Circular carbon for the Dutch chemical and fuel sectors

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Summary report

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CIRCULAR CARBON FOR THE DUTCH CHEMICAL AND FUEL SECTORS

Summary report

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Preface

The Netherlands has a world-class fuel sector, concentrated in the Harbour Industrial Cluster (HIC) Rotterdam. It also has a chemical sector in which many companies are closely linked to the fuel sector. Both the Dutch government and Europe recognise the importance of the industry and are committed to 'green growth'. The chemical and fuel sectors face a substantial challenge: they need to become climate neutral and circular. The European Union aims to be climate neutral by 2050, and the Netherlands has set itself the same target.

The chemical and fuel sectors therefore need to work with partners in the chain to replace fossil raw materials with circular ones. How big is this task and how do we get there? A number of exploratory studies have sought to answer these questions. A new approach is to take the visions of the chemical and fuel sectors themselves as a starting point and then develop a comprehensive vision from a systems perspective. The systems perspective not only includes the production chains for chemicals and fuels, but also the adjacent chains for raw materials and energy supply. To do this, SmartPort set up a research project under the title 'Circular carbon for the Dutch chemical and fuel sectors'. In this project, the consortium commissioned TNO to investigate, based on the visions of the industry itself, the chemical and fuel sectors' future need for circular raw materials and how the production of fuels and chemicals from circular raw materials and renewable energy fits into the energy system. TNO also worked with the project partners and with companies from both sectors to develop a vision and roadmap for producing fuels and chemicals based on circular carbon derived from bio-based raw materials, waste, and captured CO_2. In doing so, opportunities for synergy have been identified between the chemical and fuel sectors. TNO, together with the consortium partners, explored how the Port of Rotterdam Authority and the City of Rotterdam can facilitate this transition, as well as the joint regulatory and policy needs at EU and national level. The vision and roadmap were developed with the help of workshops with partners and industry representatives.

This summary project report sets out a comprehensive vision from a systems perspective. This vision does not represent the individual views of individual project partners, companies, or TNO. Recommendations are merely options and intended as a starting point for further discussion between sectors and between industry and the government.

Alongside this summary project report, TNO has published a background report (Dutch) describing the research findings.

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Introduction and research questions

The chemical and fuel sectors face a major challenge: transitioning to a climate-neutral and circular economy

The Netherlands has a world-class fuel sector, concentrated in the Harbour Industrial Cluster (HIC) Rotterdam. It also has a chemical sector that is the third largest in Europe in terms of size. Companies in the chemicals sector are mainly spread across six industrial clusters. A large proportion of the raw materials in chemicals come from the refining sector.

Both the Dutch government [1] [2] and Europe [3] recognise the important role and contribution of sustainable primary industry and are committed to 'green growth'. The chemical and fuel sectors therefore face a substantial challenge: they need to become climate neutral and circular. In response to the Paris targets, the European Union and the Netherlands have set themselves the goal of becoming climate neutral by 2050. On top of this, the Dutch climate agreement and accompanying additional measures challenge industry to realise a 67% CO_2 emission reduction by 2030 compared to 1990. The Dutch government is also committed to a fully circular economy by 2050. In addition to reducing emissions, the chemical and fuel sectors therefore also need to improve circularity.

Carbon remains essential for the production of chemicals and bunker fuels for aviation and marine shipping

Carbon will continue to play an important role in the chemical and fuel sectors, both as a raw material and as an energy source. The everyday products we use are largely based on materials that contain carbon: from the foam in the mattress we sleep on, to the plastic packaging of our food. Chemistry provides the necessary building blocks. Many industrial processes currently powered by fossil fuels can be electrified. Renewable sources such as solar and wind energy can also be used to produce the electricity needed, instead of using fossil sources like natural gas and coal.

The mobility sector is the largest consumer of fossil fuels. Road traffic can to a great extent be electrified through the use of battery-powered electric vehicles. In inland shipping, electric vessels powered by battery and, for longer distances, hydrogen, can play a major role. By contrast, for aviation and marine shipping, the potential for battery-based and hydrogen-base propulsion is limited. Carbon-based fuels will still be needed in these areas for a long time, at least until 2050: the focus period of this study [4].

This means that the chemical and fuel sectors must undergo a raw materials transition from fossil to circular

Using fossil raw materials involves extracting hydrocarbons from underground in the form of oil, natural gas, and coal. Combustion, either to release energy or at the end of the useful life of products, releases carbon into the atmosphere in the form of CO_2. To reduce these CO_2 emissions, it is important to focus on:

- *Reducing demand* for fuels and materials by changing consumption behaviour ('demand reduction').

- *Reducing the use of raw materials that contain carbon* by increasing the energy and resource efficiency of production processes and using fuels and chemicals more efficiently, for example through smarter circular design of products or by using more efficient engines ('carbon efficiency').
- Avoiding carbon-based *products*, for example by using green hydrogen for inland shipping instead of carbon-based fuels ('decarbonisation').
- *Substituting fossil carbon with circular carbon sources*: using carbon from bio-based raw materials and waste (including recycled plastic waste via mechanical and chemical recycling), and using captured CO_2 to meet the remaining demand for carbon ('recarbonisation').

This project looked at the overlapping needs of the chemical and fuel sectors for this carbon transition and the synergies that can be achieved in the transition

This study focused on the overlapping needs of the chemical and fuel sectors for the transition *from fossil to circular carbon as a raw material*. The aim was to use their existing, separate visions to develop a more comprehensive systems vision that reflects the quantified needs of the entire chemical and fuel sector supply chain. This systems vision addresses not only the need for raw materials, but also the need for energy. A deliberate decision was made to develop this vision together with parties from both chains, represented by the project partners VNCI, VEMOBIN, Port of Rotterdam Authority, the City of Rotterdam, Deltalinqs, Fieldlab Industrial Electrification (FLIE) and SmartPort, as well as companies from the chemical and fuel industries. TNO conducted the study, involving industry partners and companies through seven workshops and a number of working sessions. TNO also carried out desk research, analysing existing sector visions and third-party future scenarios, and performing quantitative research based on system models. It then worked with partners and the industry to translate the results into consequences for different parties in both chains.

The research questions for this project were as follows:

How can the chemical and fuel sectors work together towards a sustainable future, where synergies are exploited to maximum effect and they jointly access scarce resources for circular carbon?

What can the Port of Rotterdam Authority and the City of Rotterdam do to facilitate this transition? And how can central government and provinces implement EU policies in the Netherlands to promote the transition?

The underlying principles were:
- The study focuses on the period 2030-2050.
- The starting point is the EU and the Netherlands' goal of net zero emissions by 2050.
- This study centres around the raw materials transition (reducing scope 3 emissions through substitution).
- However, the frame of reference is a systems approach that paves the way for net zero in 2050, which includes scope 1 and 2 emissions.
- The study takes into account the goal of a circular economy by 2050, but does not impose this as a requirement in the modelling.

This summary report describes the key findings from the project results. For a detailed analysis, see the background report to this study [5].

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Starting point and opportunities for synergy

Thanks to their strategic location, infrastructure and knowledge position, the Dutch chemical and fuel sectors are well positioned to realise their ambitions

Its conveniently located seaports mean that the Netherlands plays an important role in Northwestern Europe in importing raw materials such as crude oil, oil products, and fuels. This has enabled a large refining cluster to develop in the Netherlands that carries out primary processing of crude oil into various fractions. As a result, the Netherlands not only produces fuel on a large scale but also a wide supply of raw materials for further processing into functional chemicals and materials. Excellent hard and soft infrastructure has led to an extensive, interconnected chemical super-cluster spread across the Netherlands, Flanders, and Western Germany (the ARRRA cluster). In addition to production activities in the Netherlands, major trade flows have developed for fuels, olefins, methanol, and aromatics to the hinterland. A significant proportion of fuels and chemicals produced in the Netherlands is exported [5]. These products are also re-exported.

The ARRRA cluster is working hard on developing projects to make the cluster more sustainable by preparing infrastructure for CO_2 and hydrogen, capacity extensions of the electricity grid, and biofuel production. This development utilises the Netherlands' strong knowledge of sustainability.

Thanks to their strategic location, which facilitates import and transit, the ability to reuse much of the existing infrastructure for renewable fuels and chemicals, and the Netherlands' knowledge position, the Dutch chemical and fuel sectors are well placed to embark on the transition to circular carbon.

The Dutch industry can be transformed into a climate-neutral and circular sector in line with climate legislation by exploiting synergies between the chemical and fuel sectors

As described above, the chemical and fuel sectors within the ARRRA cluster are closely interlinked. The refining sector currently produces a wide range of petroleum products, from which the chemical industry then converts the naphtha fraction into various products such as plastics.

The transition to climate neutrality and circularity will further integrate the fuel and chemical production chains (see Figure 1). Both sectors have expressed a desire to use the same circular carbon sources: biomass, waste and captured CO_2 (initially from point sources; later potentially via Direct Air Capture [DAC]). From these, platform molecules such as ethanol, pyrolysis oil, and methanol are produced. These platform molecules can be converted to fuels such as SAF (Sustainable Aviation Fuels), or to basic chemicals such as ethylene, which then serve as raw material for manufacturing products like plastics. Some of these platform molecules can also be used directly as fuel (ethanol and methanol), creating an overlap in fuels and chemicals, and the potential to use platform molecules for these products.

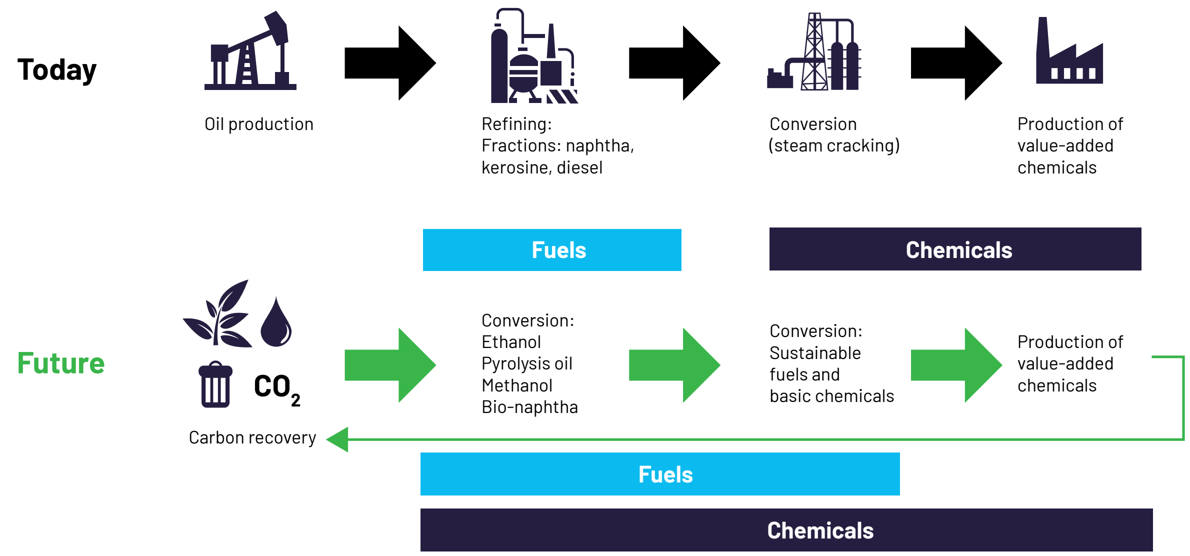

Figure 1. The chemical and fuel sectors are currently linked, particularly through the chemical sector's purchase of naphtha from refineries. In the future, the two sectors will become more integrated and overlap in some areas.

Figure 2 shows the expected development over time for the production processes of renewable fuels and chemicals. A logical sequence emerges for the use of circular carbon: sugars and lipids (fats), plastic waste, lignocellulose, and then CO_2. We first look at raw materials that are relatively simple to convert into products, followed by combinations of raw materials and conversions that require more energy and present more of a challenge.

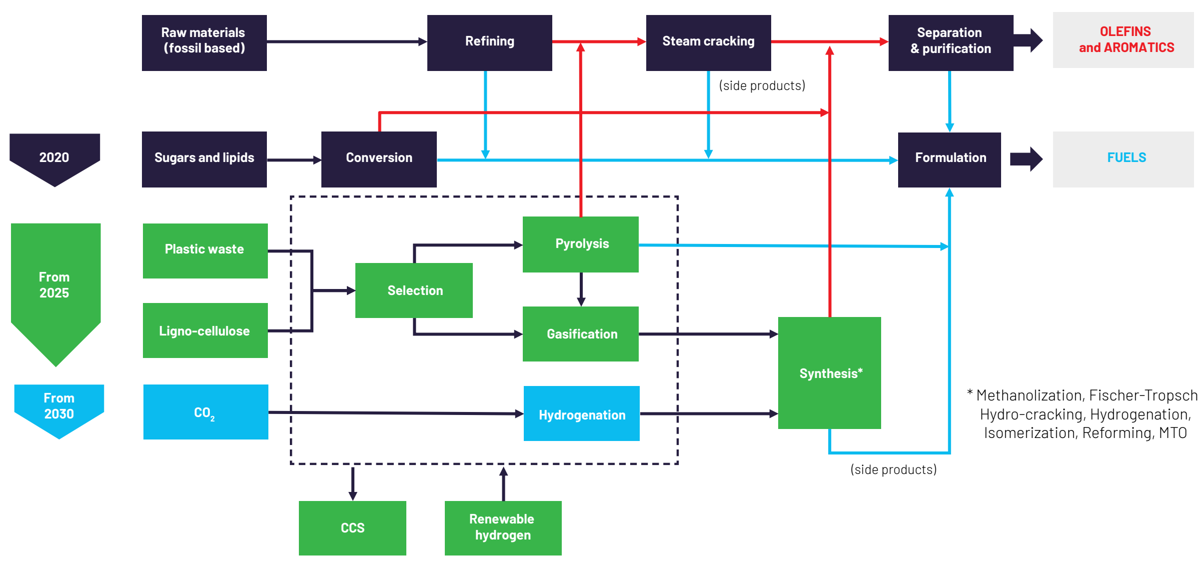

Figure 2. Processes for producing renewable fuels and chemicals and their expected development in the transition.

At present, the fossil raw materials mainly used are refined and generate naphtha for steam cracking processes to produce olefins and aromatics. Fuels and chemicals are also made from sugars and lipids. These sugars and lipids can be converted into fuels and chemicals without a large amount of external energy and with high carbon efficiency, making them attractive raw materials.

Renewable fuels and chemicals are also produced from waste and lignocellulose (biomass from plant fibres, for example woody biomass), but currently on a very limited scale. It is typically less carbon efficient and takes more energy to convert these raw materials into products than compared to coverting sugars and lipids, because gasification involves burning part of the raw material. Both sectors anticipate using technologies such as gasification and pyrolysis to harness bio-based raw materials and recycled waste streams to produce renewable fuels and chemicals. In the slightly longer term, captured CO_2 can also be used to produce fuels and chemicals. Although CO_2 conversion is highly carbon efficient, more energy and much more hydrogen is needed than in lignocellulose-based routes. Obligations relating to the use of RFNBOs (Renewable Fuels of Non-Biological origin) will apply from 2030, which will encourage their production.

There are opportunities to exploit potential synergies between the chemical and fuel sectors and join forces, particularly in the production chains based on sugars, lipids, lignocellulose, waste, and CO_2. Production chains mainly offer potential for the joint sourcing of raw material flows and joint plants to access the new raw materials, such as pyrolysis and gasification plants, achieving economies of scale. Chapter 4 takes a closer look at how opportunities for synergies can be exploited.

A sustainable chemical and fuel industry is compatible with the Dutch energy system and climate ambitions

The transition to producing fuels and chemicals from circular raw materials and renewable energy will have consequences throughout the value chain, including energy supply, imports and exports, and must meet national, European, and global framework conditions. In previous decades, system models have been developed that match and optimise energy and raw material supply and demand to minimise system costs. One example is the OPERA model. This study used the results of the ADAPT and TRANSFORM future scenarios calculated in OPERA (see box).

TNO's 2024 scenario study [6] develops and calculates two scenarios using the OPERA energy system model. The OPERA model is a bottom-up optimisation model for the Netherlands' energy system. The scenarios are based on two future scenarios for the Netherlands for the period 2030-2050: ADAPT and TRANSFORM. In both future scenarios, greenhouse gas emissions fall and climate targets are met. However, this is achieved in different ways. ADAPT is only partially circular, while TRANSFORM is an almost fully circular scenario for 2050. The key assumptions for ADAPT and TRANSFORM are summarised in Table 1. The percentages mentioned are minimum requirements, which serve as inputs for the scenarios. A more detailed overview of the future scenarios and scenario parameters can be found in the background report [5] (Work Package 2AB, Appendix C) and in [6].

Table 1. Key assumptions for the ADAPT and TRANSFORM future scenarios

Key targets for refining and chemicals	ADAPT			TRANSFORM		
	2030	2040	2050	2030	2040	2050
National emission reduction targets	55%	80%	100%	55%	80%	100%
International aviation emission reduction target	-	30%	50%	-	53%	100%
International marine shipping emission reduction target	-	45%	50%	-	70%	100%
Share of circular carbon for chemicals production	0%	0%	0%	0%	40%	80%

The system analyses carried out with computer models show that the Dutch carbon industry needs to focus on plastic recycling, CO2 storage, biofuels, and renewable electricity to help achieve the Netherlands' climate ambitions.

Figure 3 shows the flows (consisting of raw materials, fuels, and chemicals) of the ADAPT and TRANSFORM scenarios in 2050. ADAPT assumes a growing demand for chemicals, including exports. TRANSFORM assumes a 40% lower demand for chemicals than ADAPT. For fuels, ADAPT and TRANSFORM are based on the need for mobility in the Netherlands (including bunker fuels for international aviation and marine shipping). The modelling of fuel demand does not include production of fuels for export, as it is difficult to estimate volumes for 2050 at present. However, this does not mean that there will be no fuel exports in 2050.

Refineries supply the chemical sector with a limited amount of fossil naphtha by 2050. The naphtha production process simultaneously produces fossil fuels as a 'by-product'. These are largely exported in both ADAPT and TRANSFORM. This explains the small amount of fossil fuel exports shown in Figure 3, despite excluding exports in the fuel demand modelling.

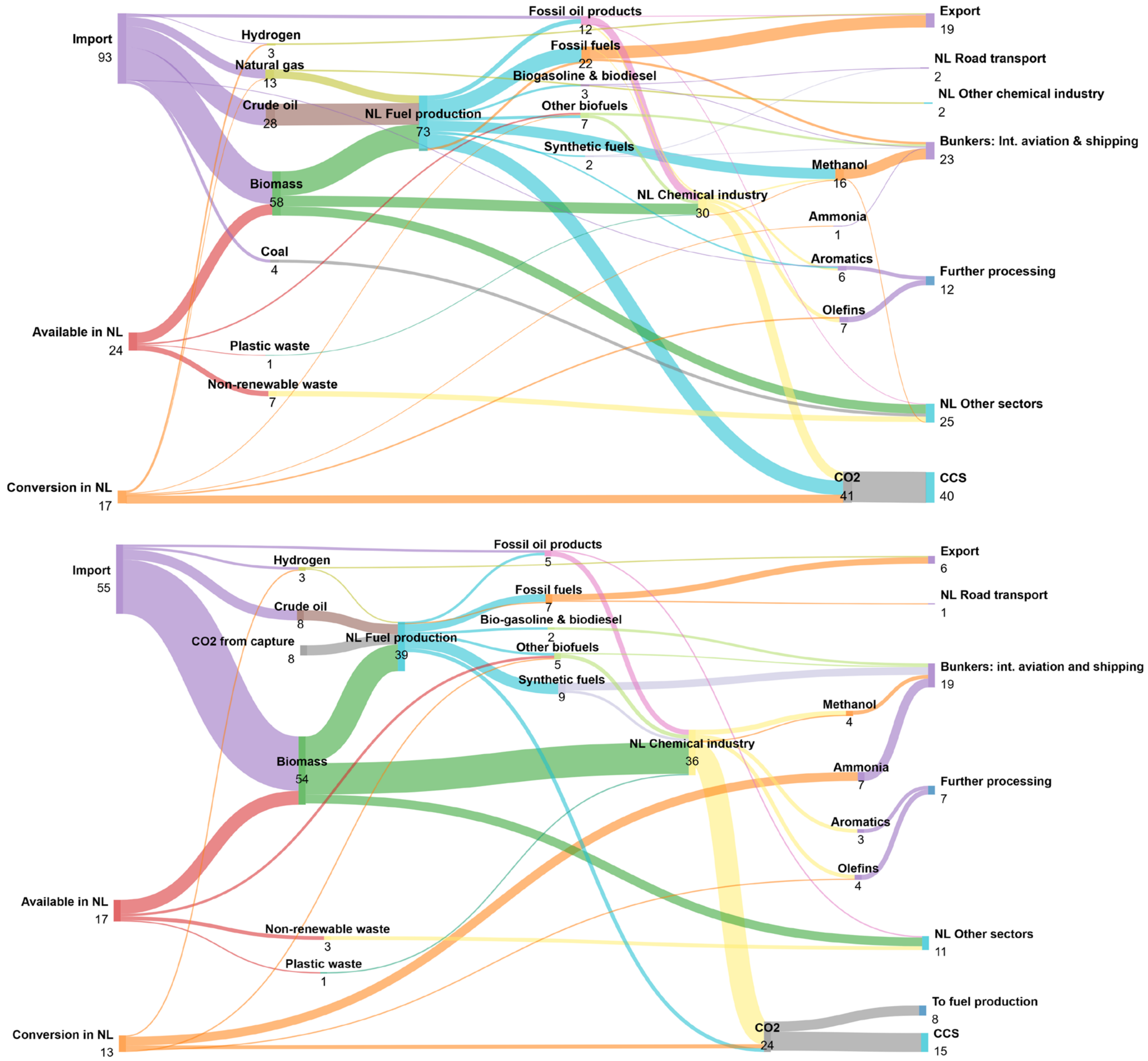

Figure 3. Sankey diagram of the ADAPT (top) and TRANSFORM (bottom) scenarios in 2050, in millions of tonnes of material. This does not include fuel demand for exports.

In the period up to 2050, demand for bio-based raw materials, recycled plastics and renewable electricity will rise sharply in all sectors to meet energy and product demand under the preconditions of emission reduction and circularity targets. However, availability of these sources is limited both within the Netherlands and abroad. It is therefore important to focus on both reducing the demand for carbon-based products and making more circular carbon sources available to the Netherlands. If supply does not increase in time, growing scarcity of circular carbon will make meeting climate and circularity targets more expensive or impossible. It will be in the strategic interest of the chemical and fuel sectors in the Netherlands to set up import chains for bio-based raw materials and recycled plastics. Bio-based raw materials in particular will account for a large proportion of carbon flows in 2050 (see Figure 4).

In the ADAPT and TRANSFORM scenarios, fossil raw materials are still part of the Dutch energy system in 2050, but significantly less so than today (see Figure 4). The modelling shows that it is more cost-effective to continue using fossil naphtha and fuels to a limited extent compared to a completely fossil-free scenario. To still meet the 2050 net zero target, released CO_2 is captured and stored in empty gas fields under the North Sea (CCS/BECCS).

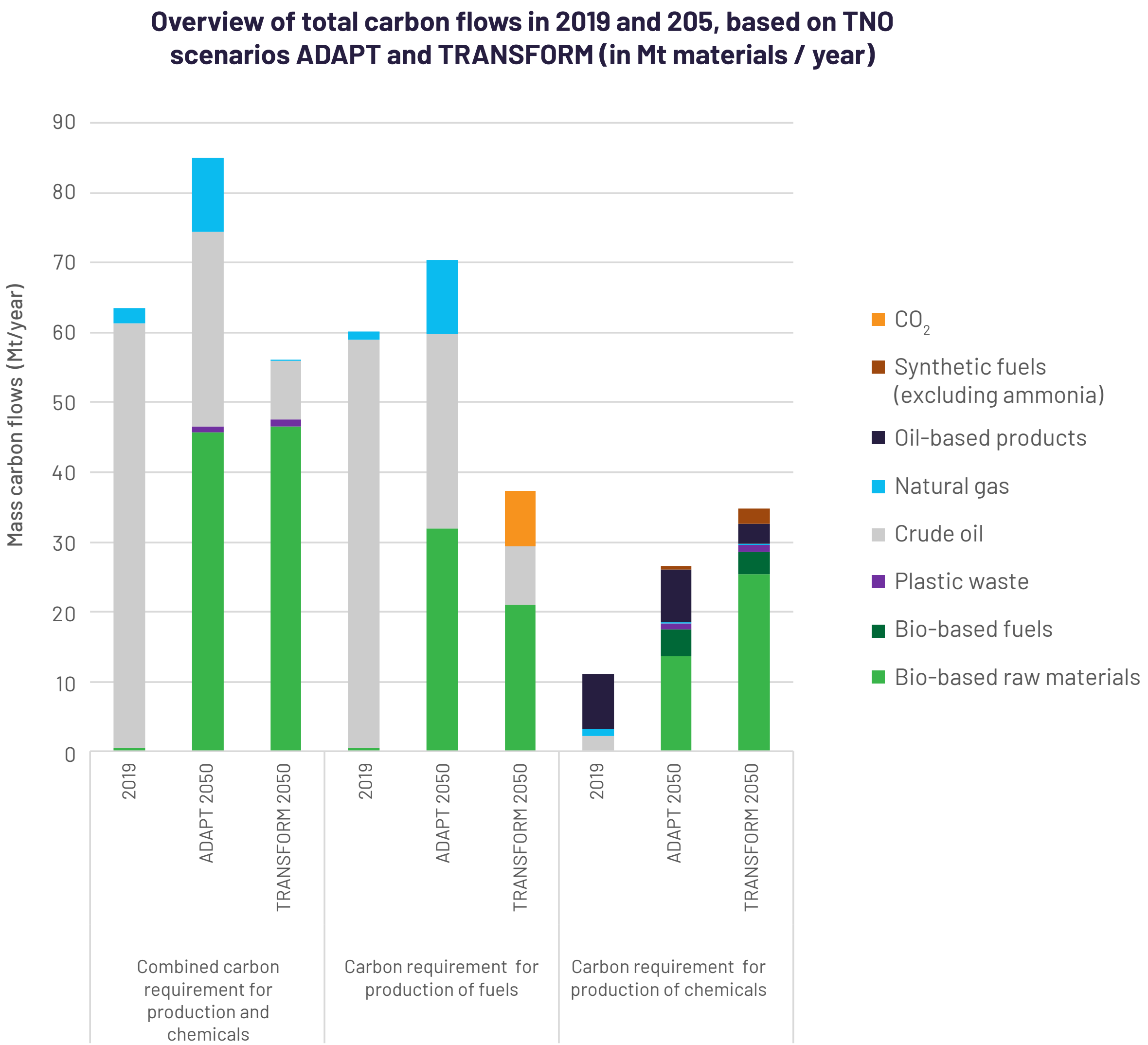

Figure 4. Carbon required to produce fuels and chemicals in 2019 and 2050 according to TNO's ADAPT and TRANSFORM scenarios. The chemical industry uses petroleum products, biofuels and synthetic fuels from fuel production. These flows are excluded from the joint demand to avoid double counting.

Hydrogen production from electrolysis needs to be scaled up to produce renewable fuels and chemicals. The corresponding demand for renewable electricity will take up a significant amount of the total available capacity in the Netherlands. Hydrogen production will account for around 30% of total electricity consumption in 2050 in both scenarios. Both TNO scenarios therefore anticipate a significant import flow of hydrogen (141 petajoules in ADAPT and 236 petajoules in TRANSFORM in 2050).

The Port of Rotterdam can play a key role as circular carbon hub

The Port of Rotterdam has potential to transform from a fossil carbon hub into a circular carbon hub. Instead of crude oil, biomass and waste will then be imported, or pre-processed products or raw materials derived from them (ADAPT and TRANSFORM do not include import of plastic waste and intermediates like pyrolysis oil, but this is an option to consider). Renewable fuels and chemicals will also be produced and further processed in the port area. The port is favourably positioned for this, with opportunities for electricity landfall from offshore wind energy, CO_2 storage using Porthos and Aramis, opportunities for local production and import of green hydrogen, infrastructure for transport and storage of circular carbon and products based on circular carbon, and a potential market for the purchase of renewable fuels.

Primary and secondary raw materials, intermediates, and products can be imported for production processes based on bio-based raw materials, plastic waste or CO_2 (e-molecules). Table 2 shows the main candidates for import for each category. A number of commodities can be used as intermediate and fuel (e.g. methanol).

Table 2. Overview of main candidates for import by category.

	Raw materials	Intermediates	Products
Bio-based	Sugar Lipids Crude and refined biomass Biomass fractions	Bio-pyrolysis oil Bio-char Bio-naphtha Bio-ethanol Bio-gas / Green gas FAME	HVO/HEFA Bio-diesel Bio-kerosene Bio-ethanol Bio-methanol Bio-LNG
Plastics (fossil and bio-based)	Unsorted waste streams Sorted waste streams	Plastics pyrolysis oil Plastics char Functional chemicals from plastic waste	Polyolefins Polyesters
E-based	CO_2 from point sources CO_2 from DAC	E-methanol E-FT liquids	E-diesel E-kerosene E-methanol E-DME
Non-carbon		H_2 NH_3	H_2 NH_3

The integration with the ARRRA cluster means that Belgium and Germany are already important markets. The German and Belgian chemical and fuel sectors will also need to transition to sustainable chemical and fuel production to meet climate targets. The HIC Rotterdam may therefore continue to play an important role in supplying circular raw materials, intermediates, and products to these countries. System studies for Germany and Belgium suggest that imports of hydrogen and carbon-based e-molecules are particularly relevant for these countries, which seem to have a limited need for transit of bio-based raw materials [5]. In the future, if the HIC Rotterdam supplies circular carbon flows not only to the companies in ARRRA but to the entire European market, the necessary value chains can be developed faster and on a larger scale, reducing costs.

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Uncertainties, barriers and solutions

There is currently still a lot of uncertainty about which circular carbon-based value chains will be built in Europe, the Netherlands, and the HIC Rotterdam

Although the Dutch chemical and fuel cluster is starting from a strong position and there are opportunities to make the cluster climate-neutral and circular, there is still a long way to go to make the transition. Both chemical and fuel sectors operate in global markets and are therefore affected by international developments. This gives rise to uncertainty and is currently putting considerable pressure on the competitiveness of the Dutch and European chemical and fuel sectors, in line with Mario Draghi's conclusions in his report 'The future of European competitiveness' [3]. The chemical and fuel sectors also depend on uncertain factors, such as trends in market demand in the Netherlands and abroad, location-specific factors such as timely availability of infrastructure facilities, speed of technology development, first-of-a-kind initiatives and opportunities to scale up, as well as policy, regulation, and public perception. In addition, political decisions in favour of more sustainable fuels and chemicals in our neighbouring countries (for example commitment to electrification of transport or construction of hydrogen infrastructure) can have a substantial impact on the Dutch industry clusters and their composition. For now, these uncertainties mean that public and private investors are reluctant to invest on a truly large scale.

The chemical and fuel sectors need a clear policy vision at European and national level

Both the chemical and fuel sectors say they lack a clear future vision from the government for their industry, at both national and European level. In the above report [3], Draghi concluded that EU industrial policy is essential for a healthy European circular industry. This raises the following questions: what role will Dutch chemical and fuel production play in the future? Do we want to maintain our current position in the integrated ARRRA cluster, and in what form (focused on the production of intermediates and/or final products)? How important is strategic autonomy in relation to raw materials and products in the Netherlands? A clear policy vision for European and Dutch industry is therefore needed to create long-term certainty.

This policy vision must also be realistically translated to the Dutch situation so that it can be achieved. Companies state they feel that the Dutch government is not currently doing enough to facilitate the implementation of circular carbon-based production processes. As a result, sustainability initiatives sometimes move to other countries inside or outside the EU.

According to the industry, the priorities should be to create market demand, speed up the licensing process, and attract biomass flows

For a successful transition to renewable fuels and chemicals, several barriers need to be eliminated. A number of workshops with industry partners and companies revealed that there are many barriers. Figure 5 provides an overview of the main barriers, focusing on barriers and solutions that can be influenced or addressed within the Netherlands or within and with Europe.

Economic feasibility

- **Insufficient market development: demand for sustainable fuels and chemicals is limited and willingness to pay is often too low.**
- Production costs for renewable fuels and chemicals are higher than fossil. The combination of high costs and low demand does not make for a viable business case.
- A policy vision for the European industry, with corresponding Dutch policies to facilitate realization of the vision, is essential but still lacking.

Infrastructure and novel production chains

- **Long turnaround times to obtain licences to set up new production chains (e.g. recycling plants).**
- Electricity grid: insufficient capacity, long leadtime for expansions.
- Necessary infrastructure for renewable carbon only partly in place to a sufficient extent.
- Available space for new infrastructure and production chains is limited.

Security of supply

- Shortage of affordable and always available electricity from renewable sources.
- **There is a high uncertainty regarding the future availability of alternative carbon sources for sustainable fuels and chemicals.**

Technology

- Not all required technologies are market ready (e.g. CCU, DAC, chemical recycling).
- Many technologies cannot yet be sufficiently scaled up.

Figure 5. Barriers to the transition to renewable fuels and chemicals. The blue barriers are those that workshop participants felt should be addressed as a priority.

In one of the workshops, participants selected three barriers that they felt should be addressed as a priority and that were examined in greater detail in this workshop. These barriers are highlighted in the figure and are discussed below. The development in market demand was identified as the top priority, followed by speeding up the licensing process, and attracting biomass flows. The industry also considers it very important to resolve some of the other barriers, such as the availability of affordable renewable electricity and transmission capacity on the power grid.

There is not enough development in market demand: renewable fuels and chemicals are still in limited and uncertain demand and willingness to pay is often too low

Renewable fuels and chemicals cannot compete with the fossil alternative and demand for these products is still heavily dependent on government incentives. Low demand means a slow transition. Government creation of market demand for these products is therefore a top priority for both sectors. The international nature of the markets will necessitate a European-level approach. There is a particular need for incentives to stimulate demand for renewable chemicals. For the transition to renewable fuels, demand is already being stimulated by initiatives such as RED (Renewable Energy Directive) II and III, ReFuelEU Aviation and FuelEU Maritime. However, RED does not currently provide clarity beyond 2030, and it is still uncertain which fuels will eventually be deployed for the maritime sector (for example methanol, ammonia). For the chemical industry, the Netherlands and a number of other countries have issued a 'Joint Statement on a European Sustainable Carbon Policy Package for the Chemical Industry'. This statement calls on the European Commission to formulate new policy, for example to create a market for circular materials. Initiatives are under way at EU level to develop a European product policy to monitor this process.

Since the markets for fuels and chemicals are global, the companies assert that some form of protection is needed, alongside measures such as mandating, to safeguard the industry in the Netherlands and Europe.

The long turnaround time for obtaining licences to set up new production chains is a factor that can substantially delay or even bring the transition to a halt

Companies report that innovative projects often stall due to stringent requirements and compartmentalised environmental targets, such as carbon neutrality, nitrogen targets, and targets for substances of very high concern (SVHCs). Companies also feel that licensing authorities often lack knowledge for first-of-a-kind initiatives, and do not liaise with each other to share new knowledge quickly. There also seems to be little social awareness of the importance of chemistry to society and particularly the sustainable and circular economy. All of this does not inspire confidence among companies and inhibits willingness to work on the transition to a climate-neutral and circular industry. As a result, companies are less willing to invest in the Netherlands, new projects stall, and companies regularly go to other countries within or outside the EU for sustainability initiatives.

Speeding up licensing procedures means that more new production chains can be set up. Ways to speed up this process include:

- Involving environmental services at an early stage in the licence application for new production facilities. There also needs to be at least a level playing field between sustainable economic activity and fossil activity.
- Proactively identifying any laws and regulations that stand in the way of circular developments and restructuring them to encourage measures such as the use of waste streams and new innovative raw materials.
- Sharing knowledge on possible solutions at national level between the different regulatory bodies and a uniform interpretation of these solutions, for example regulations on end-of-waste status.
- Introducing a cross-ministry overall steering function that can identify priorities based on an assessment framework.
- Temporarily creating greater flexibility and leeway in certain regions to allow for innovation and learning from first-of-a-kind initiatives. One way of doing this is with an umbrella permit.
- Starting a dialogue between companies and authorities to raise awareness of the companies' perspective together and look for other potential solutions to speed up licensing procedures.

There is a high level of uncertainty associated with the future availability of alternative carbon sources for fuels and chemicals

Needless to say that carbon needs to be available in order to produce circular carbon-based fuels and chemicals. There are concerns about whether enough circular carbon will be available.

Biofuels are expected to account for the largest share of carbon sources by 2050 (see Figure 4). The future availability of bio-based raw materials is highly uncertain [7] and depends on a large number of factors, such as government policies on a global and local scale, public support, willingness to invest, and the efficiency of biomass conversion and extraction. The background report to this study [5] takes a more detailed look at biomass availability on a global and European scale according to various fair share principles. Dutch biomass potential is not expected to meet demand. We will therefore need to import biomass or intermediates. Companies are already seeing a scarcity of certain types of bio-based raw materials, particularly for the production of 'advanced' biofuels (REDIII, Annex 9A). The companies anticipate that these raw materials will become even more scarce, mainly as a result of growing demand for bio-based raw materials in the chemical industry and increasing sustainability requirements for biomass.

In addition to concerns about scarcity of biomass, there are concerns about sustainability aspects. Producing and using biomass can have major positive and negative consequences for the environment. Biomass production can lead to competition with food production, deforestation, and a negative impact on biodiversity. Burning biomass also releases particulate matter. Biomass now has a negative image in the Netherlands and the EU for the above reasons. Balanced policy is therefore needed for biomass production and use, some of which already exists (including in REDIII, Annex 9A), and the debate on biomass use needs to be based on evidence.

To meet future demand for circular carbon, it is important to develop a national import strategy for circular carbon sources. There is already a market for biofuels and there is also an existing supply chain to Dutch ports for solid biomass. If bio-based raw materials are widely used, including for chemicals, industrial parties can pool their demand for bio-based raw materials to attract more import flows to the Netherlands (within the limits of competition law). These efforts can be reinforced by collaborating with the government at a strategic level (including through diplomacy and encouraging corridors) to establish biomass flows in the Netherlands. This would ensure that enough circular raw materials are available for both sectors, in a similar way to the current approach to hydrogen. Existing logistics and other facilities in Dutch ports can be used to position circular carbon hubs, such as biomass storage in locations where coal is currently stored and transhipped. Imports of raw materials can add more value at Dutch ports than imports of intermediates and products. However, from a cost perspective, it is not always feasible to gain a competitive position. From the perspective of security of supply and strategic autonomy, production in NL and EU may be an option to consider despite higher costs.

The future availability of **plastic waste** in the Netherlands depends on several factors, such as the total amount of plastic entering the waste phase (which in turn is linked to consumption and collection of plastic products), the extent to which plastic is separated from waste at source, the efficiency of separation plants, and import/export dynamics. In the ADAPT and TRANSFORM scenarios, the availability of plastic waste is limited to the supply in the Netherlands. Import of plastic waste, for example in the form of pellets or pyrolysis oil, can significantly increase the availability of this waste for Dutch industry [8].

Finally, **captured CO_2** will also be used as a source of carbon. Under certain conditions, captured CO_2 from fossil point sources may be used for the production of RFNBOs until 2040. In the longer term, it will be necessary to switch to CO_2 from DAC.

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Next steps – Roadmap

Despite uncertainties and barriers, all parties need to take steps now

Although there are still many uncertainties and barriers to eliminate, we need to speed up the transition to sustainable chemicals and fuels now. Urgent action is needed to prevent climate targets from slipping out of reach, while at the same time ensuring that Dutch industry retains a healthy competitive position.

The success of the transition depends on collaboration throughout the value chain

Many parties play a role in achieving a successful and timely transition to renewable fuels and chemicals. Authorities at EU, national, and local levels, the chemical and fuel sectors, and the Port of Rotterdam are examples of parties that play a crucial role and will need to work together. The following components need to be initiated and accelerated in parallel:

- production of renewable fuels and chemicals and realisation of joint facilities
- mobilisation of chain partners
- incentivisation of the transition through regulation and policy
- creation of a link with the ARRRA cluster.

These components are discussed below. Figure 6 shows these components as four layers in a roadmap to 2050. The layers in this roadmap are all interconnected. For example, in order to produce renewable fuels and chemicals, import flows must be set up with chain partners, and government regulation and policies are needed to create demand for renewable fuels and chemicals. Some will then be transported to Germany and Belgium, after any processing in the HIC Rotterdam.

Production of renewable fuels and chemicals and realisation of joint facilities to achieve economies of scale

As a great deal of uncertainty still remains about the raw materials or intermediates, technologies, and products that will eventually be deployed, it is advisable to initially develop a wide range of production routes. This allows for flexibility in the potential commodity flows to be imported and in the production routes for renewable fuels and chemicals. At the same time, efforts must be made to eliminate uncertainties so that convergence can be achieved over time. This can be done by working with chain partners to set up new chains based on the wide range of options. The 'winning' options will then emerge.

There are plenty of opportunities to exploit synergies between the chemical and fuel sectors. Given the potential overlap in the required production processes for renewable fuels and chemicals, it may be useful to achieve economies of scale by jointly setting up circular raw material processing facilities, such as pyrolysis and gasification plants. An additional benefit may be a positive effect on use of space: less use of scarce space in the port. Other examples of potential synergies include using each other's residual products, such as utilising non-recyclable fractions from mechanical and chemical recycling processes to produce fuels, and conducting joint research and development in the area of technology.

Mobilising chain partners to jointly set up import and processing flows and scale up energy supply
A successful transition to climate-neutral and circular production requires chemical and fuel companies to work closely with their chain partners and suppliers. As well as jointly setting up production facilities, as described above, the chemical and fuel sectors can also adopt a joint approach towards these chain partners. Examples include the import of alternative carbon sources, supply of affordable renewable energy carriers (such as electricity and hydrogen), and facilitation by raw material terminals, biomass pre-processors, waste management companies, CO_2 point sources and grid operators of infrastructure such as the electricity grid and a hydrogen network. Jointly setting up import and processing flows for circular carbon, one of the priorities discussed in the previous chapter, can help avoid a battle for feedstocks by attracting enough carbon based on a joint interest. The port's position as a hub can be leveraged to achieve economies of scale and efficiency.

A key 'no-regret step' is scaling up renewable electricity generation (including offshore wind) and expanding transmission capacity on the power grid. This electricity, besides meeting growing electricity demand from sectors such as mobility and households, will also be needed for the electrification of industrial processes and the production of green hydrogen as a raw material for processes including the production of ammonia and other e-molecules, such as e-methanol and e-SAF. Security of supply and affordability are both key factors in determining competitiveness.

Incentivising measures for the transition through regulation and policy
Authorities at all levels have a key role to play in the transition to climate neutral and circular. While industry and chain partners are working on a wide range of solutions, authorities need to make choices and eliminate uncertainties as soon as possible. As described above, parties in the chemical and fuel sectors currently feel that authorities are not doing enough to accelerate the transition. The EU and the Netherlands need to develop a policy vision on the future positioning of the sectors, which can then be translated into laws and regulations that enable policy implementation, accelerate the transition, and stimulate market development that will enable both sectors to achieve a strong competitive position. As described in the previous chapter, companies urgently need the Dutch government to speed up the licensing process, for example in relation to the issues surrounding 'end-of-waste status' legislation, which prevents reuse as a raw material. A mass balance approach is also needed to encourage reuse of waste, better facilitation of chemical recycling, and harmonisation of requirements on the sustainability of circular raw materials and products.

The municipality of Rotterdam, as part of an ecosystem of local, regional, and national players, can help drive the transition. For example, by creating support for circularity among residents and businesses, attracting suitable companies in the chain, and creating a market by procuring sustainable products itself. The municipality can also help to speed up the licensing process and create opportunities for circularity through its various roles as port shareholder, competent authority, and regional collaborator. The chemical and fuel sectors can adopt a joint approach towards authorities at different levels. Joining forces puts the individual parties in a stronger position to bring common interests, such as speeding up the licensing process, ensuring security of supply, and harmonising raw material and product requirements, to the attention of authorities.

Creation of a link with the ARRRA cluster
Just as oil and fossil-based fuels and chemicals are currently being sent on to companies in the ARRRA cluster, intermediates and products based on circular raw materials are also likely to be sent on in the future. The Delta-Rhine Corridor will play an important role in the link with the ARRRA cluster. Some of the existing infrastructure can be reused.

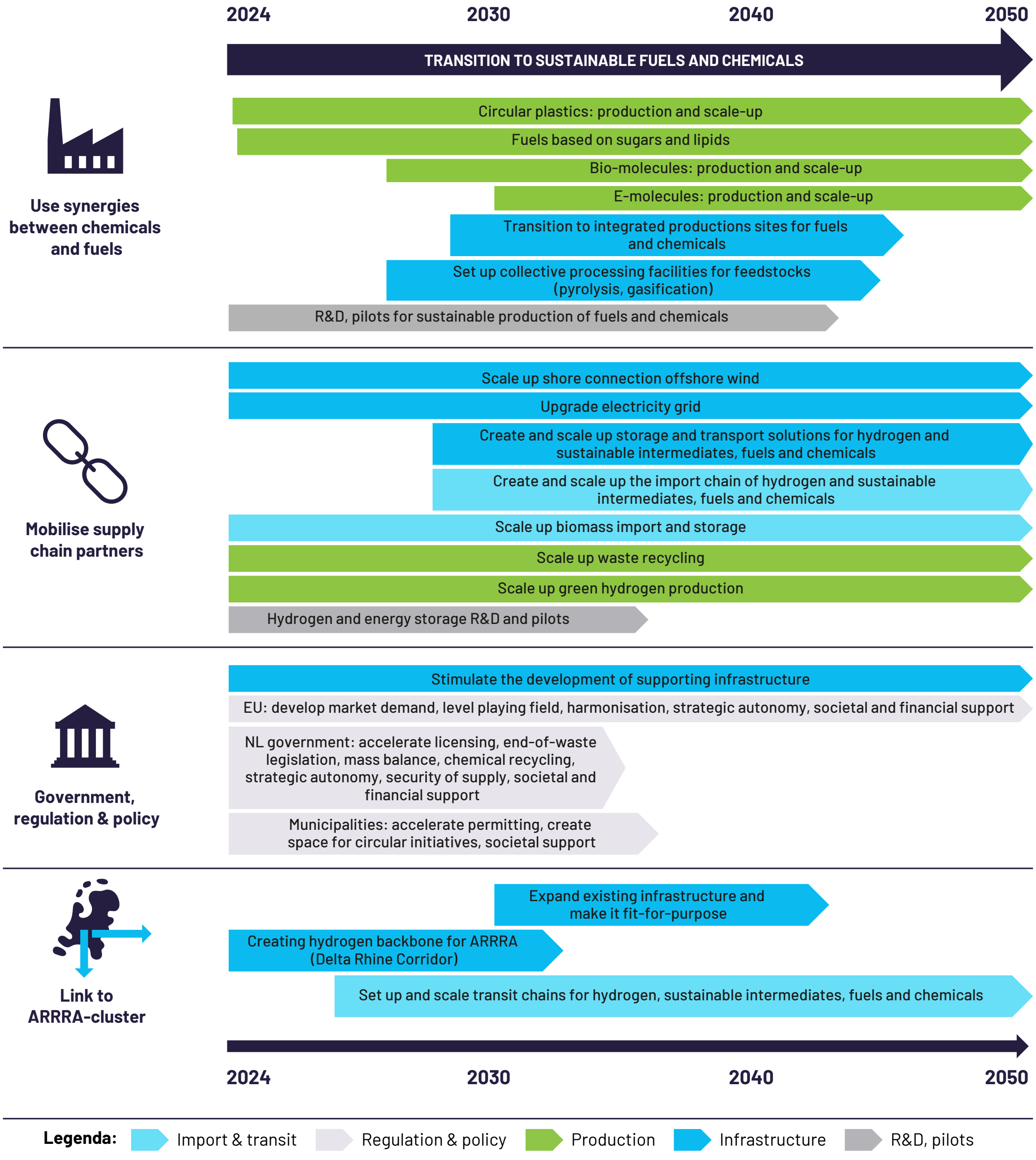

Figure 6. Roadmap for the transition to sustainable fuels and chemicals.

Overall, the transition to sustainable fuels and chemicals is a highly complex challenge. But if all parties involved make a joint effort, a future-proof and sustainable chemicals and fuels sector can become a reality.

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ANY QUESTIONS?

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