THREE STEPS TOWARDS A SUSTAINABLE INDUSTRY CLUSTER

ROTTERDAM-MOERDIJK IN 2050

CONTRIBUTION BY THE ROTTERDAM-MOERDIJK INDUSTRY CLUSTER WORK GROUP TO THE OUTLINE PACKAGE FOR CLIMATE AGREEMENT.

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FOREWORD

In recent months, the Rotterdam-Moerdijk Industry Cluster work group has been looking at one of the biggest challenges of this century: energy transition, with a view to making industry in this region more sustainable.

The subject of energy transition is extremely complex. It calls for a fundamental change in our energy and raw materials supply. Curbing global warming presents a wide range of strategies that need to be anticipated. At the consultation table of this work group – with representatives from industry, government, the environmental movement and science – the interests of the region in particular were paramount. And the interests are huge.

The region has traditionally provided high added value to the national economy.
The cluster is the location of many international companies, it provides ample employment, it is innovative and it serves a sizeable hinterland. However, this high level of activity also means the area is energy-intensive, with the corresponding greenhouse gas emissions.

It is therefore a major task to move from such a situation to one where making a sufficient contribution to the climate objectives is possible. The process began by jointly identifying a number of themes on which 'leaders' could work. This laid the foundation for possible routes towards the future. During a pressure cooker session, this was worked out in greater detail with steam and boiling water.

This eventually resulted in a proposed three-step approach which, under the right conditions, could lead to the desired outcome both for the reduction target of 49% by 2030 and for the longer term. At the same time, the competitive position of Dutch industry needs to be maintained.

As chairman, I have to say that with full commitment to the Rotterdam-Moerdijk industrial area, the work group has applied a professional process in order to make an important and realistic contribution to the outlines for a national climate agreement. And that the interests of the region can be upheld.

A much heard motto in this area is 'Make it Happen'. I think this is excellent advice we can now use to get down to business; carefully, but resolutely and purposefully.

Allard Castelein,
Chairman of the Rotterdam-Moerdijk Industry Cluster work group

Mandate for the Rotterdam-Moerdijk Industry Cluster work group

The Ministry of Economic Affairs and Climate has commissioned the national Industrial Commission to develop a shared vision for reaching a sustainable industry and to make specific agreements for 2030, with a view to setting targets for 2050.

The ministry's mandate to the five regional work groups went as follows:

- For each of their regions, these work groups are asked to identify possible measures and projects that will reduce CO_2 emissions, examine how cost-effective these measures and projects are and find out what support there is for these measures and projects.
- The work groups are also asked to propose measures and projects that will jointly involve government authorities and businesses. They are also asked to examine potential cross-regional or company-specific measures along the value chain.

COmposition of the work group

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The Port of Rotterdam Authority provided general support from Caroline Kroes, Nico van Dooren, Ruud Melieste and Mark Dijk. In a separate consultation meeting organised by Deltalinqs in conjunction with the Port of Rotterdam Authority, the other companies in the Rotterdam-Moerdijk cluster were invited to make their contribution, and the results were tested.

SUMMARY

The Rotterdam-Moerdijk industry cluster can successfully make the required contribution to the national climate target for the reduction of greenhouse gases by 2030. Over the past few months the work group for the industry cluster has put together a package of measures and projects that could achieve up to almost 10 megatons of annual CO_2 reduction (scope 1). This is in keeping with the government's mandate and, more importantly, it outlines a realistically promising perspective for a sustainable industry cluster in 2050.

The work group has drawn up a roadmap to 2050 that introduces far-reaching innovation while at the same time gives existing industry in the region the time it needs to make adjustments to its business processes. By doing so, the regional economy will be upheld, levels of employment will be maintained and a new international competitiveness will be established for the future. This is closely in line with the government's wishes as to how the energy transition should be shaped.

This report will explain the roadmap in greater detail. Following a period in which as much efficiency and optimisation as possible was introduced into the existing energy system, electrification and the use of hydrogen form the cornerstones of a new system for energy and raw materials. This allowed the work group to maintain its focus on both the short and the long term. The latter was achieved, for instance, with the input of specialists and a sketch of the port industry area in 2050. This is included in this report.

The strength of the package of measures for 2030 is that technically speaking it can now be implemented. There is still a lot of work to be done, though, and financial mechanisms will need to help to balance business cases.

The report contains a set of clear conditions for success, most of which will have to be covered by government. For example, the industry's competitive international position must continue to be given adequate attention, and the risk of carbon leakage must not be underestimated. Furthermore, societal acceptance of the projects is of huge importance.

For the capture, transport and underground storage of CO_2, a national industrial commission agreed to three-months of fact-finding for reasons of due diligence. The knowledge acquired in connection with the Porthos project may be of service in this respect. For the development of CCS/CCUS, which the industrial commission in this region considers necessary, it is also important that innovations are sought over a longer period of time, both at company level and from a social perspective.

The government had also asked the work group to look at cross-regional measures in the value chain. In particular, the work group has set these down in a list of enablers, which can be used to realise projects. For the Rotterdam-Moerdijk industry cluster, this especially concerns an expansion of the energy infrastructure, such as heat networks, CO_2 transport and storage infrastructure, steam networks, increasing the capacity of the electricity grid for industrial electrification, and the expansion of the hydrogen network.

The latter would also require creating a sufficient supply of hydrogen. This means: scaling up electrolysis for the production of green hydrogen (mainly produced by offshore wind) and immediately expanding the supply of blue hydrogen (based on residual gases or natural gas, whereby the released CO_2 is stored at once).

The important thing here is that opting for electrification and hydrogen can be done independently of the supply of solar power or wind energy and green hydrogen and other technological innovations that have yet to be scaled up. This is to avoid unnecessary supply chain dependence when making investment decisions. However, any acceleration in the roll-out of offshore wind energy cannot be seen separately from the growth in industrial demand. The development of demand in the cluster may reduce the investment risks for offshore wind energy.

Finally, it is important that emission reductions with electrification can be recorded as CO_2 reductions, even if new supply and demand do not (immediately) match. The supply of blue hydrogen can bridge the period of upscaling and availability of green hydrogen in a climate-neutral way. Part of the necessary transition is intensifying supply chain cooperation and continued chemical recycling, especially in this region.

What now? The chosen approach and the formulated framework conditions for success mean a sound basis now exists. In the summer, the Netherlands Environmental Assessment Agency will weigh up impact and costs of the proposals put forward by all climate committees. It will then be important to hold discussions with local, regional and national social and public parties and build broad support so that progress can be made on the projects with a range of coalitions and custom-made solutions.

01

PROMISING PROSPECTS

VISION OF THE ROTTERDAM-MOERDIJK INDUSTRY CLUSTER IN 2050

Working towards climate targets without a clear picture of what the Rotterdam-Moerdijk industry cluster might actually look like in 2050 is a complex task.
This prompted the work group to produce a sketch of industry in the middle of the century. Not only as a promising perspective but also as a test of whether the outlines set out are enough to achieve a radical transition on the way to 2050 and to help readers of this report form an image of a potential future.

2050

In 2050, industry in Rotterdam-Moerdijk presents a dynamic image. A high level of activity is prevailing and the port is still an important hub in the Northwest European market. New and transformed industries are flourishing in a newly designed energy and economic system. The fourth industrial revolution is in full swing.

Like satellites, companies are linked to a smart infrastructure that forms the basis of a circular system. All companies are connected to it for the supply and input of electricity, hydrogen, residual gases, steam, heat, CO_2 etc as a basis for new raw materials.

Construction of this infrastructure was started in good time. Whereas at the start of the transition fossil fuel flows were mainly exchanged over this infrastructure, in 2050 this infrastructure is being fully utilised for the purpose of renewable flows.

ADDED VALUE OF INDUSTRY

In 2017 the added value to the Netherlands of the industry cluster came to almost €13 billion. By 2050 this added value, in relative terms, has only increased. This is mainly due to the fact that the characteristic infrastructure of Rotterdam-Moerdijk offers opportunities to companies that are not available elsewhere.

This has improved the international business climate. It has a positive impact on the overall employment prospects for around 75,000 people who are active in the industry, producing an extremely wide range of products. The industry cluster supplies the building blocks for products that can be found everywhere in everyday life, such as in your home: the fibres for your carpets or the coating for your laminate floor, the insulation in your walls and refrigerator, uPVC window frames, and the filling in your mattress and sofa.

In your car too: for instance, the dashboard, steering wheel and seats, and of course the fuel. There is the nylon in your clothing and in your toothbrush, your child's plastic toys, the plastic bottles for your soft drinks, food packaging, the screen on your mobile phone, the soles of your shoes, the aromatics in your deodorant and perfume, and the solvents and binders in your paint. And many more daily consumer goods.

There are increasingly more specialised jobs. For this purpose, business, the government and educational institutions are committed to making the labour market and education more flexible.

Rotterdam-Moerdijk made a timely start in transitioning to a new system for energy and raw materials by 2050. Initially, the main focus was on the fossil fuel energy system: more efficiency, investments in cleaner finished products and the underground storage of CO_2. Sufficient scope for experimentation helped to discover and scale up new innovative paths in plenty of time. The synergy between, say, Brainport in Brabant and Mainport in Rotterdam led to an acceleration in the introduction of innovations into the market.

The desire to remain the architect of our own future led to sharp changes in the fields of energy, housing and work. In 2050 the combination of green electricity, hydrogen, biomass and waste forms the basis for the new energy and raw materials system in Rotterdam-Moerdijk and far beyond.

CLEAR CHOICES

The push for a hydrogen economy came with the construction of blue hydrogen plants on the basis of natural gas and waste gases. The CO_2 released could be stored in empty gas fields. The necessary interim phase was followed up by the arrival of large-scale green hydrogen produced by water electrolysis using green electricity, mainly from wind farms on the North Sea. In 2050 this is done partly on energy islands off the coast.

In the new energy system, sufficient heat is released to provide heating for homes, green-houses, offices and other companies. Coal-fired power plants have disappeared. For unforeseen situations, flexible boilers that can run on Hydrogen and, in emergencies, on natural gas are kept in reserve at critical locations.

CHEMICALS AND REFINING

Timely anticipation of the opportunities offered by energy transition put the chemical industry in a leading position when it came to supplying growing markets for clean fuels and raw materials. This made it possible to capitalise on the strong international market position that had been built up over the past few decades.

In 2050, the chemical sector is flourishing, with hydrogen, waste, biomass etc providing the raw materials for circular processes. Besides providing the required heat, hydrogen also forms one of the sources for producing semi-finished and finished products.
With over forty chemical companies in Rotterdam-Moerdijk, the size of the sector has remained virtually unchanged over the years. Companies run on hydrogen, circular carbons, biomass and secondary raw materials. A key example is the methanol production that uses waste, mainly for the chemical industry.

In Europe, the falling demand for fuels has led to far-reaching integration of the chemical and refinery industries. The refinery sector may be smaller in size, but its role as a manufac-turer of chemical raw materials and fuels for export has grown.

Furthermore, in 2050 the cluster is seeing a large scale conversion of synthetic raw material produced from renewable energy. This is providing the aviation and shipping industries with synthetic fuels. A 95% reduction (the climate target for 2050) has not made the industry wholly emissions free. There are still pockets that cannot be placed in the circular system. Accordingly, in 2050, the port industrial area has been allocated a limited amount of greenhouse gas emissions allowance. It also has a strict limit and should to a large extent be compensated by negative emissions, mainly through bio-based production in the chemical sector.

RE-INVENTED

Het haven-industriegebied Rotterdam-Moerdijk is daarmee in 2050 ingrijpend veranderd.
In 2050, the port industrial area of Rotterdam-Moerdijk has therefore undergone radical changes. It runs on a new system of energy and raw materials and it has consolidated its interests and international role.

Besides its new and renewed industry, the port complex fills a vital role in the international marketplace at this point of the mid-century. The Rotterdam-Moerdijk industrial area rein-vented itself in good time and has also managed to develop. Accordingly, in 2050, one of the greatest challenges of the century has been converted into a new future.

02

REDUCING CO_2 EMISSIONS

THE STEPS ON THE PATH TO ACHIEVING THE CLIMATE TARGETS FOR 2030 AND 2050

1. THE CURRENT SYSTEM

The Rotterdam-Moerdijk port industrial area consists of around 60 companies, including five oil refineries, 36 chemical companies, four waste processing companies and 14 other industrial companies.

This industry cluster produces almost €13 billion of added value to the Netherlands and offers employment to some 75,000 people[1]. The region imports raw materials and produces and supplies products with an annual energy content of more than 2,000 petajoules (PJ).

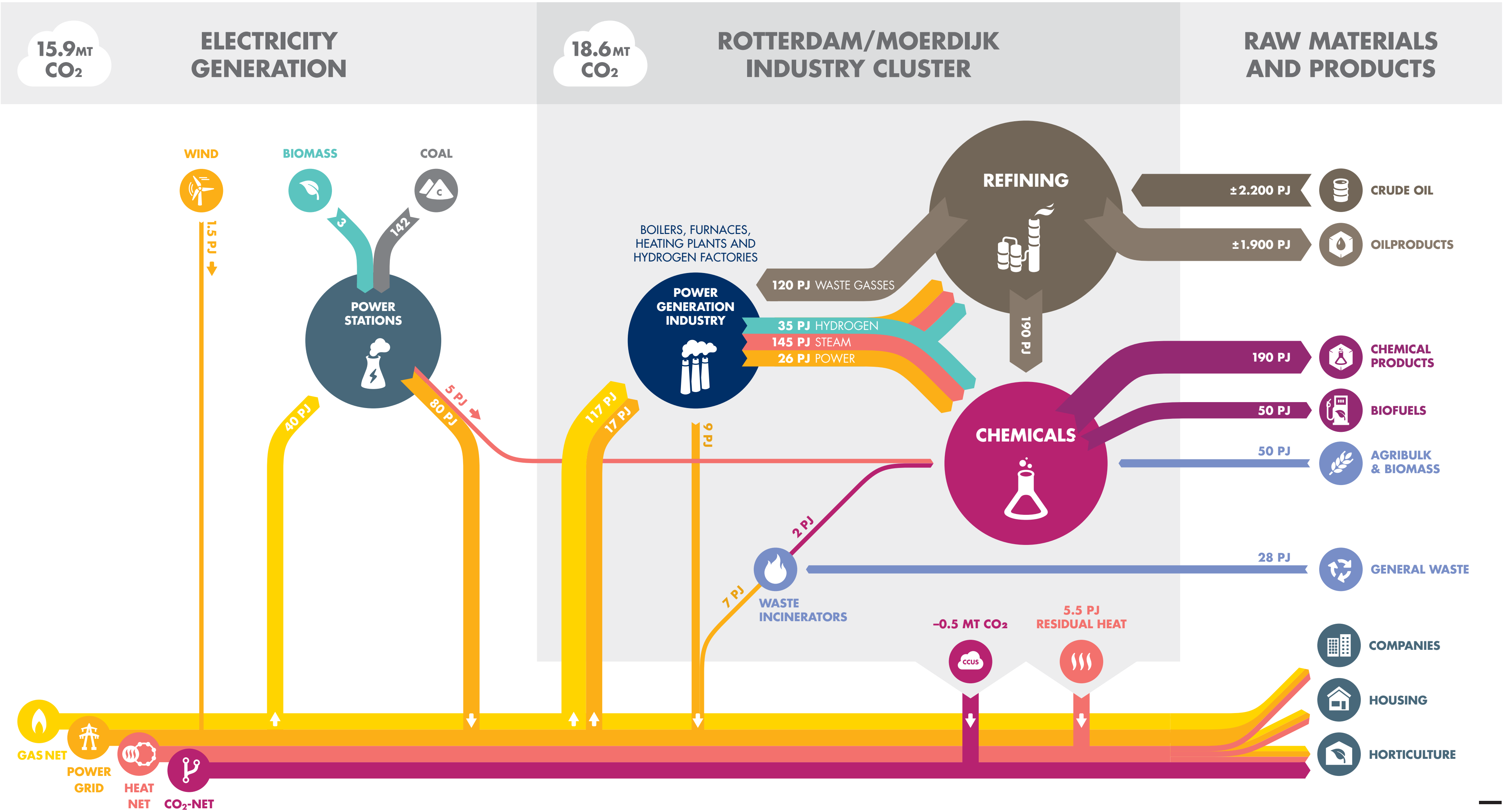
Approximately 260 PJ are consumed in the production processes. Almost half of this energy input comes from the waste gases from the refineries, with an almost equal amount of natural gas coming from the gas network and an additional small amount of energy coming from general waste and electricity from the power grid.

This energy consumption produces 18.6 megatons (MT) of CO_2 emissions (2016). Since 2005, captured CO_2 has been delivered to the greenhouse horticulture sector, and steam and heat networks have been operational for five years, allowing the reciprocal exchange of steam and the supply of residual heat to district heating networks.

[1] Including industry-related transport and purchasing among suppliers.
Source: Havenmonitor 2016 (Erasmus, Oct. 2017).

ROTTERDAM/MOERDIJK INDUSTRY CLUSTER IN 2016

ENERGY FLOWS



At the beginning of 2016, there were eight power plants (four gas fired, four coal fired) with over 5 GW capacity in the port industrial area. The CO_2 emissions from these power plants was almost 16 Mt in 2016. Three of the plants (two coal and one gas) have since closed. Incidentally, the power plants are not included in the Rotterdam-Moerdijk industry cluster work group's report, as discussions and measures in this area have been transferred to the national Electricity Commission.

A continuing focus on energy efficiency is standard and is driven by the relatively higher energy costs in Rotterdam-Moerdijk compared to the United States and the Middle East. For many years industry has been working with government on energy efficiency as part of the LTA and LEE covenants. As a result, the industry cluster has kept the level of CO_2 emissions virtually stable since 2000, while several new world scale factories have been built. An additional energy efficiency mandate is currently being worked on as part of the 2013 Energy Agreement (9 PJ nationally). Energy efficiency will remain a key pillar in the process of reducing CO_2 emissions. The focus is shifting from energy efficiency to a reduction in CO_2 emissions.

Far-reaching CO_2 reduction in the industry cluster is technically possible. However, it does entail radical changes to operational process that are often complex and expensive. The following issues are therefore of great importance to industry:

- Long-term agreements between government and the various companies in the region, so that after 2030 the follow-up steps can be taken based on the changes in processes that will be applied until 2030.
- The availability of an energy infrastructure to which industry running CO_2 emission reduction projects can connect.
- Financial resources and/or guarantees to address unprofitable peaks. From the perspective of a level playing field, an adequate market-based mechanism needs to be developed to make business cases possible.
- The availability of enough green power and molecules, or being allowed to register investments as an emission reduction measure, even if there is still no supply of sufficient green power or molecules.
- The ability to introduce measures into the maintenance/investment cycles, of which for most industries there will be no more than two until 2030.
- The ability to introduce measures onto the site requires customisation. Some technologies (such as hybrid solutions) require space that is not always available. This means either examining a more radical solution right away or waiting for space to become available.

2. TOWARDS CO_2-REDUCTION IN THREE STEPS

Technically speaking, the climate targets set for 2030 and 2050 can be achieved in three steps. In order to enable industry to achieve the required CO_2 reductions, enablers are needed to help realise the projects.
These three steps towards CO_2 reduction[2] look like this:

Step 1 – Efficiency, developing infrastructure and CCUS. In this phase, between 2018 and 2025, the focus will be on the supply and reuse of surplus energy and storage/use of captured CO_2.
Enablers expand the energy infrastructure for heat, CO_2 and steam.
Projects uncouple and connect to specific infrastructure projects that are under development, such as: South Holland Heat Alliance, EnergyWeb XL (residual heat in Moerdijk), Porthos (CCUS) and Botlek steam network
CO_2 reduction potential 4.9 Mt of CO_2 reduction (scope 1) up to 2030. In addition, the supply of industrial residual heat and CO_2 can achieve a 2.6 to 3.5 Mt of CO_2 reduction in the built environment and greenhouse horticulture.

Step 2 – Towards a new energy system. This phase (2020-2030) is mainly concerned with making energy use by industry sustainable.
Enablers expand/increase capacity of the energy infrastructure for electricity and hydrogen; and market creation through a combined strategy of blue hydrogen (roll-out) and green hydrogen (pilot & demonstration, roll-out).
Projects electrification for LT/MT heat and hydrogen for HT heat.
CO_2 reduction potential estimated to be 3 1/2 to 4 Mt by 2030.

Step 3 – Renewal of raw materials and fuel system (2030-2050)
Enablers large-scale supply of green electricity and green hydrogen, connected to the industry cluster; development of international recycling hub, biomass hub and hydrogen hub.
Projecten Waste-2-chemicals, Pyrolysis-to-cracker, pyrolysis-to-refinery, biobased chemicals.
CO_2 reduction potential estimated to be 1 Mt by 2030.

[2] Steps 1 and 2 may overlap one another, but infrastructure is an essential condition for being able to implement step 2 and 3.

STEP 1 (2018–2025)

EFFICIENCY, DEVELOPMENT OF INFRASTRUCTURE AND CCUS

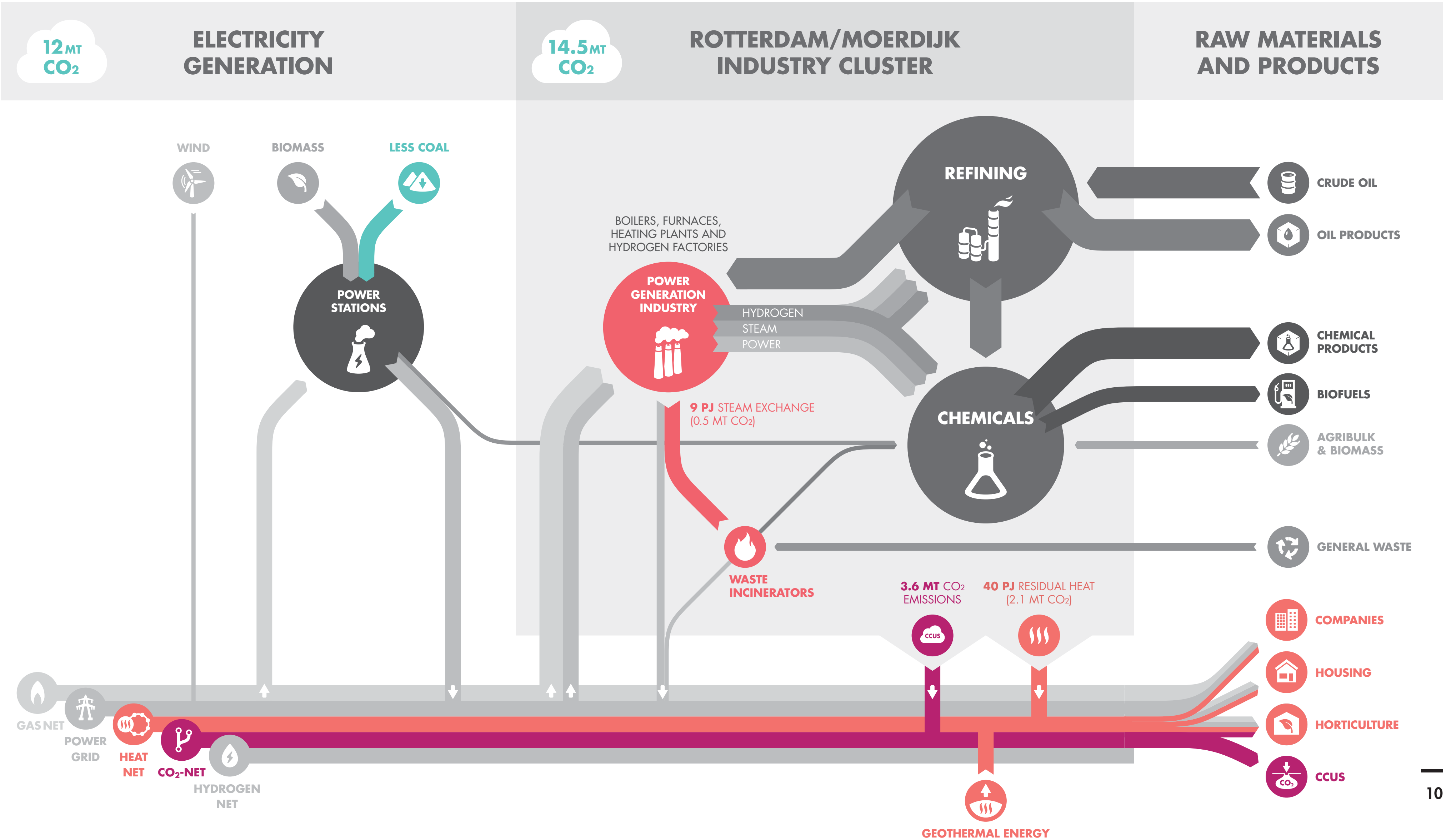
In this phase, the focus is on the supply and reuse of surplus energy as well as storage/use of captured CO_2.

1. INFRASTRUCTURE DEVELOPMENT
- Steam network
- Heat network
- CO_2 network
- Hydrogen network
- Increasing capacity electricity grid

2. STEAM EXCHANGE

3. HEAT SUPPLY TO GREENHOUSES AND CITIES

4. CARBON CAPTURE, USAGE & STORAGE (CCUS)



STEP 2 (2020–2030)

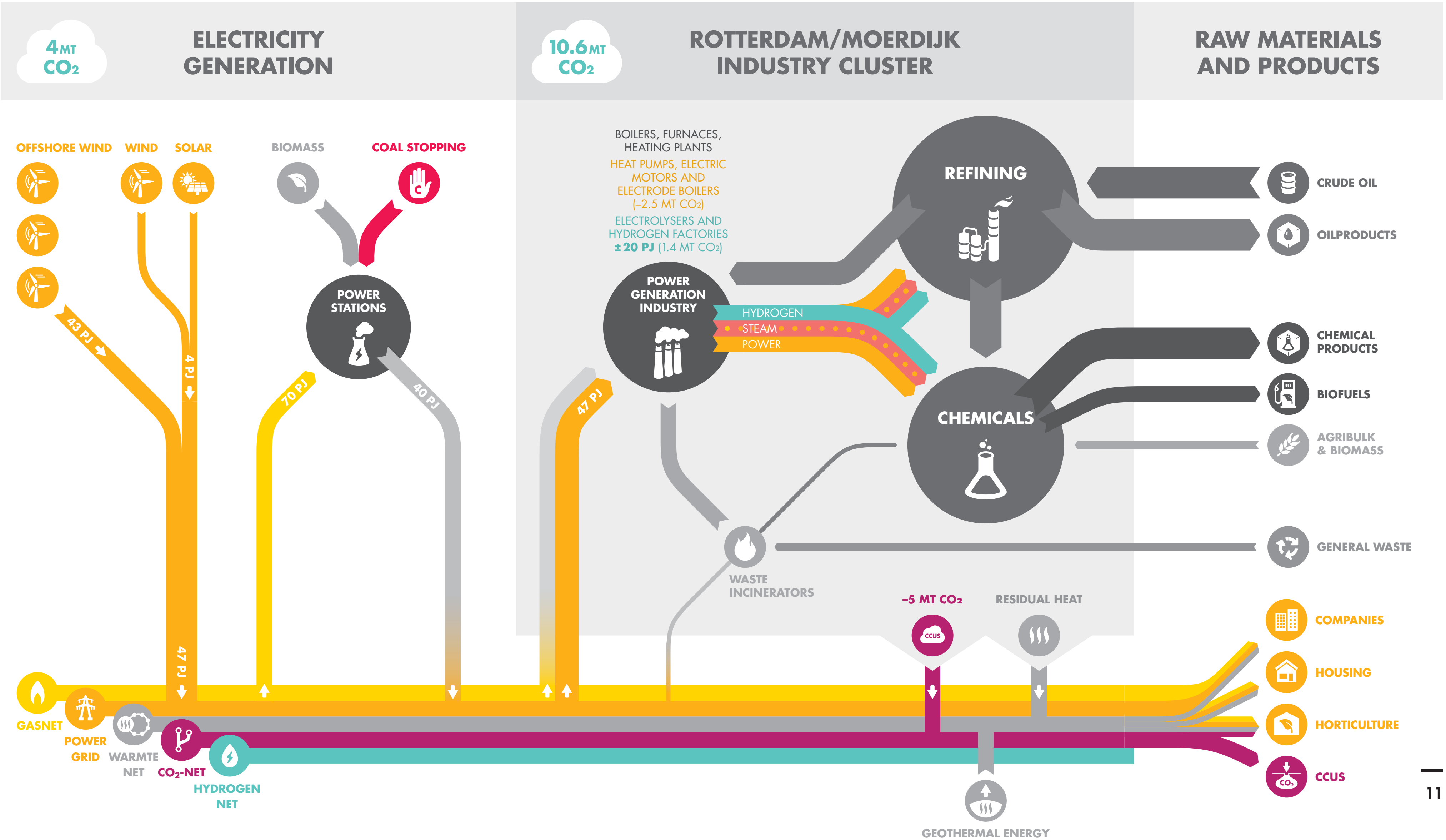
TOWARDS A NEW ENERGY SYSTEM

This phase mainly concerns making energy use for industry sustainable

ELECTRICITY GENERATION
Coal is stopped and replaced by gas and offshore wind power.

5. CO_2-NEUTRAL HYDROGEN
(1.4 MT of CO_2 REDUCTION)
- Blue hydrogen (roll-out)
- Green Hydrogen (pilot and demonstration)

6. ELECTRIFICATION
(2.5 MT OF CO_2 REDUCTION)
Steam from green electricity instead of natural gas
- Heat pumps, Electric motors, Electrode boilers



STEP 3 (2030-2050)

RENEWAL OF THE RAW MATERIAL AND FUEL SYSTEM

ELECTRICITY GENERATION
- Major expansion of offshore wind power
- Expansion of solar & wind power in ports
- Back-up of green hydrogen

7. RECYCLING

8. BIOCHEMICALS/BIOFUELS

9. HYDROGEN AND CO/CO_2 FROM RENEWABLE SOURCES

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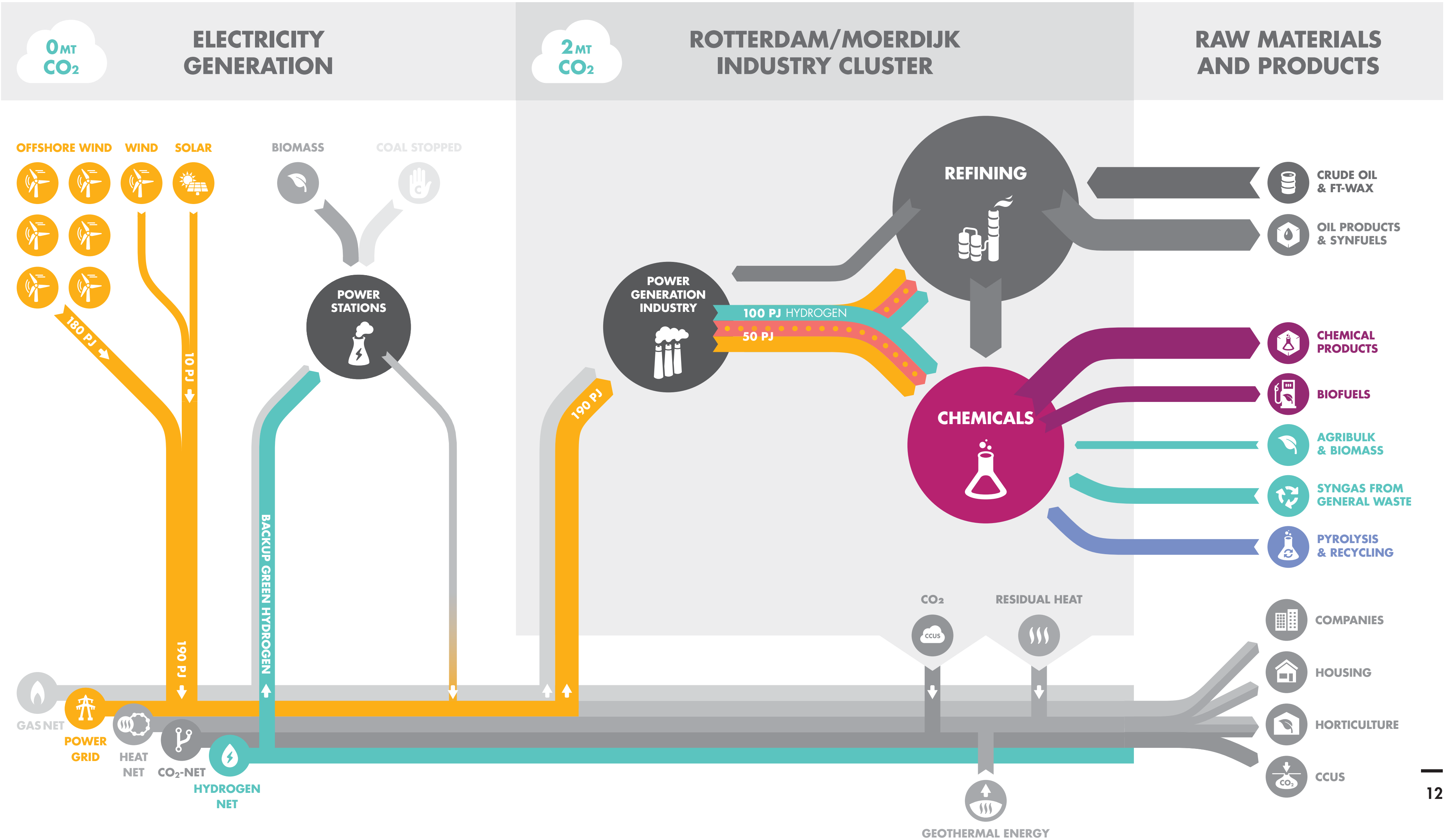


EXPLANATION STEP 1
ENERGY INFRASTRUCTURE FOR STEAM, HEAT AND CO_2

Botlek steam network The Botlek area of Rotterdam is home to a number of large industrial (high pressure and temperature) users of steam as well as parties who have steam left over from the nuclear process (fatal steam) or who generate steam from waste and waste wood. Although there are several steam pipes between companies, a lot more steam could be exchanged, offering a potential reduction in emissions of 0.5 Mt of CO_2 per year by 2030. This would require an extensive and integrated steam network in the Botlek.

Heat delivery by industry can help reduce emissions by 2.1 Mt of CO_2 per year in the built environment and greenhouse horticulture by 2030. Industry could make this possible if the parties supplying heat were also allowed to register part of the CO_2 emissions avoided to justify investments, or were compensated in some other way. There are specific business cases for the required heat infrastructure, such as those of the South Holland Heat Alliance and EnergyWeb XL.

For Carbon Capture, Usage & Storage (CCUS) an exploratory project was carried out by Port of Rotterdam Authority, Gasunie and Energie Beheer Nederland (EBN), under the name of Porthos (Port of Rotterdam CO_2 Transport Hub & Offshore Storage). The project involves the construction of a 33 km collection pipeline through the port, connection to the OCAP CO_2 network for supplying the greenhouse horticulture sector, and connection to a new compression station on the Maasvlakte from where the CO_2 will be transported along a newly laid 25 km long pipeline to a North Sea gas platform, where it will be injected into two gas reservoirs, 3 1/2 km beneath the seabed. The potential for CO_2 reduction is 3.6 Mt per year by 2030, involving mainly relatively pure CO_2 flows from factory processes. Besides being captured, the CO_2 could also be used in greenhouse horticulture. At the moment, 0.5 Mt is already being supplied to the sector. The total market potential for CO_2 supply to greenhouse horticulture in South Holland and North Holland is estimated to be 1.2 Mt. Moreover, there is additional potential for CCUS if production of blue hydrogen were rolled out (see explanation of step 2). In addition, CCUS in Rotterdam could form a gateway for other industry clusters to connect to the pipeline and supply captured CO_2 (Zeeland, Chemelot). Finally, CCUS also offers an option for achieving negative emissions by storing short-cycle CO_2 from biomass. In the long term this could prove necessary, should climate change move more quickly than anticipated or energy transition take longer than imagined.

EXPLANATION STEP 2
MAKING ENERGY CONSUMPTION SUSTAINABLE: ELECTRIFICATION AND HYDROGEN

Electrification is, **technically speaking, relatively straightforward** in the following cases:
- production of hot water (wet steam): **heat pumps**
- production of steam for propulsion: **electric motors** (replacing condensing steam turbines)
- production of saturated steam for process heat: **electric boilers** (replacing steam boilers, CHP)

The replacement of steam turbines and steam boilers by electrical equipment can result in reduced reliability. Furthermore, using electric boilers is currently often only possible up to more limited capacities than the current capacities.

Electrification is **technically not straightforward** when it comes to the production of superheated steam and/or higher steam pressures, due to the high pressure and temperature of the steam. It also requires a great deal of electrical capacity (MW) and additional space. Electrification is **technically complex** when it comes to the production of heat in process furnaces due to the extremely high temperatures.

For **heat pumps** a reduction potential of 0.5 Mt of CO_2 by 2030 is estimated, for **electric motors** and **electric boilers** around 2 Mt of CO_2 by 2030. Sufficient green electricity (offshore wind) will have to be brought to the region to be able to utilise this electrification potential: approximately 12 TWh in 2030, corresponding to approximately 3 GW of offshore wind power. This will require strengthening of both the grid and, where necessary, connections and internal company networks. It will also require close cooperation and coordination of projects between industry and the grid operators.

Hydrogen For the production of process heat, hydrogen may be an alternative where electrification is not straightforward or complex: in the production of superheated steam and the production of heat in process furnaces. This is mainly the case with refineries and chemical crackers. At the current state of the art of green hydrogen production using electrolysis, it is not opportune for the industry to develop this sustainability option before 2030, although research, pilots and expansion will certainly be backed. The step towards hydrogen could be different if industry were able to make use of blue hydrogen: hydrogen produced from natural gas or residual gases, where the CO_2 released is stored underground or reused in greenhouse horticulture.

For the time being, the CO_2 avoidance costs of this option are still considerably lower than with green hydrogen.

One possible route is therefore for the Rotterdam-Moerdijk industry cluster to opt for a combined strategy involving blue and green hydrogen:

- **Roll out blue hydrogen (+CCUS)** one possible route is therefore for the Rotterdam-Moerdijk industry cluster to opt for a combined strategy involving blue and green hydrogen:
- **Roll out blue hydrogen (+CCUS)** for the rapid creation of a larger hydrogen market, enabling industry to make an early choice regarding new fuel and/or technology, rather than having to wait for the green hydrogen market to come of age.
- **Green Hydrogen pilot and demonstration** (electrolysis of 20 MW to 100 MW plus in the port) so that the then increased market for hydrogen can switch to green hydrogen after 2030
- **Commit to pilots for energy storage and conversion**

Thanks to this combination strategy of market creation and sustainability, a possible mismatch between supply and demand is avoided: industry can adapt to hydrogen during its maintenance and investment cycles at the sites without having to take the pace of wind farm construction and electrolysis development into account.

By producing blue hydrogen, the industry also retains an outlet for waste gases from the refining process, which are currently used to replace natural gas and for which there is no alternative.

Market creation for hydrogen also facilitates the introduction of green hydrogen because more users are expanding the current specific user market. By creating a larger market, it may also be possible to move along the learning curve more quickly and reduce the cost of use – unlike in current applications (comparable to the development of LNG, not only for generating electricity but also for mobility).

Depending on how fast we can scale up the supply of green hydrogen, which currently has relatively high CO_2 avoidance costs, 1 or 2 new hydrogen factories could be built by 2030. These could each contribute around 0.7 Mt of CO_2 to the CCUS project on top of the base case (3.6 Mt) of Porthos.

In addition, a scaling up of the regional hydrogen network will then be needed. Hydrogen can be used first of all for the production of high temperature heat and later for the production of sustainable raw materials as well (see step 3).

In addition, hydrogen can also be used for mobility and can be blended with the natural gas network.

Supplying blue and later green hydrogen to other industrial clusters is also an option (e.g. for ammonia production in Zeeland and Chemelot). There are proposals for linking the various clusters in the Netherlands (and perhaps also the ones in Germany and Belgium) by converting natural gas networks into hydrogen networks or by laying a new hydrogen network.

Developing energy storage and conversion techniques could yield a great deal of knowledge and expertise, which would allow us to make the chemical industry in particular more sustainable after 2030.

Furthermore, research needs to be carried out in cooperation with the network operators to determine the best location for a new hydrogen factory, either centralised in the port or decentralised for larger customers. The location of green hydrogen production also requires coordination in connection with synergy benefits arising from the use of oxygen and residual heat released during the electrolysis of water.

After 2030, hydrogen production at sea will also come into play. It will either be generated directly in turbines or with electrolysers on an island or platform before being piped ashore. The import of hydrogen by sea will also be an option if solar farms in overseas areas continue to scale up and the transport of hydrogen by ship to large markets becomes increasingly attractive.

The construction of import and storage facilities would then become opportune after 2030. The import of blue hydrogen would also be possible, as would green hydrogen from other world markets. In the longer term, blue hydrogen capacity, together with hydrogen imports (solar and wind from elsewhere), could be used to balance supply and demand (and supply security).

EXPLANATION STEP 3
MAKING RAW MATERIAL USE SUSTAINABLE: HYDROGEN AND CARBON

Hydrogen: Some time after 2030, as soon as green electricity can be offered on a larger scale and there is enough electrolysis, raw materials and fuels for greening will also come into play along this route: power-to-chemicals, power-to-liquids and synfuels. Consequently, the demand from Rotterdam-Moerdijk for green electricity for raw materials and energy alone could grow to 50 TWh in 2050[3]. Then there is the fuel market as well. In addition to the large scale of offshore wind power in the North Sea, this also requires a great deal of import, also for any market demand from other clusters and neighbouring countries, which can be connected to the Rotterdam-Moerdijk system.

Carbon: Besides being a hub for electricity and hydrogen, the port is an import hub for secondary raw materials (waste & plastics) and sustainable biomass. After all, in addition to hydrogen, carbon is also need to make products. The port mainly needs to focus on concentrated, large, circular carbon sources:

SOLID WASTE

Mechanical recycling: is the most environmentally and cost efficient way of converting plastics so they can be properly recycled. Due to the growing demand for high-quality recyclate for new plastics, there is a need for further expansion, scaling up and professionalisation of the recycling capacity in Europe. The presence of primary plastics manufacturers and the large supply of waste and sorted flows make Rijnmond an interesting location for high-quality mechanical recycling.

[3] Source: Decarbonisation Pathways for the Industrial Cluster of the Port of Rotterdam, Wuppertal Institute, October 2016.

Chemical recycling: In addition to mechanical recycling, chemical recycling technologies offer the opportunity of converting non-recyclable plastic waste into products such as polymers, monomers, fuels, waxes, aromatics or synthetic gases.

- **Gassification:** The first project in this area is a new gasification plant at Enerkem, which can process some plastic fractions and produce methanol for the chemical industry. The plant can process 360 ktons of waste into 220 ktons of green methanol, which can achieve a CO_2 reduction of approx. 300 kton. If this technology can be successfully expanded, there could be four such factories there in the long term. Rotterdam could then be developed into a recycling hub for national and international general waste.

- **Pyrolysis:** In Rotterdam there is an ongoing initiative for an integrated pyrolysis cluster that includes various pyrolysis initiatives that can produce naphtha fractions to be processed as co-feed in the existing naphtha crackers or pyrolysis oil for upgrading in existing oil refineries. Companies, the government and educational institutions in the pyrolysis testing ground in the southern part of the Netherlands are also exploring the possibilities of processing waste streams using pyrolysis technology in Moerdijk.

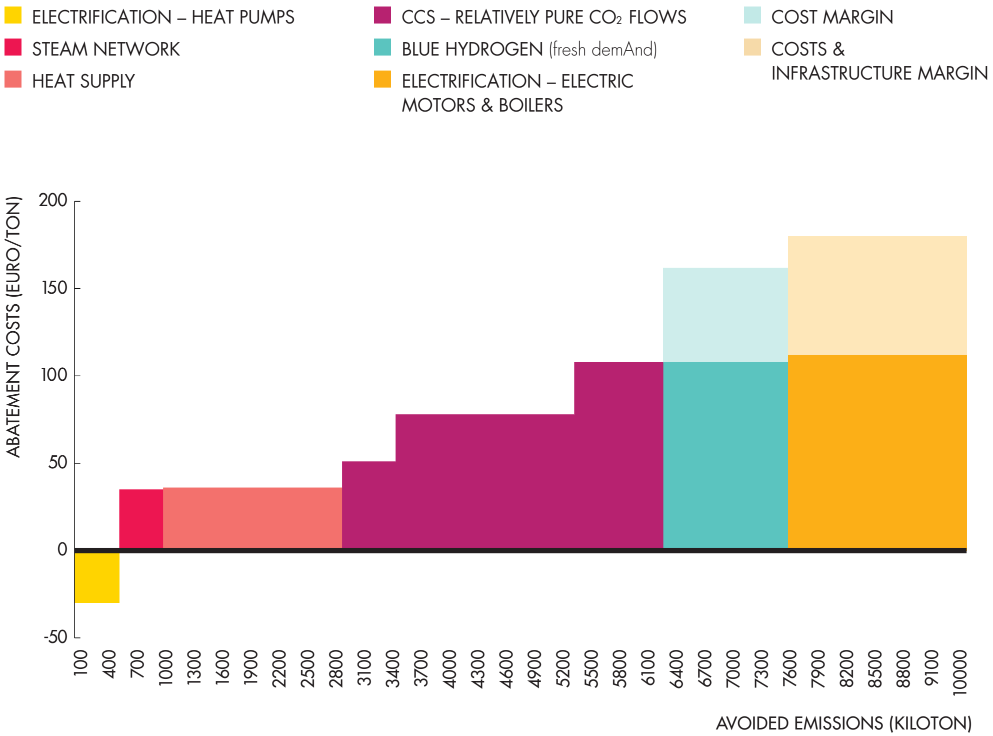
BIOMASS

Rotterdam-Moerdijk is already one of the largest biobased clusters in the world. Nevertheless, there are still plenty of opportunities to further strengthen this position:
- Cascading wood as much as possible: first extract sugars and then gasify the rest for chemistry or burn it for energy
- Biobased (sugar & photosynthesis) solutions such as top up '(Sugars on Top)' for high-quality products, usually in lower volumes.

With the greening of raw materials and products, CO_2 reductions can be achieved elsewhere in the production chain outside the Netherlands (for example, if with Waste-2-Chemicals, methanol or other basic chemicals that are currently imported can be produced in the Netherlands).

PROVISIONAL ABATEMENT CURVE PROJECTS UP TO 2030

The figure below gives an indication of the cost range of avoided CO_2 and the amount of CO_2 that is involved in the projects in the region up to 2030. This figure is an indication that needs further clarification in order to understand the cost of other abatement technologies. For the time being, a more detailed and region-specific picture of the costs of avoided CO_2 is not available. It takes time and diligence to create such a curve. There are several recent studies (e.g. VEMW, VNCI and VNPI) that can be drawn from; however, the figures reveal differences in the reduction potential and the CO_2 reduction costs. Moreover, there are differences in framework conditions such as the scope of costs included. A deeper comparison of the data and assumptions is therefore required.



SOURCES

Electrification – Heat pumps: Eneco
Steam network – Port Of Rotterdam Authority/ECN
Heat supply – South Holland Heat Alliance; CE Delft
CCS – relatively pure O_2 flows: Porthos, VNPI
Blue hydrogen – IEAGHG TR201702/Sintef
Electrification – Electric motors & boilers: VNCI, VEMW

03

ROLL-OUT, PILOTS AND RESEARCH

LIST OF CONCRETE MEASURES FOR 2030 TARGETS

POTENTIAL ROLL-OUT OF MEASURES

The participants in the Rotterdam-Moerdijk industry cluster work group identified eight themes that are promising in the region: hydrogen, electrification, CCS/CCUS, residual heat, steam, raw materials transition, infrastructure, energy efficiency. The table below outlines the following potential for 2030:

Scope 1 indicates the effect on the Rotterdam-Moerdijk port industrial area concerned. Scopes 2 and 3 show the effect beyond.

MEASURE / TECHNOLOGY	IDENTIFIED ROLL-OUT MEASURES (2030)	CO_2 REDUCTION BY 2030 (SCOPE 1)	CO_2 REDUCTION (SCOPE 2 AND 3)	REMARKS
Hydrogen	· 100 MW electrolyser · Blue hydrogen	0.1 Mton 1,4 Mton		
Electrification	· Electrode boilers · Electric motors · Heat pumps · Replace CHP with import of green electricity	2 – 2.5 Mton (estimate based on total potential in NL)		Potential measures from the sites must be made even more specific.
CC(U)S	· PORTHOS · CCU: CO_2 supply to greenhouse horticulture	3,6 Mton	0.7 Mton CCU	Work out other CCU options
Steam	· Botlek steam pipeline · Site optimisation (steam recompression)	0.16 – 0.5 Mton		
Raw material transition	· Chemical recycling (Waste 2 Chemicals/pyrolysis/depolymeri-sation/waste to aromatics) · Mechanical recycling · Bio-based Speciality chemicals	0.3 – 1 Mton (of which 0.3 Mton W2C)		CO_2 reduction often in the product chain/outside NL
Residual heat	Residual heat supply: · South Holland Heat Alliance · EnergyWeb XL Ultra-deep Geothermal Energy (UDG)	0.04 – 0.8 Mton (first a pilot of 0.04 Mton)	2.1 – 3 Mton	Achievement of CO_2 reduction in built environment/agriculture UDG can also supply heat outside the port area, in which case scope 3 CO2 reduction
		7.6 – 9.9 Mton	2.6–3,5 Mton	

*The measures can compete with each other, so it is expected that the total CO_2 emissions will overlap. In addition, some measures (CCUS, residual heat supply, Waste-2-Chemicals and Botlek steam network) are already much more concrete and their feasibility in relation to others has been tested.

PILOTS AND RESEARCH

Besides the roll-out of measures with their corresponding CO_2 impact, a number of pilot and research measures have been identified:

MEASURE / TECHNOLOGY	DEMOS AND PILOTS	RESEARCH AND INNOVATION
Hydrogen	· 100 MW electrolysis demos · Voltachem field lab	· 1 to 2 GW Electrolysis · H_2 in the built environment · E-refiners Power to chemfuels
Electrification	· Flexible H_2 electrolyser · Electrification field lab	· E-boilers for making medium and high-pressure superheated steam and process heat including research into (integrated) hybrid solutions · Heat pumps for making steam at higher pressures and temperatures
CC(U)S	· CCU applications (Carbon to PUR)	· CCU applications
Steam	· Redundancy E-infra with E-boilers	
Raw material transition	· Biobased bulk chemicals (bio-ethylene) · Chemical recycling (waste-to-aromatics) · Synthetic hydrocarbons	· Waste to ethylene/propylene · Energy research and the valorisation of synthetic hydrocarbons
Residual heat	· Heat storage · Feeding geothermal energy into (waste) heat networks	· Ultra-deep Geothermal Energy

04

FRAMEWORK CONDITIONS FOR SUCCESS

The previous sections have shown that there are ample opportunities for achieving CO_2 reduction in the Rotterdam-Moerdijk cluster. However, the implementation of these measures is economically unviable, and it will be necessary to develop a mechanism with the right framework conditions so that the projects can be carried out. We agree with the framework conditions set out in the working document of the Industrial Commission[4], with the following fragment taken from the report of the National Industry Commission for Climate Agreement. When developing measures, we would therefore request:

1. **Long-term stable investment climate and multi-annual stable legislation and regulations:** with the focus on continuing and strengthening the various industrial clusters in the Netherlands. In addition, legislation will need to be changed, for instance in the area of improving the feasibility of rules surrounding energy efficiency and the network codes required for direct current networks.
2. **Solution to the OPEX problem**[5]: the price difference between natural gas/fossil fuel and sustainable energy sources and (too low) ETS prices. An additional CO_2 price in (NW) Europe could be an option, provided it applies to all companies and there is no 'leakage' (or compensation is made for leakage; but there are numerous other options that also need to be examined). Incidentally, this would not work for the natural gas carbon atoms that are used as a raw material.
3. **Funding structures**, where the risk of an insufficiently level international (at least European) playing field and an ETS price that does not rise quickly enough are partially funded by governments[6] (e.g. InvestNL, EIB or guarantee schemes). These may include new public-private partnerships between network companies and government, in which infrastructure is built as a catalyst for the transition.
4. **Investments in renewable energy and critical infrastructures** and control of infrastructure (including the reuse of former (gas) infrastructure) at national level based on a national structural concept and regional coordination by provinces and local authorities. A timely and sufficient supply of affordable green electricity is needed.
5. **A change to international/national rules around CO_2 accounting** focused on the circular economy, among other things. Agreements on CO_2 accounting of cross-border projects, shipping and aviation, and elaboration of international chain effects (e.g. CCU, green and circular feedstock). Amend ETS rules for transport (other than via pipelines) and storage of materials (plastics).

[4] https://www.klimaatakkoord.nl/industrie/documenten/publicaties/2018/07/10/bijdrage-industrie
[5] In addition to this specific problem regarding the difference in energy prices, the profitability of the CAPEX is also at stake.
[6] It is also important to take market-based funding conditions into account.

6. A change to (international) **waste and chemical legislation** and waste transport legislation aimed at optimum value creation of waste substances so that either the conversion from waste to raw material is conducted more quickly or waste is never classified as waste. In addition, the development of a targeted import strategy for waste and secondary raw materials so that there is enough supply of biobased and waste-based raw materials for industry.
7. **Programme-based coordination and cooperation** between network companies and government bodies (including knowledge institutions in the case of innovation) aimed at building new value chains and sustainable partnerships[7] where the Netherlands can play a distinctive role, and carrying out projects and measures that allow permit procedures to run smoothly enough. Speed and flexibility of granting permits partly determine the pace of transition.
8. Take account of the **whole energy system**. The measures for industry have such a wide impact on energy supply that an integrated approach is needed; one that fosters synergy in the reduction of CO_2 in other sectors (electricity, built environment).
9. Enough **highly-educated staff** with the right qualifications (training programme/National Technology Pact).
10. **Speed up (mission-driven) innovation programmes, demonstrations and pilots**[8] so the industrial transition can be expanded and accelerated on a large scale and simultaneously in many places. This will require enough scope for experimentation.
11. **Joint communication and an area-based approach** by the Climate Agreement partners regarding the usefulness and necessity of industrial transition, its impact on our future prosperity and the way in which (global) consumption is the ultimate key to a more sustainable society. Due to the local impact of measures in the regions, the role of industry within its surroundings is of major importance.

NB: SCOPE FOR GROWTH

Since the transition will ideally be paid for by increasing prosperity and the Netherlands needs to remain attractive for the required investments, it is important to draw up agreements that allow for the growth of industry within the principles of the emissions caps. The investment in new production units often precedes the disposal of obsolete ones, and that requires reaching one-to-one deals with existing industry covering the temporary easing of emission limits (assuming a 'normal weather year') based on an agreed reduction schedule.

In addition, new investments may increase absolute CO_2 emissions, whereas CO_2 emissions per product may decrease. Arrangements within the Climate Agreement should support such developments rather than slow them down. This type of investment can also lead to a consolidation of industry in the most energy-efficient clusters. Measures that will require temporarily higher CO_2 emissions in industry but which, on balance, turn out to be more favourable in scopes 2 and 3 are also conceivable.
It is necessary to determine in advance which framework conditions apply to the new entrants, who may affect the course of the transition. Scope for this has been created in the ETS system; perhaps something similar can also be included in the Dutch agreements.

On all these points, it is important that industry is encouraged to take the measures in scope 2 (more sustainable energy supply and energy savings) and scope 3 (residual heat, climate-neutral raw materials). In some cases, this will require financial support.

[7] In recent years, PPP links have disappeared; we really need them again now.
[8] Knowledge and Innovation Agenda (H8), on which the Dutch government's innovation budgets are based.