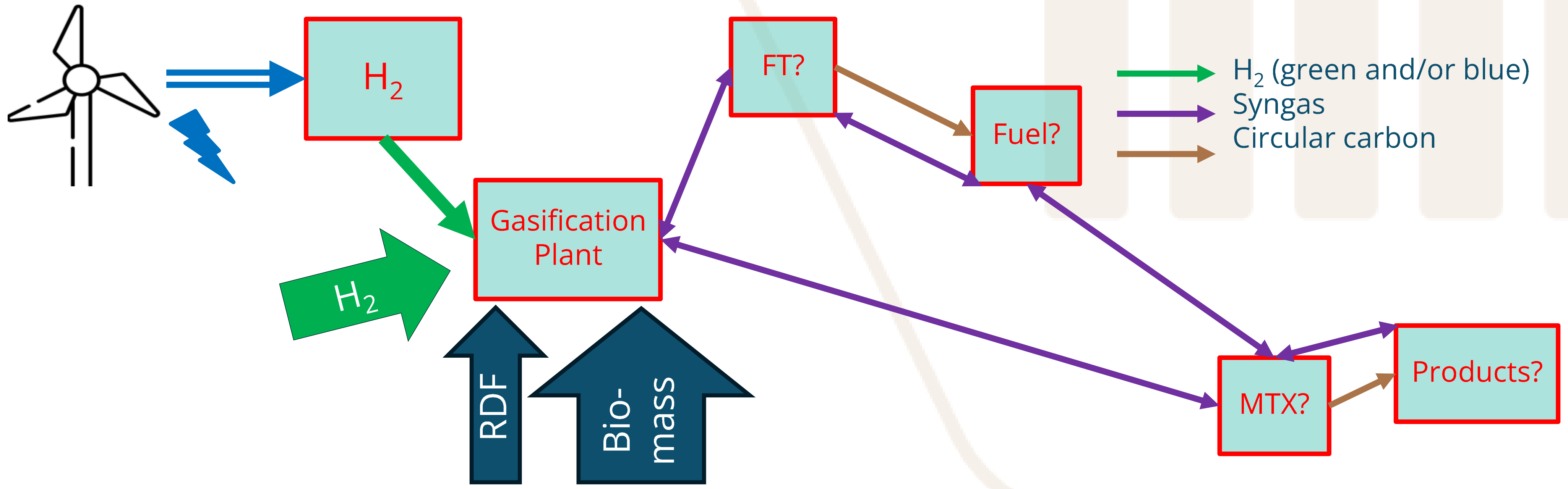


Figure 13: Visualization of Version 3, shown as a connected, distributed system where parts of the full archetypes are gradually developed

Version 3 – What it could look like (3)

External hydrogen supply

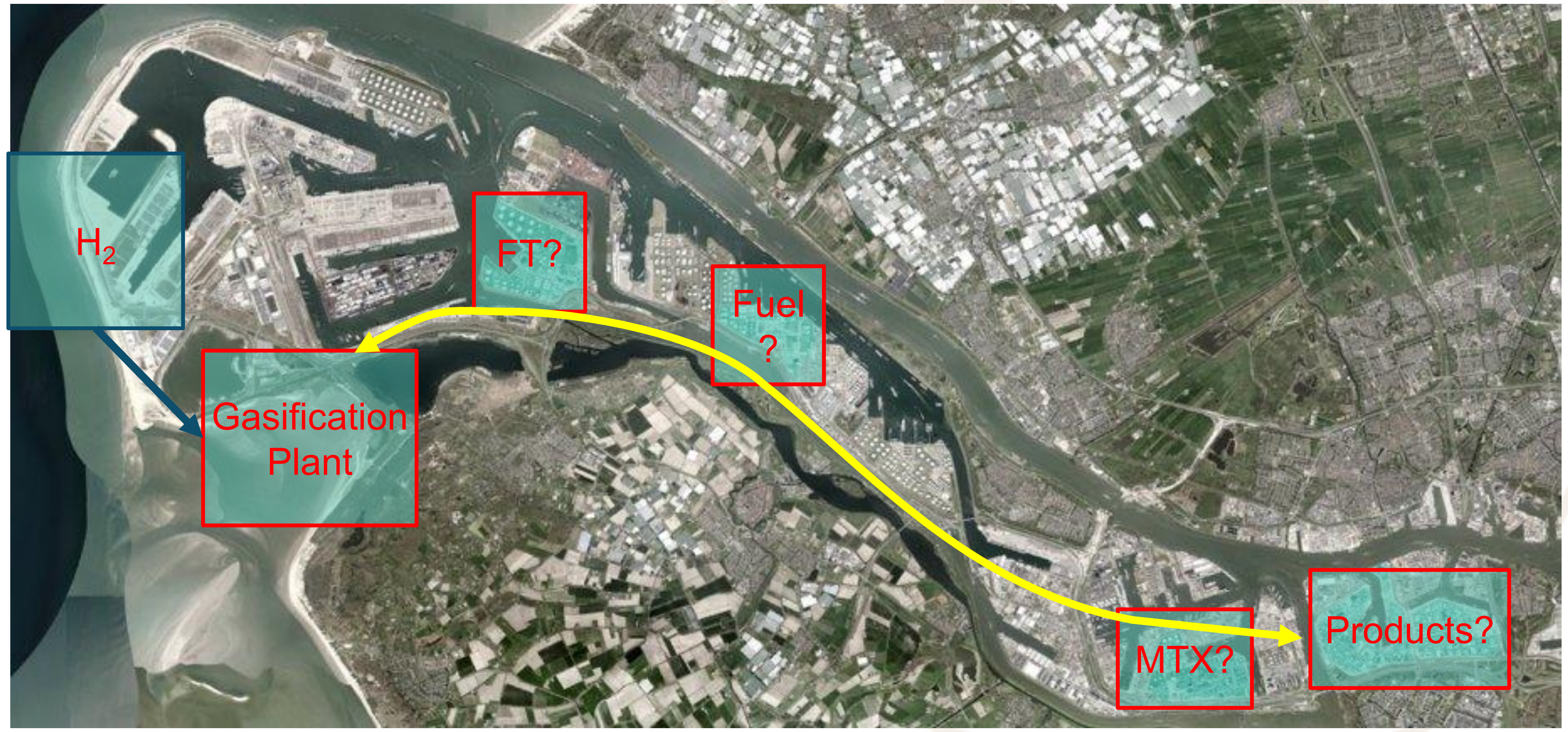
Version 3 requires hydrogen at a scale that is unprecedented. Feeding 10Mton/yr of circular carbon through gasification requires 2.5Mton/yr of hydrogen, demanding approximately 22GW of electrolysis capacity. For reference, this is 100 times the planned Holland Hydrogen 1 facility. Even assuming significant efficiency gains and partial use of blue hydrogen as a transition bridge, the generation, storage and distribution challenge is enormous.

This probably cannot be handled locally only. Version 3 requires a national hydrogen grid with large-scale storage facilities to ensure continuous supply. In practice, a significant share of hydrogen will need to be imported from dedicated generation hubs in Europe (Scandinavia, the Iberian Peninsula) or elsewhere. Hydrogen supply for Version 3 is therefore not a utility assumption — it is a parallel infrastructure program of comparable scale and complexity to the carbon conversion system itself.

Ecosystem behavior

Version 3 is designed to function as a single integrated system — and that integration is what gives it resilience. Assets breathe together: utilization fluctuates within designed bounds, and the system absorbs variation rather than being destabilized by it. When a facility turns down, the system compensates; when capacity grows, it is absorbed into the whole. This is not uncoordinated decline — it is conscious, governed coordination of the transition. Unlike Version 2, where each building block operates largely independently and discontinuity risk grows with each iteration, Version 3 manages the systemic S-curve by design. The syngas grid is what makes this possible — it is the connective tissue that turns distributed assets into one functioning system.

Figure 14: Visualization of Version 3, shown as a distributed, connected system across the HIC. The shown locations and functions are arbitrary, not related to any project plans.



Version 3 – What it could look like (4)

Phasing & Adaptiveness

Version 3 is built in stages — not because the ambition is uncertain, but because sequencing is strategic. The master plan defines what comes first: the syngas grid, initial gasification capacity, import facilities for hydrogen and methanol. These create the platform from which everything else can grow. Subsequent phases follow as space becomes available, investment rounds close and capacity builds — always synchronized with external development tracks: offshore wind and hydrogen capacity, waste collection and RDF infrastructure, biomass supply chains and cross-border feedstock logistics. These develop on their own timelines, largely outside the HIC's direct control. Phasing is what allows the system to grow in sizeable but manageable chunks, absorbing what is available when it is available.

A development horizon of several decades spans multiple technology generations, policy cycles and market shifts. The master plan sets the direction, but each phase needs the intelligence to be informed on what has changed — in technology, feedstock markets, regulation and geopolitical context. Adaptiveness is not optional; it is a designed requirement of the governance structure.

Execution

Executing Version 3 means the Rotterdam HIC enters a permanent state of construction — for decades. This is not a single megaproject with a defined end date, but a continuous active development running alongside normal industrial operations. That demands dedicated space for laydown, logistics and contractor facilities that persists throughout. It demands a sustained pipeline of skilled construction workers, with the housing, infrastructure and planning that comes with it. And it demands that the port and cluster remain fully operational while all of this unfolds around them.

Managing this permanent construction state is itself a governance and planning challenge of the first order — one that must be anticipated from the start, not solved ad hoc as each phase arrives.

Multiplication / Diversification

Version 3 is not replicated at the Rotterdam HIC — the full HIC is the scope. Elsewhere in the Netherlands, Version 1 and Version 2 initiatives remain relevant: building experience, covering regional circular carbon needs and providing local waste solutions where feedstock is not directed to Rotterdam. Beyond the Netherlands, the Version 3 logic is inherently European — the carbon conversion in the HIC represents only a fraction of the total carbon moving through Rotterdam, with four times more oil products transshipped onward to Germany and beyond. For a truly independent Europe, other major industrial clusters will need to follow a similar path.

Version 3 – What it could look like (5)

Rotterdam as European circular carbon hub

The Rotterdam HIC currently serves the ARRRA super-cluster primarily as a hub for crude oil and oil products — with chemicals and intermediates playing a supporting role. Version 3 transforms that position: Rotterdam becomes the key hub supplying circular and biogenic base chemicals to the ARRRA and the wider Western European hinterland. A transformation of this scale cannot be accomplished purely by private companies, even working together in one or more JVs. It must be agreed, prepared and set in motion at national level, with European alignment on feedstock, hydrogen and market conditions.

Multi-level Governance

Version 3 requires governance at a scale and permanence that matches its ambition. The starting point is a national strategic priority decision — establishing circular carbon development in the Rotterdam HIC as a long-term national commitment, not a policy program vulnerable to political cycles. This is the Deltaplan logic: an institutionalized, multi-decade commitment that provides the stable foundation everything else builds on.

When that commitment is in place — spanning national, provincial, port and European levels, with aligned regulation and cross-border coordination across the ARRRA — it creates the investment climate in which the private sector can commit at the required scale. The balance between incumbents and innovators must be deliberately managed: incumbents bring scale and existing infrastructure; innovators bring the technology and systems of the future. Neither alone is sufficient.

Get this right, and Version 3 becomes more than a carbon transition — it lays the cornerstone for an entirely new economic sector, with Rotterdam as its industrial and technological center.

Impact

Version 3 is the only version that achieves the full circular carbon target — 100% of the 10Mton/yr goal — and the only version that gets there by design rather than by accumulation. Where Version 1 offers a meaningful first step and Version 2 a significant contribution, neither reaches strategic autonomy. Version 3 does: sufficient local conversion capacity to secure the region's long-term industrial position, reduce dependency on fossil imports, and anchor the ARRRA connection.

Version 3 achieves industrial continuity. The phased, master-plan-driven approach ensures the HIC remains a functioning industrial cluster throughout the transition. Continuous industrial presence is the necessary precondition for strategic autonomy — and the key difference between a managed transition and unmanaged decline.

The path is long and the hurdles are real — space, alignment, capital and time all demand sustained commitment. But the perspective to act is clear: a system that grows continuously toward a defined goal, without the discontinuity risks that make Version 2 structurally fragile. Every step forward is a step that holds..

Version 3 – Asset process archetype

Figure 15: Asset process archetypes of Version 3, showing the multi-site, feed and product characteristics and the infrastructure as key connector.

Both feedstocks, multiple sources and pre-processing sites

Which technologies? Multiple technologies needed.

How to implement a central syngas infrastructure?

Which product? Which technologies?

Feedstock

Biomass

Biomass

Biomass

Biomass

Waste

Waste

Site 1

Gasifying agent

H_2

Feedstock Pre-treatment

Gasification

Purification & Conditioning

Site 2

Gasifying agent

H_2

Feedstock Pre-treatment

Gasification

Purification & Conditioning

Site 3

Gasifying agent

H_2

Feedstock Pre-treatment

Gasification

Purification & Conditioning

Syngas

Site 4

H_2

Syngas Upgrading

Methanol Synthesis

Separation

Methanol

Site 5

H_2

Syngas Upgrading

Methanol Synthesis

Separation

Methanol, MTO, MTF

Site 6

H_2

Syngas Conditioning

Fischer Tropsch

Processing & Separation

Naphtha

Jet fuel

Diesel / Petrol

Version 3 – Characteristics & Screening

Implementation

Version 3 involves the installation of a connected, gradually expanding set of facilities, ultimately converting 10Mton C/yr. Such an orchestrated set-up of an industrial ecosystem for circular carbon has not been seen yet.

Target capacity	*10Mton C/yr (or smaller)*
Replicability in HIC	*No replication. Phased development.*
Feedstock	*(Mainly) Biomass*
Process & Product	*All relevant products, using most multiple plants and processes (Methanol to X, FT)*
Implementation	*Full HIC conversion plus new plants and area. Needs access to huge scale hydrogen.*
Integration	*Fully integrated, new ecosystem with synergies between plants, pipe connections*
Space, Time	*1,000-2,000ha depending on what process steps to include locally or import. 10-30 years, phased development*
Costs, finance	*50-100bln€ order of magnitude, excluding costs of hydrogen*

Screening

This Version fulfills the requirements of a circular carbon industry (100% of HIC syngas target of 10Mton C/yr). It could provide a value solution for all available waste, in one or more of the plant locations.

	Impact of	*HIC only*	*HIC + V2 plants*
ETS1 CO2 emissions (2030)		*Late*	*Relevant*
Circular Production (2040)		*High*	*Very high*
Domestic Chemicals (2040)		*Most*	*All*
Investment (2025-2040)		*High*	*High*
Strategic autonomy		*High*	*Very High*
		depends on biomass / H_2 sources	

Additional value, pros and cons:

Perspective to Act (perceived)	*Hard*	*Hard*
Effective as temporary step	*N/A*	*N/A*

TEKENKAMER VAN DE INDUSTRIE

Versions in the Netherlands landscape (1)

The NL landscape

The Netherlands has five major industrial clusters, with Rotterdam the largest and most logistically centralized. Waste collection and incineration are distributed across the country, with no single focal area for biomass. All clusters have port access, which can support feedstock import and product export. That geography shapes where each version can emerge. In figure 16 on the next slide this emerging pattern is shown.

Version 1

Version 1 plants follow opportunity — and opportunity concentrates first in and around the industrial clusters where feedstock, logistics and offtake are closest. Once the best co-location spots are taken, later plants disperse to where waste is available: regional waste processors, biomass hubs, smaller ports. Each plant stands alone, without dependency on shared infrastructure. The creaming effect is real — the further from a cluster, the harder the project.

Version 2

Version 2 is large — 1Mton C/yr requires refinery-scale space, coordinated hydrogen supply and direct access to off-takers. That points exclusively to the major industrial clusters. Rotterdam/Moerdijk may accommodate two or three plants, given its scale and logistics. Zeeland, Groningen and Chemelot each have capacity for one, where conditions allow — Furec is already developing in this direction at Chemelot. Beyond these locations, Version 2 scale is unlikely to materialize in the Netherlands.

Version 3

Version 3 is Rotterdam. The logistical concentration, port scale and existing industrial base make it the only viable location for a full ecosystem at 10Mton C/yr. This is not a project — it is a national commitment, decades in the making, transforming the HIC into Europe's circular carbon hub.

Polarized versions vs reality

In practice, development does not start from a strategic choice between versions — it starts with projects. Version 1 scale initiatives are already being tried by companies and developers who see an opportunity. That is how it always begins. But reaching true scale requires a fundamentally different mode: top-down coordination, national commitment, and the willingness to think beyond individual projects.

Version 2 may appear to be the pragmatic middle ground, but it carries the logic of status-quo market thinking — large projects, driven by asset owners, competing for the same space, feedstock and hydrogen. That fragility grows with each iteration. Version 3 demands something more unconventional: a high degree of centralized coordination and a government willing to act as architect of an entirely new industrial ecosystem, not just a facilitator of individual investments.

Do we dare to make that choice?

Versions in the Netherlands landscape (2)

Figure 16: Indication of size and distribution of Versions 1, 2 and 3 in The Netherlands. Note that Version 1 type facilities can still be applied in addition with Version 2, and Version 1 and 2 with Version 3.

Version 1

Characteristics

Unit size
- 50 to 100 kton/yr carbon
- *125 to 250 kton/yr syngas*

Reasonable number of units
- 5 to 10 in HIC
- 10 to 20 in NL

Resulting: 0.5-1.5 Mton/yr carbon

Version 2

Characteristics

Unit size
- 0.5 to 1 Mton/yr carbon
- *1.25 to 2.5 Mton/yr syngas*

Reasonable number of units
- 1 to 4 in HIC
- 2 to 6 in NL

Resulting: 2-5 Mton/yr carbon

Version 3

Characteristics

Unit size
- Up to 10 Mton/yr carbon
- *Up to 25 Mton/yr syngas*

Reasonable number of units
- 1 in HIC
- 1 in HIC plus few Version 2 in NL

Resulting: 10 Mton/yr carbon

Hydrogen (1)

The hydrogen choice

For gasification of circular carbon, external hydrogen supply is the preferred route. Generating hydrogen internally from syngas shifting is possible, but it halves the effective carbon output and generates a CO_2 stream requiring capture or emission. Where circular carbon performance is the goal, external supply is the better answer.

Hydrogen costs and scoping

In this deliverable we focus on circular carbon; which feedstock, which processes, which locations. Utilities including hydrogen are considered as technically feasible, require relatively little space and are assumed to have their own funding, so for the circular carbon, their costs were not included (only as OPEX). However, the gasification of 1Mton of circular carbon from waste or biomass, some 250kton of hydrogen is required, and producing this is a substantial task, while importing this is a challenge of its own.

External supply options

- **Green hydrogen** from electrolyzers, creating H_2 and O_2 from water, powered by sustainable power, is an important part of the possible value chain. Current initiatives for green hydrogen in Rotterdam are Holland Hydrogen 1 and ELYgator, both 200MW capacity. CAPEX per plant is >500mln€, and they have been enabled with active support and subsidies. 200MW produces 23kton of H_2, which is already required for ~100kton of circular carbon from waste or biomass gasification.
- **Blue hydrogen** from natural gas (methane), also including CCS to reduce environmental impact. In this case, natural gas is still used, but CO_2 from it is not emitted to the atmosphere. The value of syngas production with blue hydrogen should be compared with direct natural gas use in a Fischer-Tropsch plant combined with CCS.
- Hydrogen from **industrial waste streams**. The H-Vision project aims to produce hydrogen form refinery gases combined with CCS storage of CO2, to use in firing furnaces in refineries. This route can supply hydrogen for syngas routes as well, or over time can transition into an additional syngas generation hub.
- **Import** of green or blue hydrogen from other countries, or indirectly as ammonia with ammonia cracking installed.

Different solutions may be applied over time. Imported and locally produced hydrogen may be balanced as needed.

The grid as precondition

Ideally, a local hydrogen grid is connected to a national grid and storage facilities, to absorb fluctuations from hydrogen produced through offshore wind and support balancing with imported hydrogen volumes. A hydrogen network is likely required for all versions, as it seems illogical to distribute green hydrogen generation across all locations. This means a certain level of infrastructure organization and HIC planning is needed.

Hydrogen (2)

Scale and infrastructure

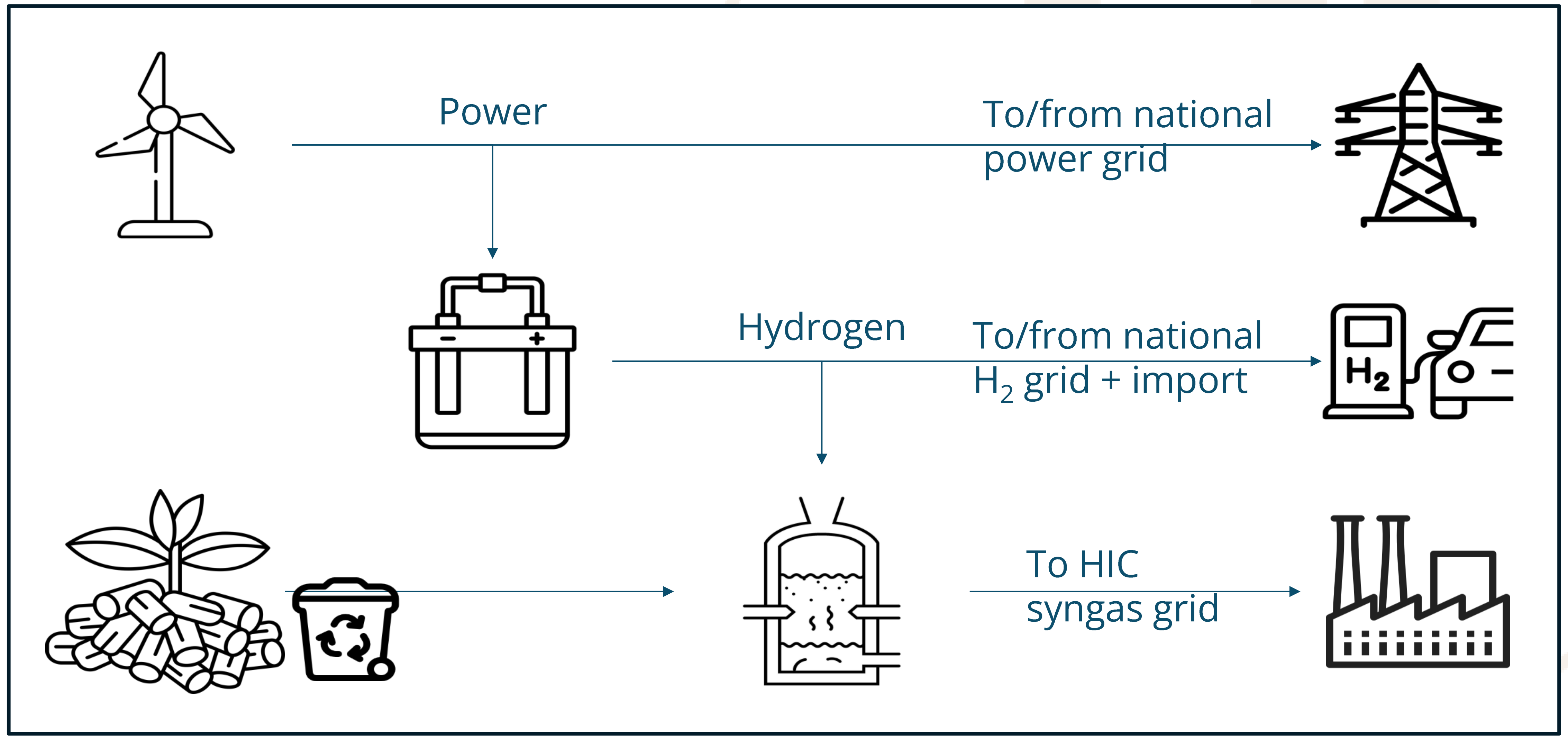
The hydrogen generation and supply also has an impact on the overall ecosystem layout and infrastructure. The system is schematically drawn in figure 17. Electrolyzers could be installed centralized (e.g. with HH1 and ELYgator), or de-centralized, possibly co-locating with the gasification plants. Assuming some centralization or import, this also requires a hydrogen network in the HIC, likely connected to the national grid. Such a grid can also help overcome (local) storage needs, e.g. to cater for low-wind periods during which no green hydrogen is generated.

A hydrogen network is likely required for all versions, as it seems illogical to distribute green hydrogen generation across all locations, requiring power grid connections instead. The larger the version and end goal, the larger the hydrogen needs, and the related wind energy needs, if green hydrogen is pursued. This means once more that a certain level of infrastructure organization and HIC planning is needed. In Version 3, it is assumed that a large-scale hydrogen generation area is applied.

Conversion factors to support circular carbon from gasification:
1Mton/yr Carbon 🡐 250kton/yr H_2 🡐 2.2GW electrolyzers 🡐 140-200 offshore wind turbines

A fully green hydrogen fed Version 3 with 10Mton/yr circular carbon capacity would need 22GW of hydrogen capacity, similar to ~10x the NEOM initiative in Saudi Arabia. It would require ~500ha for the hydrogen generation, and 1400-2000 offshore wind turbines.

Figure 17: Simplified schematic of power and hydrogen requirements to enable circular and sustainable carbon.



Colophon

Title	Syngas value chain in Rotterdam HIC Deliverable 2: Syngas Staircase
Publication date	March 2026
Authors	Tjerk Hassing, Andreas ten Cate (TvdI)
Assignment	This document is a deliverable of the project "Ontwikkeling Synthesegasketen HIC", assigned by Provincie Zuid Holland, registered under number PNR20085654. The project is carried out by Tekenkamer van de Industrie and Sproule ERCE. The project ran from October 2025 to February 2026.
Cover image	Generated using OpenAI ChatGPT (DALL·E)
Copyright	© Provincie Zuid-Holland
Published by	Tekenkamer van de Industrie (TvdI) on behalf of the Province of South Holland.
E-mail	info@industrys-drawing-room.com
Website	tekenkamer-industrie.nl // industrys-drawing-room.com
Suggested citation	Hassing, T. & Ten Cate, A. (2026). *Syngas value chain in Rotterdam HIC – Deliverable 2: Syngas Staircase.* Tekenkamer van de Industrie / Sproule ERCE, commissioned by Provincie Zuid-Holland. Available at: industrys-drawing-room.com/syngas-rotterdam

TEKENKAMER VAN DE INDUSTRIE