Public CTM Scenario 2030

A scenario based on the publicly available plans of the industry

No one knows exactly what the industry *will* look like in 2030, however, we're starting to get an idea of what it *may* look like. Kalavasta created a scenario in the Carbon Transition Model that contains all publicly available plans of the largest industrial sites. What are the consequences of Tata Steel's DRI path? How much does H-vision contribute to the Dutch emission reduction goal? We invite all partner to explore these questions in a public 2030 CTM scenario, at www.carbontransitionmodel.com.

This scenario is completely open access and available for anyone that is interested in the industrial transition.[1]

Where are we in 2030?

While the scenario probably contains both over- and underestimations of the emission reduction in 2030 for different sites, it gives an impression of the industrial landscape in 2030. We see that the DRI route of Tata Steel could reduce emissions with around 1 Mton. H-vision could contribute a comparable volume, but its full potential is not yet reached in 2030. Various plans for large-scale electrolysis plans at refineries and other chemicals companies are incorporated in the scenario, ranging from 100-250 MW. Finally, some companies (Nobian and Dow) could reach near zero-emissions in 2030 if their plans are executed. What do you think will change between now and 2030?

We invite you to explore this scenario of the Dutch industry landscape in 2030.

The CTM contains 23 large energy intensive sites and 5 waste processing sites that are modelled bottom-up, including atom-balances. Together these sites are responsible for the majority of the industrial emissions. The remainder of Dutch industry has been modelled using a top-down approach based on national energy statistics and site-specific emission data. In this documentation, you can find a brief description of the public plans of each bottom-up modelled site in the CTM and one general approach used to model the remaining industry.

[1] Disclaimer: we have carefully interpreted all public announcements and support all interpretations in this documentation with sources. We cannot guarantee that no misinterpretations have occurred. No input from the industry, other than public announcements, was used to create this scenario. Be aware that this scenario can contain over-ambitious plans, that may not be realized, and may lack plans that are still confidential.

Multi-partner projects

Porthos

Porthos is the first common large-scale CO_2 transport and storage system to be developed in the Rotterdam harbour area. This project will transport CO_2 from industry in the Port of Rotterdam and store this in empty gas fields under the North Sea. In total Porthos will store around 37Mton CO_2. This is approximately 2.5 million tons CO_2 per year for 15 years and is equal to 10% of the total emissions produced by Rotterdam's industrial sector.[2]

The final investment decision was made in October 2023 and the system is expected to be operational from 2026. Air Liquide, Air Products, ExxonMobil and Shell are the four customers who will be suppling CO_2 to Porthos.

If Air Liquide, Air Products, ExxonMobil and Shell would send all their CO_2 to Porthos, a total of around 9 Mton of CO_2 would be captured and stored per year. We have scaled the CCUS so the capacity of Porthos to capture 2.5 Mton is matched. For ExxonMobil the CTM modelling is limited to a maximum capture of 0.47 Mton (16% of its total emissions). For the remaining three companies we have scaled carbon capture to 34% of their total emissions.

H-vision

H-vision is a project that intends to convert waste gases from the Rotterdam industrial cluster into blue hydrogen. The H-vision partners include Air Liquide, Shell, BP and ExxonMobil.[3] H-vision is reported to be able to capture and store 1.3 Mton of CO_2 per year from 2027 and double that by 2032.[4] The CO_2 will be captured and transported via the Porthos pipeline towards a storage site in the North Sea. The CO_2 captured by H-vision is additional to the CO_2 already captured by the Porthos project.[5] As of February 2024, the final investment decision for this project has not been made.

If Air Liquide, Shell, BP and ExxonMobil would all convert their waste gases into hydrogen through H-vision a total of 840 kton of hydrogen would be produced and 6 Mton CO_2 captured and stored. Note that H-vision adds 10% of natural gas to the waste gases. We have scaled the percentage of waste gases converted to hydrogen of the three partners to 22%, so the capacity of H-vision in 2030 to capture 1.3 Mton of CO_2 is matched.

[2] https://www.porthosco2.nl/

[3] The remaining partners are Royal Vopak (hydrogen infrastructure), Detlalinqs (industrial business association), and the Port of Rotterdam Authority

[4] https://www.h-vision.nl/cijfers

[5] https://energeia.nl/porthos-en-h-vision-cruciaal-voor-2030-ambitie-rotterdamse-industrie/

Individual activities

The Dutch government is supporting the industry transition through a series of individual tailor-made agreements with the largest 10-20 industrial emitters. Through these agreements the government will support industry to develop and implement fundamentally new sustainable technologies. The first step in reaching the tailor-made agreements is an *Expression of Principles* which outline the intentions of both parties. These documents are non-binding.

Fertilizers

OCI

According to their *Expression of Principles*, OCI will "reduce its scope 1 CO_2 emissions in the Netherlands by 0.8 - 1.7 Mton before 2030 (versus 2020)".[6]

They describe three pathways to achieve this:

- Producing ammonia from low carbon, circular and renewable hydrogen on site.
- Importing of low carbon circular and renewable ammonia through the Port of Rotterdam.
- Using carbon capture and storage as a transition technology.

In addition, on their website[7], OCI writes: "OCI Nitrogen currently produces grey ammonia using natural gas as feedstock. The facility can introduce circular hydrogen from FUREC in its processes to replace 20% of current natural gas consumption."

We have translated these statements in the following settings:

- Hydrogen is bought rather than produced with an SMR, to lower natural gas consumption with 20%. Percentage of hydrogen bought is increased to 20% or ~36 kton.
- Ammonia import is increased from 0 to 5% (exact number is not given, so assumed).
- Carbon capture of process emissions is increased to from 65 to 80% (exact number is not given, so assumed).

Yara

Yara is committed to reducing their CO_2 emissions by 1.5 Mton in total in 2030 relative to 2020.[8] This will be achieved by:

- **Carbon Capture and Storage:** Yara entered into the first ever cross-border CO_2 transport and storage agreement. From 2035, 800,000 ton of CO_2 will be captured, compressed and liquified in the Netherlands and then permanently stored under the seabed off the coast of western Norway.
- **Green hydrogen:** Installation of a 100MW electrolyser (Haddock) which will produce 14.5 kton of hydrogen.
- **Altering existing assets:** Multiple adjustments are described including replacing burners in plant NA-7 and replacing a steam turbine with an electromotor.

[6] https://www.rijksoverheid.nl/documenten/publicaties/2023/01/26/expression-of-principles-oci
[7] https://www.oci.nl/ammonia-initiatives/furec/
[8] https://www.rijksoverheid.nl/documenten/publicaties/2023/07/11/expression-of-principles-yara

Note not all adjustments can be set in the CTM, instead we have matched the emissions saved through electrification to the expected CO_2 savings outlined in Yara's Climate Roadmap (135 kton).

We have translated these statements in the following settings:
- Electric compression is increased to 15%.
- Carbon capture for process and energetic emissions in increased to 100%.
- Electrolysis is increased to 5% (making 15 kton hydrogen).

Steam Cracking

Shell Moerdijk

In their 2023 *Expression of Principles*, Shell announced its aim to reduce its annual emissions, across the Moerdijk and Pernis sites, by 3.9 Mton in the year 2030 when compared to 2020.[9]

On the Moerdijk site Shell has developed plans for the following projects:

- **Pyrolysis oil upgrader plant**: Increasing the capacity of their pyrolysis oil plant (which converts plastic waste into chemical feedstock) from 30 to 50 kton.
- **Hydrogen (pending investment decisions):** Building a facility to produce hydrogen from residual gases from Park's production processes. This hydrogen would be used to heat the industrial furnaces. CO_2 produced in the process of making hydrogen will be captured and stored.

We have translated these statements in the following settings:

- Production of plastic pyrolysis is increased to 50 kton in the BWE refinery Rotterdam-Moerdijk.
- We have not integrated the production and use of blue hydrogen, since the decision is not final yet.

Dow

In 2022, Dow signed an *Expression of Principles* with the government.[10] In this document Dow outlined their decarbonisation plan featuring three stages:

- **Stage 1: Capturing residual waste gas from the cracker production process**. The residual waste gas will be turned into two separate streams. A CO_2 stream for CCUS and a hydrogen stream that will fuel the production process. "The crackers on the Terneuzen site will be among the first crackers in the world that will be capable to run on 100% hydrogen."
- **Stage 2: Replacing gas turbines with electromotors**.
- **Stage 3: Direct electrification of the crackers**. The technology, called e-cracking, is under development. In collaboration with Shell, TNO and ISPT Dow is investing in the development of e-cracking with the aim to start implementing this technology between 2035-2045. To this end, Dow intends to build a pilot plant between 2025-2030.

We have translated these statements in the following settings:

- All methane (825 kton) is converted to hydrogen (35 PJ) using an ATR and WGS.

[9] https://www.rijksoverheid.nl/documenten/publicaties/2023/04/13/expression-of-principles-shell
[10] https://www.rijksoverheid.nl/documenten/publicaties/2022/12/06/expression-of-principles-dow

    - Waste gases to ATR is increased to 100%.
    - CO to WGS is increased to 100%.
    - Carbon capture is increased to 100%.
- The fuel mix is changed to 100% hydrogen.
- Electrification of processes can be modelled by increasing electric compression to 30% to reduce 300 kton of emissions.
- No electric cracking is expected in 2030.

Sabic

In May 2024 Sabic will close naphtha cracker Olefins 3, the older of its two naphtha crackers.[11] From the CTM modeling we know the oldest cracker has a slightly lower capacity than the newer one.

Sabic is investing in a demonstration plant for large-scale electricity heated steam cracker furnaces in Germany. If this demonstration is successful, they plan to incorporate this technology more broadly.[12]

We have translated these statements in the following settings:

- Production volume is reduced to 55%.
- No electric cracking is expected in 2030.

Inorganic base chemicals

Albemarle

Albemarle has a multi-year plan for the period up to 2030 to reduce its energy consumption and related CO_2 emissions. This plan focuses on heat reuse, electrification and the introduction of more energy-efficient technologies. Abermarle has committed to "invest tens of millions in the coming years in the conversion and new construction of its processes."[13] Examples of steps already taken are:

- The construction of a new energy heart for the generation of steam.
- The optimization of the heat recovery towers in the FCC plant.
- The use of less water in its factories so that less water needs to be evaporated during drying processes.

Note not all adjustments can be set in the CTM, instead we have matched the emissions saved through electrification to the expected CO_2 savings outlined in Albemarle's Climate strategy (Bromine and Catalysis, 27% net reduction by 2030 versus 2019, or 18.9 kton.).[14]

We have translated these statements in the following settings:

- Energy efficiency of processes can be modelled by decreasing the heat required for Abermarle's spray dryer (FCC) from 11.6 GJ/t to 4.9 GJ/t.

[11] https://www.limburger.nl/cnt/dmf20231026_94891367?utm_source=ground.news&utm_medium=referral
[12] https://www.basf.com/global/en/media/news-releases/2022/09/p-22-326.html
[13] https://albemarle.nl/duurzaamheid
[14] https://www.albemarle.com/storage/wysiwyg/albemarle_climate_policy_61.pdf

Nobian

In November 2023, Nobian became the first company to sign a *Joint Letter of Intent* with the Dutch Cabinet.[15] Following the *Expression of Principles*, this is the next stage of reaching a tailor-made agreement.

Nobian's specific targets include an ambition to reach close to zero scope 1 CO_2 emissions in 2030 (a total emissions reduction of 600 kton CO_2 and 440 ton NO_X between 2020 and 2030). This letter elaborates on their previously drawn up sustainability plans for their sites in Delfzijl, Hengelo and Rotterdam:

- **Project 1: Delfzijl** – electrification of two (of the three) steam-driven salt production plants based on heat pump technology (MVR). The third steam-driven plant will continue to be run on steam from external sources (EEW-waste and BGR/Eneco-biomass).
- **Project 2: Hengelo** – replacement of one (of the two) large steam driven salt production plant with two electricity driven plants (MVR). The remaining steam driven plant will continue to use third party steam currently sourced from Twence (municipal waste/ biomass).
- **Project 3: Rotterdam (Botlek) –** Upgrade the remaining 24 electrolysers towards zero gap technology reducing electricity consumption by 15%.

We have translated these statements in the following settings:

- Delfzijl: water evaporation of the brine increased from 15% to 70% MVR.
- Hengelo: water evaporation increased from 15% to 70% MVR.
- Botlek: membrane electrolysis 100% zero gap.

Organic base chemicals

BioMCN

BioMCN is owned by OCI and discussed in OCI's *Expression of Principles*.[16] "BioMCN (Delfzijl) is a producer of (bio-)methanol. OCI's intention is to produce methanol by using hydrogen instead of natural gas. The pathways for acquiring hydrogen include a choice, or mix, between the production of hydrogen (and CO_2) by circular waste-gasification or by purchasing locally produced or imported hydrogen and captured (bio-)CO_2."

We have translated these statements in the following settings:

- CO_2 import is increased to 50%.
- Electrolysis is increased to 50%, hydrogen bought is decreased to 50%.

Air Products

Air Products announced the construction of a second liquid hydrogen plant in Rotterdam[17]. According to the *ontwerpbeschikking*[18], the new plant replaces an existing plant. It is not clear if

[15] https://www.rijksoverheid.nl/ministeries/ministerie-van-economische-zaken-en-klimaat/documenten/publicaties/2023/11/21/joint-letter-of-intent-nobian
[16] https://www.rijksoverheid.nl/documenten/publicaties/2023/01/26/expression-of-principles-oci
[17] https://www.airproducts.com/news-center/2022/09/0921-air-products-to-start-construction-of-second-liquid-hydrogen-plant-in-rotterdam
[18] https://zoek.officielebekendmakingen.nl/prb-2022-1462.html

this is a new SMR/ATR or simply a liquefaction plant. We did not find the public data on the plant sufficient to change any settings of Air Products.

Air products is one of the four Porthos customers.

We have translated these statements in the following settings:

- *Porthos* - carbon capture of process emissions from reforming is increased 55.5%, capturing 404 kton of emissions (34% of total emissions).

Air Liquide

Air Liquide signed an *Expression of Principles* in December 2023, in which they communicated their aim to "reduce its annual industrial CO_2 emissions by 1.05 Mton (+/- 60%) in the year 2030 compared to 2020.[19] To do so they intend to accelerate and mature a portfolio of carbon abatement and energy efficiency projects including:

- **Large-scale renewable and low carbon hydrogen production.** Air Liquide is building two new 200 MW electrolyser sites on the Rotterdam Maasvlakte and in Terneuzen. The two projects will produce a total of around 30 kton of hydrogen per year.[20] The website mentions that the demand for hydrogen is rising, therefore we assume that the hydrogen production of the electrolysis is additional to the current production. In addition Air Liquide is a partner of H-vision and will be converting a portion of their waste gases to blue hydrogen.
- **Carbon capture and storage.** Air Liquide will develop and install a CryoCap unit to capture CO_2 from its hydrogen plant in the Rozenburg site. This will be connected to the Porthos system and should be operational from 2026.[21]

Air Liquide also intends to reduce its industrial NO_x emissions by 10% in 2030 compared to 22 emission levels.

Air Liquide

In this scenario, we only include the Rotterdam site, since the CTM shows results based on industrial clusters and includes an estimation of required infrastructure to a site. Adding a Zeeland-based electrolyzer to the Air Liquide site in Rotterdam will give faulty results.

We have translated these statements in the following settings:

- *H-vision* – additional 4 kton (0.5 PJ) of hydrogen produced for Air Liquide.
    - SMR syngas conversion to hydrogen via WGS is increased by 9% to 66% (corresponding to a 22% increase in CO).
    - Carbon capture of process emissions from reforming is increased by 14.3% to capture 86 kton of emissions.
    - Hydrogen in the fuel mix is increased to 7% to match the hydrogen produced by H-vision (0.5 PJ).
- Increased the percentage of hydrogen produced on-site by electrolysis from 0 to 11%, producing 15 kton, the ratio of SMR and ATR is kept constant.
- Total volume of hydrogen production is increased by 15 kton to 110.5%

[19] https://www.rijksoverheid.nl/ministeries/ministerie-van-economische-zaken-en-klimaat/documenten/publicaties/2023/12/21/expression-of-principles-air-liquide

[20] https://www.airliquide.com/group/press-releases-news/2022-12-21/air-liquide-receives-support-dutch-state-two-large-scale-electrolyzer-projects-netherlands

[21] https://nl.airliquide.com/news/air-liquide-gaat-een-co2-afvanginstallatie-bouwen-om-bij-te-dragen-aan-het-koolstofvrij-maken-van-het-rotterdamse-industriegebied

- *Porthos* - carbon capture of process emissions from reforming is increased by 50,3% to 64,6%, capturing 302 kton of emissions (34% of total emissions).

Air Liquide – BOZ

We are not aware of any public carbon abatement and energy efficiency projects on the Air Liquide Bergen op Zoom site.

AnQore

AnQore aims to reduce its annual CO_2 emissions by 0.4 Mton in the year 2030, compared to the year 2020.[22] In 2020 AnQore's emissions were 0.5 Mton, of which 0.4Mton CO_2 equivalents are from N_2O emissions. It will achieve this through building a new Thermal Oxidizer to process the off-gas from AnQore's production of acrylonitrile.

- N_2O breakdown is increased to 100%.

Fibrant

In 2021 Fibrant achieved the largest industrial CO_2 reduction in the Netherlands since the climate agreement by reducing its NO_x emissions by 75% (in total a 0.6 Mton reduction in CO_2 equivalent emissions).[23] They did so by building in catalytic systems to remove the excess nitrous oxide alongside a regenerative thermal oxidizer which reduces the gas to N_2.

We have translated these statements in the following settings:

- N_2O emissions capture is increased to 82.6%, resulting in total CO2 equivalent emissions of 165 kton (a 0.6) Mton reduction from its total initial emissions of 765 kton).

LyondellBasell

LyondellBasell aims to reduce its annual scope 1 and 2 CO_2 emissions by 0.35-0.55 Mton in 2030, compared to 2020, across its sites in Botlek and Maasvlakte sites.[24]

The largest project Lyondell is investing in is the "Botlek Heat Integration Project" through which it will purchase residual steam from its neighbours, replacing steam generated by natural gas.

We have translated these statements in the following settings:

- Heat bought is increased to 100%, replacing natural gas.

[22] https://www.rijksoverheid.nl/documenten/publicaties/2023/07/13/expression-of-principles-anqore
[23] https://energeia.nl/chemiebedrijf-fibrant-vermindert-jaarlijkse-co-uitstoot-met-0-6-megaton/
[24] https://www.rijksoverheid.nl/ministeries/ministerie-van-economische-zaken-en-klimaat/documenten/publicaties/2023/10/13/expression-of-principles-lyondellbasell

Metals

Tata Steel

Tata Steel signed an *Expression of Principles* with the Dutch government in 2022[25]. Here Tata Steel announced they are "pursuing a direct decarbonisation route towards hydrogen".

It describes that one Blast Furnace will be closed prior to 2030 and a second after 2030: "TSN foresees two further key steps, consisting of the closure of a further blast furnace and related facilities by replacing it with DRI, REF or Recycled Steel facilities as soon as reasonably feasible and viable". We assume that the introduction of DRI is combined with electric arc furnaces[26].

In addition, the *Cluster Energie Strategie* of the *Noordzeekanaalgebied* contained a description of the energy demand of Tata Steel in 2030.[27]

We have translated these statements in the following settings:

- Iron production with the blast furnace is reduced to 50% of the base year and replaced with 50% DRI.
- Within DRI, the ratio of CH_4 and H_2 is determined by matching the energy demand to the data provided in the CES: 35% DRI H_2 and 15% DRI CH_4.
- Steel production is done by 50% electric arc furnaces.

Refineries

Shell Pernis

In their 2023 *Expression of Principles*, Shell announced its aim to reduce its annual emissions, across the Moerdijk and Pernis sites, by 3.9 Mton in the year 2030 when compared to 2020.[28]

On the Pernis site Shell has committed to the following:

- **Hydrogen:** Shell plans to build a 200 MW electrolyzer (Holland Hydrogen I), producing around 18 kton of hydrogen per year.[29] In addition, Shell is a partner of H-vision, see H-vision paragraph.
- **Biofuel refinery**: Building a biorefinery with the capacity to produce 820 kton of sustainable aviation fuels and renewable diesel per year. The Rotterdam biofuels facility is expected to start production in 2024. It will produce low-carbon fuels such as renewable diesel from waste in the form of used cooking oil, waste animal fat and other industrial and agricultural residual products.

We have translated these statements in the following settings:

- *H-vision* – additional 41 kton (5.1 PJ) of hydrogen produced for Shell. *(Shell already produces 44 kton of hydrogen through ATR and WGS).*

[25] https://www.rijksoverheid.nl/documenten/kamerstukken/2022/07/15/22310250bijlage-1-eop-tata-steel-nederland-final-for-signing
[26] https://eurometal.net/tata-steel-picks-hydrogen-dri-eaf-path-for-ijmuiden/
[27] https://openresearch.amsterdam/image/2022/10/17/cluster__energie__strategie__nzkg__sept__2022.pdf
[28] https://www.rijksoverheid.nl/documenten/publicaties/2023/04/13/expression-of-principles-shell
[29] https://www.shell.nl/media/nieuwsberichten/2022/holland-hydrogen-1.html

    - Refinery gas used to produce syngas by is increased from 13.1% to 32% (corresponding to a 22% increase in CO).
    - Conversion of carbon monoxide to hydrogen using the water-gas-shift (CO to WGS) is kept at 100%, carbon capture of this process is increased to 48% (assuming only the CO_2 produced by H-vision is captured).
    - Hydrogen in the fuel mix is increased to 12.2% to match the hydrogen produced by H-vision (5.1 PJ).
- Remaining hydrogen sourcing is set to 100% electrolysis. Hydrogen percentage in feedstock is increased by a further 5.3% (2.2 PJ), resulting in a total hydrogen production by electrolysis of 18 kton.
- Production in the bio, waste and e-refinery is increased to 820 kton (through the hydrotreatment to HVO route).
- *Porthos* - capture 1,321 kton of emissions (34% of total emissions).
    - Carbon capture of emissions from the WGS is increased to 100%.
    - Carbon capture of CO from coking fired is increased to 100%.
    - Carbon capture of CO_2 from coking fired is increased to 100%.
    - Carbon capture of residue gasification is increased to 66.7%.
    - Carbon capture of energetic emissions from the reforming process is increased to 50%, these are the most difficult emissions to capture.

BP

In BP's *Expression of Principles*, signed in November 2023, it announced it would aim to "reduce its annual operational CO_2 emissions by 1,2 Mton (60%) by the end of the year 2030 when compared to the year 2020".[30]

- **Hydrogen:** The largest project BP is undertaking to reduce their emissions is known as "H2-Fifty" and involves installing a 150MW electrolyzer on the Conversion Park at the 2nd Maasvlakte, which will produce 20-30 kton of green hydrogen per year. BP is also a partner in H-vision, and thus will be converting a portion of their waste gases to blue hydrogen.
- **Biofuels:** In February 2023, BP announced it's aim to grow it's biofuels production (focused on SAF) to around 100,000 barrels per day by 2030, as part of this they are building a biofuel plant in the Netherlands which will produce around 10,000 barrels per day (~500 kton p.a.).[31]

We have translated these statements in the following settings:

- *H-vision* - 36 kton (4.4 PJ) of hydrogen produced for BP.
    - Refinery gas used to produce syngas to is increased to 22%.
    - Conversion of carbon monoxide (in syngas) to hydrogen using the water-gas-shift (CO to WGS) is increased to 100%, carbon capture of this process is increased to 100%.
    - Increase hydrogen in the fuel mix to 18.5% to match the hydrogen produced by H-vision (5.7 PJ).

[30] https://www.rijksoverheid.nl/ministeries/ministerie-van-economische-zaken-en-klimaat/documenten/publicaties/2023/11/16/expression-of-principles-bp-rotterdam-refinery
[31] https://www.bp.com/en/global/air-bp/news-and-views/air-bp-news/bp__plans__to__deliver__five__projects__to__increase__SAF__supply.html; https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2021-approximate-conversion-factors.pdf

- Remaining hydrogen sourcing is set to 100% electrolysis. Hydrogen percentage in feedstock is increased by a further 12.5% (3.1 PJ), resulting in a total hydrogen production by electrolysis of 25 kton.
- Production in the bio, waste and e-refinery is increased to 500 kton (through the hydrotreatment to HVO route).

ExxonMobil

In December 2023, ExxonMobile announced it is building a carbonate fuel cell pilot plant on its site in Rotterdam. Carbonate fuel cells capture CO_2 and simultaneously produce electricity, heat and hydrogen. The captured CO_2 will be transported and stored via the Porthos project.

We have translated these statements in the following settings:

- H-vision – additional 51 kton (6.3 PJ) of hydrogen produced for ExxonMobile. *(ExxonMobil already produces 24 kton of hydrogen from natural gas).*
    - Refinery gas used to produce syngas is increased to 22%.
    - Conversion of carbon monoxide to hydrogen using the water-gas-shift (CO to WGS) is kept at 100%, carbon capture of this process is increased to 68% (assuming only the CO_2 produced by H-vision is captured).
    - Hydrogen in the fuel mix is increased to 20.2% to match the hydrogen produced by H-vision (6.3 PJ).
- *Porthos* - capture 473 kton of emissions (16% of total emissions, the maximum possible).
    - Carbon capture of energetic emissions from the reforming process is increased to 100%.
    - Carbon capture of emissions from the WGS is increased to 100%.

Gunvor

Gunvor has shut down the crude distillation unit[32].

In September 2023 Gunvor announced the construction of a large-scale Sustainable Aviation Fuel industry at the Gunvor Energy Rotterdam site in partnership with VARO Energy. The site will have a total production capacity of 350 kton p.a., with a SAF production capacity of 245 kton p.a., alongside a mixture of bio-naphtha and bio-propane. Production is expected to commence by 2026.[33]

We have translated these statements in the following settings:

- CDU and VDU of the existing refinery are set to 0%.
- Production in the bio, waste and e-refinery is increased to 350 kton (through the hydrotreatment to HVO route).

[32] https://www.argusmedia.com/en/news/2206072-gunvor-confirms-permanent-closure-of-europoort-cdus

[33] https://www.varoenergy.com/en/news/varo-announces-plan-to-invest-600m-to-build-major-sustainable-aviation-fuel-manufacturing-facility-in-rotterdam-which-will-meet-up-to-7-of-the-eus-2030-saf-target/

VPR Energy

In 2022 VPR Energy integrated XRG Technologies Xceed system, a dispersed combustion system to inject fuel at high velocity into the chamber, in the refinery's furnace. With this technology VPR energy halved their NOx emissions and reduced their energy consumption by 40%.[34]

We have translated these statements in the following settings:

- Reduction in energy consumption can be modelled by increasing heat recovery from 70 to 100%.

Zeeland Refinery

Zeeland Refinery intends to reduce its scope 1 CO_2 emissions by 1 Mton by 2030 (relative to 2022 in which it emitted 1.6 Mton). The Refinery's strategy involves:

- **Carbon Capture and Storage (CCS):** Zeeland Refinery is building a CCS plant. Once operational, the plant will capture more than 90% of emissions from the two existing hydrogen production units (capturing more than 800 kton per year).[35]
- **Step-wise phasing in of renewable hydrogen production and/or intake on site.** The company recently received a grant for a 264 MW green hydrogen plan on-site.[36] Part of the renewable hydrogen generated will be used internally, and part will be supplied to other industries.
- **Renewable feedstock:** Replacing 10% of its fossil-based feedstock (petroleum) by renewable feedstock in 2030.

We have translated these statements in the following settings:

- Electrolysis is increased to 16.3% (making 13 kton of hydrogen).
- Carbon capture on energetic emissions in the reforming and WGS processes are set to 100%, capturing 658 kton of CO_2. The CTM modelling is limited to this max.
- Production of CDU in the existing refinery is reduced by 10% (equal to 528 kton of fossil oil products).
- Production in the bio, waste and e-refinery is increased to 528 kton (through the hydrotreatment to HVO route).

Waste incineration

Twence

In 2021 Twence received investment aid from the European Commission to capture 100 kton of CO_2 emissions, to be used primarily by greenhouses in the horticulture sector[37]. The project is expected to start capturing and delivering CO_2 in 2024.

We have translated these statements in the following settings:

- Carbon capture of emissions waste incineration is increased to 15.5% (to capture 100 kton of emissions).

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[34] https://www.vitol.com/case-studies/vpr-refinery/
[35] https://engineering.airliquide.com/air-liquide-engineering-construction-supports-decarbonization-zeeland-refinery
[36] https://www.smartdeltaresources.com/en/hydrogen-delta
[37] https://www.twence.nl/projecten/grootschalige-co2-afvang

AVR Rijnmond

AVR is currently applying for funding for a CO_2 plant to capture 100 kton of CO_2 per year.[38]

We have translated these statements in the following settings:

- Carbon capture of emissions waste incineration is increased to 7.15% (to capture 100 kton of emissions).

EEW Delfzijl

EEW has announced its intention to capture 400 kton of CO_2 per year.[39] In 2019 EEW Delfzijl had a particularly low production volume compared to previous and subsequent years.[40]

We have translated these statements in the following settings:

- Waste incineration is increased to 140% to correct for the low production volume in 2019.
- Carbon capture of emissions waste incineration is increased to 50% (to capture 400 kton of emissions).

AEC Moerdijk

Attero is investigating the possibilities of capturing CO_2 emissions. Attero is a partner in the Delta Corridor Project which contains, among other things, CO_2 infrastructure to efficiently store or transport captured CO_2.[41] Attero have not communicated a target volume so we have not changed any settings of AEC Moerdijk.

Waste gasification

RWE: FUREC

RWE: FUREC will produce enough hydrogen to lower natural gas use of OCI by 20%, this translates into approximately 40 kton of hydrogen[42]. FUREC plans to store the CO_2 that is captured[43].

We have translated these statements in the following settings:

- Hydrogen production is increased to 100%.
- Carbon capture for the gasifier and WGS is increased to 100%.

[38] https://www.onderglas.nl/avr-vangt-co2-af-voor-glastuinbouw/#:~:text=AVR%20wil%20op%20termijn%20ook,2%2Dafvang%20is%20beduidend%20lager.
[39] https://energeia.nl/energeia-artikel/40099111/eew-delfzijl-gaat-co-afvangen-en-leveren-aan-industrie
[40] Ministerie van Infrastructuur en Waterstaat (2023). Afvalverwerking in Nederland, gegevens 202
[41] https://www.attero.nl/nl/nieuws/atteros-co2-footprint-2021/
[42] https://www.oci.nl/ammonia-initiatives/furec/
[43] https://www.chemelot.nl/nieuws/rwe-en-john-cockerill-bouwen-proefinstallatie-voor-waterstofproject-furec

Other sectors

For the remaining sectors we have calculated the energy use and emissions based on the Climate and Energy Outlook (KEV 2022).[44] The KEV results were translated into assumptions in the Energy Transition Model to arrive at the final demand per carrier and per sector 2030. The results from this analysis were carried over to this scenario.[45]

[44] https://www.pbl.nl/publicaties/klimaat-en-energieverkenning-2022
[45] https://energytransitionmodel.com/saved_scenarios/15969