14 Climate

14.1 Methodology

14.1.1 Delimitation of study area

The Climate chapter examines both the aspect of climate impact (carbon balance; impact of the project on climate change) and the aspect of climate adaptation (impact of climate change on the project).

The climate is a global phenomenon and defining the study area is therefore not straightforward:

- For the climate impact aspect, the study area is defined at a global level;
- For the aspect of climate adaptation, the study area is defined as the project area and its wider surroundings, bounded by the Scheldt to the west, the Canal Dock to the east, and by the businesses to the north and south.

14.1.2 Description of the reference situation

First, an overview is provided of the available climate scenarios for Flanders in the reference situation. Based on these climate scenarios, the expected climate changes for these regions are outlined. Next, an overview of European and Flemish climate policy is provided. This is because the impact description is then assessed against the stated policy as the current reference to be pursued.

14.1.3 Impact description and impact assessment

There is currently no guideline manual, no assessment framework and no specific assessment criteria for the discipline of Climate in EIAs, which means that no significance level can be assigned to the impact groups under consideration. However, the climate manual is applied/followed to the maximum extent possible. The impact groups are assessed against European, federal and Flemish climate policy.

The relevant regulations concerning impact assessment can be found in the Decree on General Provisions for Environmental Policy (DABM), more specifically in Article 4.3.1 and Annex IIbis to the DABM.

14.1.3.1 Construction phase

As the construction phase has already been partially completed (see schedule in sections 3.1 and 3.2), we indicate below, where relevant, which items have already been carried out or realised. However, the entire project is included in the assessment within the climate chapter. In the context of the construction phase, in particular the site preparation and construction works, a carbon balance will be drawn up for the following impact groups:

Emissions from land use change (already implemented in 2022-2023): removal of vegetation, excavation of the topsoil and forest compensation: the amount of carbon stored in the biomass and in the soil, the CO_2 storage capacity of the project area in its current state and the CO_2 storage capacity of the legally required forest compensation were quantified in a carbon balance.
Emissions from timber transport and soil removal and delivery (already implemented in 2022-2023): based on estimated traffic generation, transport routes and means of transport, an estimate was made of the CO_2 emissions from this transport.

- Emissions from site activities (already started but not yet completed): quantitative calculation of CO_2 emissions from fuel consumption by site machinery, transport of materials and commuting by site personnel. The heating of site huts is considered to have a negligible impact on the carbon balance of the construction phase and is therefore not estimated separately.

- Emissions from material use – the extraction and production of building materials generate an environmental impact. CO_2 emissions will be estimated using the emission factors found in available literature, based on an estimate of the quantities of concrete and steel, which are considered to be the main sources of greenhouse gas emissions for the construction of Project One.

14.1.3.2 Operational phase

For the impact assessment of the operational phase of the ECR and supporting infrastructure, the following impact groups will be discussed:

- Carbon balance:
  - Process-related emissions from the ECR and supporting infrastructure:
    - Carbon balance for assessment against EU ETS benchmark (European Emissions Trading System or EU ETS):
      - The calculated carbon balance is used for process-related CO_2 equivalent emissions and the assessment against the EU ETS product benchmark. Energy studies conducted by IOB and PDC are used for the energy-saving measures applied in Project One's industrial installations. The impact of Project One on the tightening of the EU ETS benchmark is shown. The potential impact of Project One on the carbon footprint of customers is also calculated.
    - Reduction of emissions through the import of green electricity:
      - The purchase of green electricity means eliminating the emissions associated with the import (purchase) of electricity. The impact on the carbon balance of the ECR and supporting infrastructure is shown.
    - Future prospects: The INEOS Group is committed to achieving the EU's 2050 climate and energy targets and reducing net CO_2 emissions to zero. Project One has been designed with *net zero* CO_2 emissions in mind and aims to be the first CO_2-neutral cracker in Europe, playing a role in Antwerp's sustainable industrial future. Project One is currently confident that this trajectory can be achieved within 10 years of the cracker's start-up. For each of the future prospects, the impact on the carbon balance of the ECR and supporting infrastructure and the associated technology and space requirements are discussed:
      - Post-combustion reduction of direct emissions through CO_2 capture: the impact on the carbon balance is discussed on the basis of an energy study carried out by PDC.
      - Pre-combustion reduction of direct emissions through 100% green and/or blue H_2 content in fuel gas.
      - Pre-combustion reduction of direct emissions through partial green electrification of the furnaces in combination with 100% green and/or blue H_2 content in fuel gas.
  - Emissions from administrative building: the sources of CO_2 emissions from the administrative building are described on the basis of an energy study carried out by the architectural firm.
  - Emissions from commuting by Project One employees, transport of raw materials and products by Project One: qualitative description of the sources of CO_2 emissions and, where relevant and possible, a quantitative calculation of CO_2 emissions.
- Climate adaptation:
  - Flooding, water supply, climate resilience of industrial installations and heat stress: the consequences of climate change can have an impact on the project area itself. These effects will be described (semi-
) described quantitatively, based on, among other things, the maps and figures on the VMM's Climate Portal Flanders, the water balance for the project and the surface area of paved surfaces in the project area.

14.1.3.3 Life Cycle Thinking

In the climate chapter, Life Cycle Thinking is applied to Project One, with a focus on the use of raw materials and products, upstream and downstream of Project One. Project One will bring ethylene to market. A project EIA, as defined by European and Flemish regulations, deals with the effects of a project and not those of a product. The emissions resulting from the use of raw materials and products upstream and downstream of the project should therefore not be analysed in an EIA.

However, the climate chapter goes beyond what is required by the relevant regulations. It has been decided to apply Life Cycle Thinking. Since Project One will bring ethylene to market, the Life Cycle Thinking chapter discusses the climate impacts that occur during the life cycle of the end product ethylene – upstream and downstream of Project One – in a qualitative manner. The application of Life Cycle Thinking is valuable, given that production and consumption influence each other due to the reality of complex, interconnected value chains.

The aim of this chapter (§ 14.5) is to identify the most significant greenhouse gas emissions of the end product throughout its entire life cycle and to indicate where the main challenges lie in terms of the efficient use of raw materials and products, in line with European and Flemish climate policy.

14.2 Reference situation

14.2.1 Climate scenarios and expected climate change

14.2.1.1 Climate scenarios and uncertainties[133]

The climate scenarios for Flanders are based on calculations from:

- global climate models
- regional (European) and local (Belgian) climate models
- multiple global RCP scenarios

RCP stands for Representative Concentration Pathways. These scenarios take into account the different levels of ambition in global climate policy. There are scenarios that assume few measures and few technological breakthroughs, as well as scenarios with very ambitious climate policy. In Flanders, three variants are used – a low (L), medium (M) and high (H) scenario – to cover the existing uncertainties in the climate models and RCP scenarios as well as possible.

When we list all currently available climate model results relevant to Flanders, the high-impact scenario corresponds to the upper limit of the 95% confidence interval calculated on the basis of the entire range of climate model projections for Belgium: 95% of those results give a lower estimate of climate change and 5% an even higher one. The high-impact scenario used corresponds to the internationally used RCP8.5 greenhouse gas scenario. The low variant indicates the lower limit of the 95% confidence interval and outlines an optimistic climate projection. The middle climate scenario corresponds to the median (or middle) of all climate model projections.

The high-impact climate scenario is a 'business-as-usual' scenario for global greenhouse gas emissions and concentrations, in which the current emissions trajectory continues and humanity fails to transition to a global low-carbon economy in the coming decades.

The high-impact scenario takes into account a global average temperature increase of between 3.2 and 5.4 degrees Celsius. °C by 2100, compared to the pre-industrial era. The actual climate change will most likely be somewhere between the current climate and what the high-impact scenario indicates. This can already be seen in the developments and will gradually continue in the coming decades.

133 Source: VMM Climate Portal

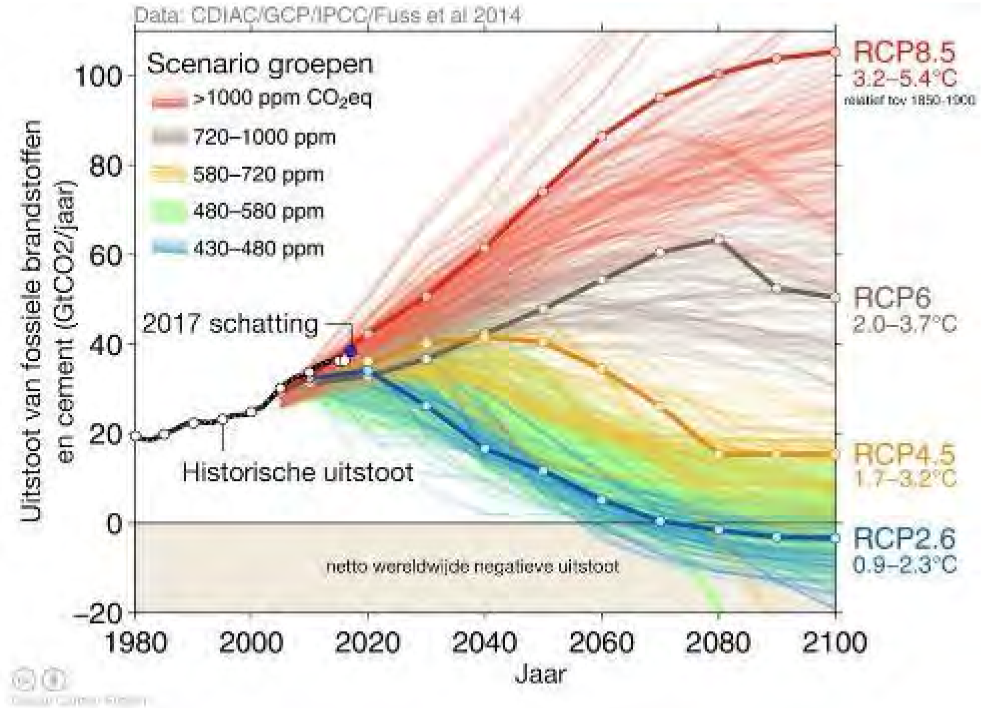

Figure 14-1: CO2 emissions according to the RCP scenarios (colours) and actual emissions (black) (Source: Climate Portal VMM)

What the actual climate will be like in 2100 really depends on global greenhouse gas emissions over the next few decades. Global efforts will have a significant impact on this. However, if Flanders wants to anticipate possible climate change, the high-impact scenario – which can no longer be ruled out – offers a good frame of reference for making our region more resilient and climate-proof.

14.2.1.2 Expected climate changes[134]

In order to assess Project One's specific vulnerability to climate change, an overview of the expected climate changes in Flanders is provided below, based on the various climate scenarios for Flanders and Belgium:

- A warmer climate: all VMM forecasts (2015) show an increase in both the annual average temperature (from +0.3°C (L) to +3.6°C (H) by 2050 compared to the year 2000) and seasonal temperatures (from 0.4°C (L) to +3.1°C (H) in winter and from +0.1°C (L) to +4.5°C (H) in summer by 2050 compared to the year 2000);
- Change in seasonal precipitation: a change of -26% (L) to +9% (H) in 2050 in summer compared to the year 2000 and a change of -0.6% (L) to +19% (H) in 2050 in winter compared to the year 2000;
- More periods of intense rain in winter and heavy thunderstorms in summer, increasing the risk of flooding;
- More frequent heat waves in summer;
- Lower river flows in summer due to decreasing summer precipitation combined with greater evaporation, creating risks of water shortages. Calculations of climate scenarios for Flanders indicate a future decline in low water discharges along watercourses for all river basins studied.
- In addition to changing flood risks, changing water levels along the coast on the one hand and changing catchment areas on the other will lead to changes in salt concentrations and also in the boundary between salt and fresh water. Both along the coast and inland, this can lead to changes in the

[134] Sources: klimaat.be and MIRA Climate Report 2015 VMM

habitats. Physiological effects are also expected for certain animal and plant groups, which in turn may have consequences for the food chain of ecosystems;
- An expected rise in sea level along the Belgian coast;
- Sea level rise and increased storm surges not only increase the risk of flooding along the Belgian coast, but also along the rivers connected to the North Sea. This is the case, for example, along the Scheldt estuary, where the project area is located. Flood conditions in such areas are also determined by a combination of factors in the upstream and downstream areas. Strong north-westerly winds in particular can cause extreme storm surges in combination with heavy rainfall inland, which can lead to even greater increases in water levels and flood flows.

For Belgium, the RMI compiled the report 'Climate Report 2020: from climate information to climate services' as an update to the previous 'Eye on the Climate' report from 2015. This report also examined the various parameters and their effect on the climate in Belgium. The changes for the various parameters are expressed in relation to a 30-year historical period (1961-1990 for temperature, and 1976-2005 for the other parameters). The figures in this report are in line with the calculations of the VMM (2015), such as:

- Depending on the scenario, the average temperature for Belgium will rise by 0.7°C to 5.0°C, with an increase mainly in the average temperature during the winter period.
- In terms of precipitation, winters are expected to become significantly wetter.
- In the second half of the century, at least one heatwave per summer is expected (regardless of location in rural, suburban or urban areas), with the RCP8.5 scenario in the centre of Brussels by 2100:
  - 3 times more heat waves;
  - twice as intense heat waves;
  - 50% longer heat waves.

14.2.2 European, Federal and Flemish climate policy

European and Flemish climate policy focuses on the 2030 and 2050 time horizons, described separately below.

14.2.2.1 Horizon 2030

Europe

In line with the European Green Deal to become the first climate-neutral economy by 2050 (see § 14.2.2.2.2), a **more ambitious target for 2030** was set**.** On 29 July 2021, the new **European Climate Law** came into force. This law increases the EU target for reducing greenhouse gas emissions by 2030 from 40% to at least 55% compared to 1990 levels. The increase in the European 2030 reduction target from 40% to (at least) 55% obviously also has consequences for the targets of the Member States. The target for the ETS sectors was increased from 43% to 62% reduction (in 2030 compared to 2005). In July 2021, the Commission published a proposal to amend the **Effort Sharing Regulation**, proposing new reduction targets for certain sectors (excluding ETS sectors) for the various Member States. For Belgium, this amounts to an increase in the original target for non-ETS sectors from 35% to 47% reduction (in 2030 compared to 2005).

On 14 July 2021, the **'Fit for 55' package** was published. This comprises a series of legislative proposals to align EU legislation with the 2030 climate target. Additional legislative proposals are expected.

In 2023, the ETS Directive was revised. Among other things, this created a new emissions trading system, ETS2. This emissions trading system covers CO2 emissions from fuel combustion in buildings, road transport and additional sectors not covered by the existing EU ETS.

The Carbon Border Adjustment Mechanism (CBAM) is an EU tool designed to put a fair price on CO2 emissions during the production of carbon-intensive goods entering the EU and to encourage cleaner industrial production in non-EU countries.

For the time being, this legislation only applies to trade in steel, cement, aluminium, fertiliser, electricity and hydrogen. However, the EU has plans to extend the application of the CBAM to other sectors, including possibly the chemical industry.

The **LULUCF Regulation**, which regulates greenhouse gas emissions and removals from land use, land use change and forestry, sets an EU target for carbon removal through natural carbon sinks of net –310 million tonnes of CO_2 equivalent in 2030. Specific targets have been set for each Member State.

Belgium (federal level)

At the end of 2019, Belgium submitted the final version of its National Energy and Climate Plan (2021-2030) to the European Commission. This plan sets out the national targets and objectives, as well as the policy guidelines and measures. It covers the following topics:

- Decarbonisation and Energy Efficiency
- Energy security
- Domestic energy market
- Research, innovation and competitiveness

This Energy and Climate Plan was fully approved in 2023. The action plan also endorses the target of reducing greenhouse gas emissions by 55% in 2030 compared to 1990 levels. For ETS sectors, this means, for example, the gradual phasing out of subsidies for fossil fuels. In order to provide these sectors with sufficient green electricity and enable the phasing out of fossil fuels, the federal government is focusing, among other things, on the North Sea as a green power plant of the future and on increasing the electricity connection rate with neighbouring countries.

In 2023, the European Commission assessed the initial progress towards climate neutrality and related adjustments. The Commission believes that current progress towards climate neutrality is still insufficient, despite the downward trend in greenhouse gases. Emissions from buildings and transport, for example, still need to be reduced significantly. Progress in agriculture is still too slow and the trend for carbon sinks has deteriorated in recent years.

As Belgium had not drawn up national energy and climate plans in time, no recommendations were made by the Commission in this regard. According to the Commission, Flanders, for example, needs to update and raise the ambition and quality of its national long-term strategy. This can be achieved by clarifying Belgium's long-term climate neutrality target and by underpinning Belgium's emission reduction and removal enhancement targets in individual sectors with credible policies and measures.

Flanders (Flemish level)

On 9 December 2019, the Flemish Government definitively approved the **Flemish Energy and Climate Plan 2021-2030**. On 12 May 2023, the update to this initial VEKP was approved by the Flemish Government. With this plan, Flanders commits to the following objectives:

- Greenhouse gas reduction in the ESR sectors (emissions from transport, households, trade & services and agriculture): -40% GHG emissions in 2030 compared to 2005;
- LULUCF sector: comply with the new regulation, i.e. the 'no-debit rule' for the period 2021-2025, and contribute to the 320 kt CO^3-eq additional storage by 2030;
- Energy savings (Article 7 of the Energy Efficiency Directive): 91.845 TWh
- Renewable energy: 31,974 GWh in 2030

In the autumn of 2022, the Flemish Government reached an agreement on an integrated **Flemish climate adaptation plan for 2030**, with a view to achieving a climate-proof Flanders by 2050. The aim of the Flemish Adaptation Plan is to gain an understanding of how vulnerable Flanders is to climate change, to increase Flanders' resilience to the effects of climate change and to adapt Flanders as effectively as possible to the expected effects. The plan focuses primarily on the approach to and management of water, e.g. promoting circular water consumption in order to make the best possible use of the available water.

Project One belongs to the ETS sector and is subject to the EU ETS system, which is described below. Due to the vegetation removal and land use change in Project One, the policies for the LULUCF sector are described below.

14.2.2.1.1 ETS for industrial installations

EU ETS system

Since 1 January 2005, the European Union has had an emissions trading system (EU ETS) for industrial installations. The system applies to large installations (with a thermal input of more than 20 MW) including those active in industry, electricity production and aviation. The ETS covers more than 11,000 installations and accounts for around 45% of European CO_2 emissions.

The principle of the EU ETS system is as follows[135]:

- In emissions trading under an absolute emissions cap ("cap-and-trade"), an annual emissions cap is set for a number of sectors and installations. By setting an absolute limit on emissions and linking this to emissions allowances, a scarce commodity is created that also has economic value. In the EU ETS, an emission allowance represents the right to emit one tonne of CO_2. Trading emission allowances should result in emission reductions being achieved at the lowest possible cost to industry. The idea is to achieve emission reductions where they are cheapest and to minimise the total cost of climate policy through trading. At the time of writing this chapter (mid-February 2024), the price is approximately 54 euro/tonne CO_2.
- Some of the emission allowances are allocated directly to the operators of the installations and some are auctioned. Since 2013, harmonised allocation rules have been applied throughout the EU (before 2013, allocation was still carried out by the Member States). The share of free emission allowances has decreased each year, to 30% in 2020. In addition, an allocation reserve is established for new entrants (and for the expansion of existing installations). The mechanism for allocating free emission allowances to installations is described below.
- Every year, the emission reports for each installation are verified, first by independent verifiers and then by the competent Belgian authorities.
- There is no maximum emission limit per installation. Operators must surrender as many allowances each year as they have actually emitted.
- The emission allowances and transactions involving those allowances are recorded in the European Greenhouse Gas Register.
- Revenues from the auctioning of ETS emission allowances amounted to more than €14 billion in 2019. Member States spent (or earmarked) a total of 77% of these revenues on specific climate and energy-related objectives in 2019[136].
- Under the EU ETS Directive for phase 4 of the EU ETS system (2021-2030), two new funds were established to support energy-intensive industrial sectors and the energy sector in the transition to a low-carbon economy:
    - The innovation fund will support the initial market development and demonstration, on a commercial scale, of innovative technologies and breakthrough innovation in EU ETS sectors, including innovative renewable energy sources, energy-intensive industries, carbon capture, utilisation and storage, energy storage, as well as substitute products and cross-sectoral projects.
    - The modernisation fund will support investments in the modernisation of the energy sector and broader energy systems in ten lower-income Member States.

Rules for allocating free emission allowances to industry[137]

[135] Source: klimaat.be
[136] Source: Brussels, 18.11.2020. COM(2020) 740 final. Report from the Commission to the European Parliament and the Council. Report on the functioning of the European carbon market.
[137] Source: energiesparen.be

Phase 4 of the EU ETS system runs from **2021** to **2030**. The rules for free allocation of emission allowances were changed in phase 4 compared to the previous phase 3 (2013-2020), so that the chance of the amount of free emission allowances being as high as in phase 3 would be virtually nil. As in phase 3, the free allocation of emission allowances is calculated on the basis of a (historical) activity level, a benchmark value, and exposure to the risk of carbon leakage (in certain sectors there is a risk of activities being relocated outside the EU), with a number of changes:

- Activity level: measures have been taken to ensure better alignment between developments in activity levels on the one hand and allocation on the other. Firstly, the trading period 2021-2030 is divided into two five-year allocation periods (2021-2025 and 2026-2030), each with its own reference period. Secondly, within each allocation period, the allocation will be adjusted more quickly when activity changes compared to the historical reference period.
- Benchmarks:
  - The benchmark values reward the most efficient installations in each sector. These benchmark values for greenhouse gas emissions were developed for each product, where possible. A product benchmark is based on the average greenhouse gas emissions of the 10% best-performing installations producing the product in question in the EU and EEA-EFTA countries[138] . The benchmarks are based on the principle of "one product = one benchmark". This means that the methodology does not vary according to the technology or fuel used, the size of an installation or its geographical location.
  - Installations that meet the benchmarks and are therefore among the most efficient installations in the EU will, in principle, be allocated all the emission allowances they need to cover their emissions free of charge. Installations that do not meet the benchmarks will receive fewer emission allowances than they need, requiring them to take one or a combination of the following measures:
    - Implementing emission reduction measures;
    - Purchase additional allowances or credits to cover emissions.
  - The benchmark values are tightened for each allocation period based on the observed improvement in greenhouse gas intensity in the 10% most efficient installations. The current benchmarks were published in the Commission Implementing Regulation on 12 March 2021[139] . For Project One, the benchmark for steam cracking applies.
  - Since the requested emission allowances for all industrial installations in the EU exceed the total amount of free emission allowances available, the emission allowances per installation are reduced by the same percentage for all installations. This is the cross-sectoral correction factor that has been applied since 2013. In 2013, the correction factor was approximately 11%. As the amount of free emission allowances decreases each year, the correction factor increases each year. In 2020, the correction factor was approximately 22%. From 2021 onwards, the linear reduction factor was tightened to 2.2%. From 2024 to 2027, the linear reduction factor will be further tightened (4.3%). This is a result of the Fit for 55 package. After that, the linear reduction factor will be 4.4%. This reduction factor ensures that the cap decreases annually by a specific number of million allowances (e.g. by 48 million allowances from 2021). In addition, in 2024, the cap will be reduced by 90 million emission allowances on a one-off basis. In 2026, it will be reduced again by 27 million emission allowances.
- Risk of carbon leakage: an updated carbon leakage risk list has been published for 2021-2030[140]. Sectors on this list will be allocated emission allowances equivalent to 100% of the relevant benchmark free of charge. Project One belongs to the industry 'Manufacture of other basic organic chemicals' (NACE code 2014). This sector is included in the carbon leakage risk list. For other sectors, the free allocation of emission allowances will be limited to 30% until 2026 and then phase out linearly (0%) by 2030 (with the exception of district heating).

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[138] The European Economic Area was established following an agreement between the European Union and the European Free Trade Association (EFTA) (excluding Switzerland). The aim of the EFTA is to promote free trade between member states. The EFTA includes Liechtenstein, Norway, Iceland and Switzerland.

[139] Commission Implementing Regulation of 12 March 2021 establishing revised benchmark values for the free allocation of emission allowances for the period from 2021 to 2025 pursuant to Article 10a(2) of Directive 2003/87/EC of the European Parliament and of the Council.

[140] Commission Delegated Decision (EU) 2019/708 of 15 February 2019 supplementing Directive 2003/87/EC of the European Parliament and of the Council as regards the determination of sectors and subsectors deemed to be exposed to a risk of carbon leakage for the period from 2021 to 2030.

- The CBAM has entered into force and currently only covers imports of certain goods and selected precursors whose production is carbon-intensive and poses the greatest risk of carbon leakage (cement, iron, aluminium, fertilisers, etc.).

14.2.2.1.2 LULUCF

LULUCF is the abbreviation for Land Use, Land Use Change and Forestry and encompasses the emission and capture of carbon into and from the atmosphere through the use of soil, forests, plants, biomass and wood. The way in which land use is organised has a direct impact on atmospheric CO2 concentrations. After all, atmospheric $_{CO2}$ that is stored in soils and (long-lived) biomass does not contribute to climate change. Better land use and management can slow down climate change, while careless land use can actually exacerbate it. For the first time, LULUCF also forms a separate pillar of the European Union's climate policy.

The LULUCF Decision No 529/2013/EU[141]entered into force in June 2013. This Decision establishes accounting rules for emissions and removals from the LULUCF sector. The subsequent LULUCF Regulation (EU) 2018/841 entered into force in July 2018[142] , builds on the existing accounting rules and aims to update and improve them for the period from 2021 to 2030. The target applicable to all European Member States for the period 2021-2030 is the so-called **'no-debit rule**'. This means that, according to the rules defined in the LULUCF Regulation, the existing carbon stocks at the beginning of the period must at least be maintained at the end of the period, subject to the flexibility provided for. This does not mean that no land use category may cause emissions, but it does mean that carbon stocks as a whole may not decrease (taking into account the accounting rules described in the LULUCF Regulation). The definition of 'carbon stock' in the LULUCF Regulation is as follows: *'carbon stock' means the mass of carbon stored in a carbon pool.*

The LULUCF Regulation sets the annual net emissions or net removals for two sub-periods, namely 2021–2025 and 2026–2030. Member States that record a surplus receive credits for this and can sell them to Member States that record a deficit. Another option is to use these credits – to a limited extent – to meet the target set by the Effort Sharing Regulation (ESR). This flexibility – from LULUCF to ESR – amounts to 380 ktonnes of CO2 equivalent per year for Belgium as a whole. Conversely, any deficit must be offset by purchasing LULUCF credits from Member States (or regions) that have a surplus or by using – without restriction – their own emission allowances from the ESR sectors.

A revision of the LULUCF Regulation was approved by the Council on 28 March 2023. As a result of the revision of the LULUCF Regulation, the no-debit rule will be amended from 2026 onwards, and the accounting rules will be abandoned. For the calculation of the LULUCF inventory, net emissions/storage will be used in the period 2026–2030, without the application of certain accounting rules. The new 2030 target is expressed as additional storage to be achieved compared to the average storage in 2016–2018. For Belgium, this was set at -320 kt CO2-eq additional storage by 2030, on top of the average storage (negative emissions) in the period 2016–2018, which amounted to -1032 kt CO2-eq for Belgium (based on the figures reported in 2020).

Flanders has set itself the objective of complying with the requirements of the new Regulation in a Belgian context, i.e. the no-debit rule for 2021-2025, and contributing to the 320 kt CO2-eq additional storage by 2030.

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[141] Decision No 529/2013/EU of the European Parliament and of the Council of 21 May 2013 on accounting rules for greenhouse gas emissions and removals resulting from activities relating to land use, land use change and forestry and on information concerning actions relating to those activities
[142] Regulation (EU) 2018/841 of the European Parliament and of the Council of 30 May 2018 on the inclusion of greenhouse gas emissions and removals from land use, land use change and forestry into the 2030 climate and energy framework, and amending Regulation (EU) No 525/2013 and Decision No 529/2013/EU (Text with EEA relevance)

Deforestation is a major source of emissions within the LULUCF sector. Reforestation, on the other hand, increases carbon storage, but this is a slow process. Long-standing grasslands also have very carbon-rich soils. These soils sometimes contain even more carbon than forest soils. Furthermore, (semi-)natural grasslands and wetlands contain high amounts of carbon. When land use categories change, carbon losses usually occur much faster than the accumulation of new carbon stocks. In general, however, LULUCF policy dictates that avoiding deforestation is more efficient than compensating for deforestation through new afforestation. This also applies to long-standing grasslands. In terms of carbon storage, it is also more beneficial for wetlands to preserve existing wet areas than to replace them with rewetting elsewhere. These carbon stocks should be preserved as much as possible if the LULUCF target is to be achieved.

The Flemish greenhouse gas inventory[143]estimated the evolution of emissions and storage by the various land use categories over the period 1990-2016. This evolution is shown in Figure 14-2 and described below:

- Forests are the largest 'sinks' that remove CO_2 from the atmosphere.
- The main source of greenhouse gases in the atmosphere is the conversion of grassland to arable land. Arable land has been a rapidly increasing net source of emissions since 1990.
- The second most important source of greenhouse gas emissions is the conversion of forests and grasslands to buildings and infrastructure. The area covered by buildings and infrastructure has been gradually increasing since 1990. Increasing urbanisation of areas explains this growth, and the conversion of grassland and forests to buildings and infrastructure causes emissions of carbon stored in biomass and soils to be released into the atmosphere.
- The overall trend is an increase in net sources of CO2 emissions and a decrease in net removal of CO_2 from the atmosphere since 1990. In 1990, there was net storage in the LULUCF sector. In 2021, CO2-equivalent emissions in the LULUCF sector amounted to +28 ktonnes CO2-eq (>0 emissions; <0 storage).

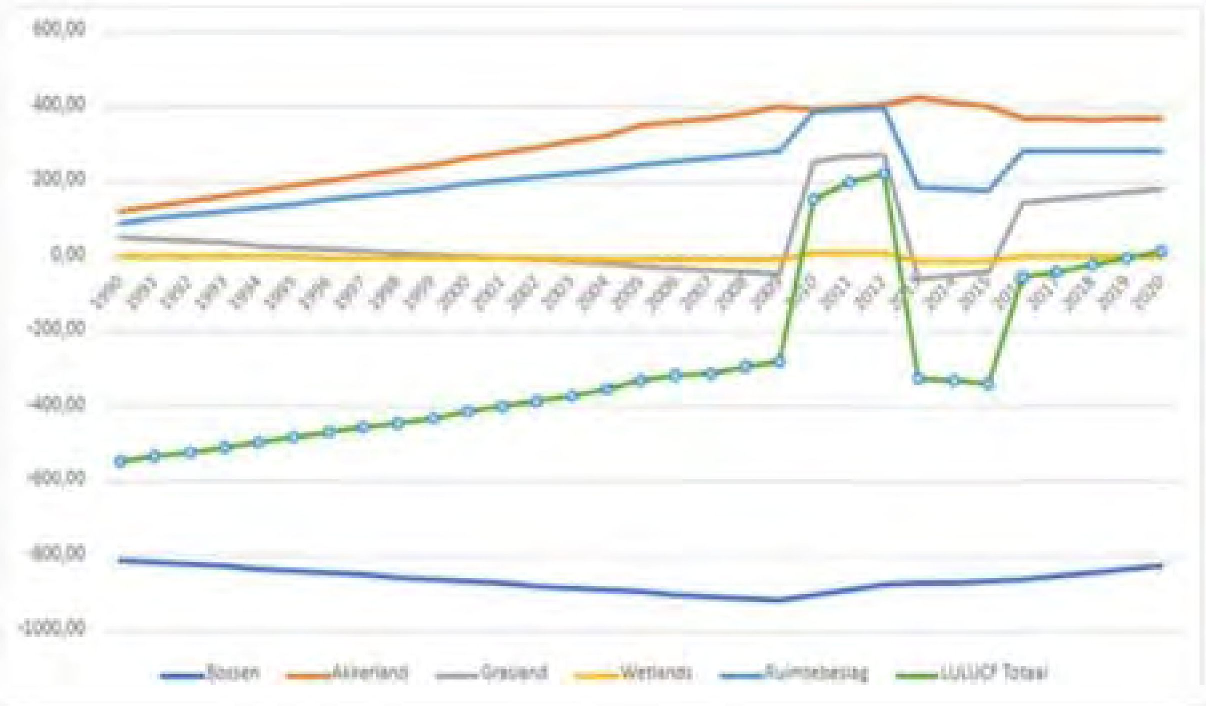

Figure 14-2: Evolution of emissions (Y>0) and storage (Y<0) by different land use categories as included in the Flemish greenhouse gas inventory (1990-2020, in kton CO2-eq)

143 Flemish Environment Agency (2018), Greenhouse gas emissions in Flanders, 2000-2016

14.2.2.1.3 Circular economy

The contribution of the circular economy to climate policy

The circular economy forms a transition framework in the Flemish Energy and Climate Plan 2021-2030. In order to achieve a complete transition to a low-carbon industry by 2050, a major industrial transition will have to take place in the coming decades, not only in Flanders but worldwide.

Circular economy is a concept that originated in waste and materials policy. Traditional waste policy focused on processing waste materials in the most environmentally friendly way possible. Materials policy focuses on designing and organising material cycles that can, in principle, continue indefinitely to meet our needs. Waste materials become new raw materials and products are designed to be recyclable and/or consist of recycled materials. However, the circular economy is about more than just recycling. It is also about meeting our needs with fewer resources. To this end, we need to thoroughly rethink the products and the systems in which they are used: reusability, dismantlability for repair and replacement, the introduction of product-service combinations, the support of other consumption models based on shared use, etc.

The climate challenge is not just an energy issue; this perspective must be complemented by a focus on the underlying drivers of high energy demand, namely high material consumption resulting from a linear economy. After all, more than half of Flanders' greenhouse gas emissions are material-related: 55 to 65% of emissions come from waste disposal, food production and storage, goods transport, production goods and fuels, compared to 34 to 45% of emissions from residential and non-residential energy consumption and passenger transport. The Flemish Energy and Climate Plan 2021-2030 frames the climate challenge as a materials issue and, by extension, a challenge caused by a linear economy. This framework opens up perspectives for proposing new solutions for greening the economy.

14.2.2.2 Horizon 2050

14.2.2.2.1 Global carbon budget

The Paris Climate Agreement aims to keep global warming well below 2°C (compared to the pre-industrial period) and to pursue efforts to limit this temperature increase to 1.5°C. In order to limit global warming to 1.5°C – a threshold that the IPCC, the United Nations' scientific climate panel, considers safe – it is essential to be carbon neutral by 2050. This objective was also set out in the 2015 Paris Climate Agreement, which was signed by 195 countries, including the European Union.

Mitigation targets are quantified by the IPCC in the so-called "carbon budget", which links cumulative CO2 emissions to a global average temperature increase. The remaining carbon budget of approximately 420 $_{GtCO2}$ corresponds to a 2/3chance of limiting global warming to 1.5°C. The remaining carbon budget of approximately 580 $_{GtCO2}$ corresponds to a 1/2 chance of limiting global warming to 1.5°C. The remaining carbon budget is defined here as cumulative CO2 emissions from the beginning of 2018 until the time of achieving global carbon neutrality, defined in terms of a change in global average temperature increase. Staying within the carbon budget of 580 $_{GtCO2}$ implies achieving carbon neutrality within 30 years. Staying within the carbon budget of 420 $_{GtCO2}$ implies achieving carbon neutrality within 10 to 15 years (between 2030 and 2035).

14.2.2.2.2 European long-term strategic vision for a prosperous, modern, competitive and climate-neutral economy

In 2018, the European Commission published the **European strategic long-term vision** for a prosperous, modern, competitive and **climate-neutral economy**[144] . The aim of this long-term strategy is to confirm Europe's commitment to taking the lead in global climate action and to present a vision for achieving greenhouse gas neutrality by 2050 through a socially just and cost-effective transition. This vision is based on the following pillars:

- make optimal use of the benefits of energy efficiency, including zero-emission buildings;
- optimising the deployment of renewable energy sources and the use of electricity to make Europe's energy supply completely carbon-free;
- embracing clean, safe and connected mobility;
- a competitive European industry and the circular economy as a crucial prerequisite for reducing greenhouse gas emissions;
- developing adequate smart grid infrastructure and interconnections;
- fully exploiting the benefits of the bioeconomy and creating essential carbon sinks;
- addressing remaining CO2 emissions through carbon capture and storage.

14.2.2.2.3 European Green Deal

During the international climate summit at the end of 2019 (COP25 in Madrid), the European Commission launched its ambitious **"European Green Deal" plan**. This plan aims to make Europe the first climate-neutral continent by 2050, with net greenhouse gas emissions of zero. At the COP28 UN Climate Conference in Dubai, European Union negotiators reached agreement with partners around the world on accelerating the transition to renewable energy and reducing emissions by 43% by 2030. They also agreed to set the world on track to achieve net-zero emissions by 2050.

The Green Deal is essentially a roadmap that will help the EU transition to a fair and prosperous society with a modern, resource-efficient and competitive economy, in which economic growth is decoupled from resource use.

This plan aims to tackle major challenges in the areas of the environment, climate, biodiversity and sustainability, with a focus on social equality. To succeed in this endeavour, the transition to a circular economy is one of the key elements.

[144] Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee, the Committee of the Regions and the European Investment Bank. A Clean Planet for All. A European strategic long-term vision for a prosperous, modern, competitive and climate-neutral economy. COM/2018/773 final.

The Green Deal is an integrated and cross-cutting strategy covering almost all policy areas:

Figure 14-3: European Green Deal

In order to meet the set ambitions, the following steps forward have been or will have to be taken
, including:

- the development of a **climate law**, which legally establishes that Europe will be climate neutral by 2050 and will meet its long-term objectives. The European Climate Law was approved on 24 June 2021;
- the development of a **new action plan for the circular economy** (approved in March 2020);
- the revision of all relevant **climate directives** (emissions trading - ETS, renewable energy, etc.);
- a legislative proposal to reduce **methane emissions** in the **energy sector** (bill presented in October 2021);
- a proposal to revise the *Energy Taxation* Directive;
- the development of a new, more ambitious **EU Adaptation Strategy** (approved in February 2021).

14.2.2.2.4 Federal Climate Strategy 2050

The strategy and targets at federal level are based on the long-term strategies developed by the Flemish, Walloon and Brussels governments. This resulted in a Belgian climate strategy for 2050 and a vision document.

The 'Belgian Long-Term Strategy' memorandum refers, among other things, to the approach to reducing greenhouse gases by avoiding carbon leakage.

The vision document 'Vision and strategic projects for a low-carbon Belgium by 2050' refers, among other things, to recorded where the industrial sector stood in 2017 in terms of emissions:

- -32% compared to total industrial GHG emissions relative to 1990
- 30% of total industrial GHG emissions came from the chemical industry

However, the memorandum also refers to the vision of achieving climate neutrality within the industrial sector. The main focus here is on:

- Circular economy (e.g. focusing on the sharing economy)
- Energy efficiency and new technologies and raw materials (including: switching to innovative low-carbon processes, fuel switching and raw material switching)
- Industrial symbiosis

At the same time, a roadmap is being developed to guide the modernisation of Belgium's industrial sectors and developments in line with the transition to climate neutrality. In addition, a vision and framework for the use of biomass, hydrogen, e-fuels and carbon storage is also being provided. A national industrial strategy for a bio-economy is also being developed. This is based on biomass products that do not add extra carbon to the atmosphere when processed at the end of their life cycle.

These components are virtually identical to the Flemish government's vision for the future.

14.2.2.2.5 Flemish climate strategy 2050

The **Flemish climate strategy – which runs until 2050** – was approved by the Flemish Government on 20 December 2019. In this Flemish Climate Strategy 2050, Flanders recognises and endorses the need to limit global temperature rise to well below 2°C compared to pre-industrial levels, and to make efforts to limit the increase to 1.5°C compared to pre-industrial levels. Flanders aims to reduce greenhouse gas emissions from sectors not covered by the EU ETS (so-called non-ETS sectors) by 85% by 2050 (compared to 2005), with the ambition of evolving towards complete climate neutrality. For the ETS sectors, the Flemish Region is complying with the context set by Europe for these sectors, with increasingly tight emission allowances under the EU ETS, and is committed to supporting companies in making a far-reaching transition to climate-friendly production systems.

The Flemish Climate Strategy 2050 sets out an indicative contribution for each sector, as shown in Table 14-1, and a vision for the future for the year 2050. The following vision for the future applies specifically to the industrial sector:

- Continued commitment to efficiency improvements: First and foremost, industry will continue to focus on energy efficiency, energy saving and process improvements.
- A circular economy by 2050: The circular economy serves as the basic framework for the industrial sector. A far-reaching commitment to the circular economy can make a very significant contribution to Flanders' climate ambitions. The Flemish Climate Strategy 2050 understands this to mean that products are manufactured with as little material input as possible, are shared as much as possible (e.g. shared vehicles), their lifespan is extended as long as possible (through sustainable design and repairs), and products are recycled as much as possible at the end of their life cycle.
- Switch to renewable and climate-neutral fuels and raw materials: Today, industry is a major consumer of fossil fuels: oil, coal and natural gas. Part of this consumption cannot be electrified in the future. Therefore, industry will also partially switch to climate-neutral fuels. Where economically viable, further electrification of industry can also lead to a drastic reduction in emissions. Sustainable biomass can be used as a source of carbon molecules in the chemical sector. In this way, the available biomass is used for production processes with high added value. This valorisation of biomass is preferable to burning biomass for energy supply. The electrolysis process can convert water into sustainable hydrogen using electricity. This molecule can be used as a raw material in the chemical industry.
- CO_2 capture and reuse: Measures in the areas of energy efficiency, the use of climate-neutral sources and the reuse of materials reduce dependence on fossil fuels and lead to CO2 reductions. However, if these measures do not result in sufficient emission reductions, the capture and storage or reuse of CO_2 (carbon capture, utilisation and storage or CCUS) is a promising way to eliminate remaining emissions. This involves capturing CO_2 at the point of production, either for permanent storage (CCS) or for processing into products (CCU). In the long term, CCU will ensure that as much CO_2 emissions as possible remain in a closed cycle.

- Industrial symbiosis in clusters: Flemish industry is highly concentrated in clusters around certain logistics hubs, such as the Port of Antwerp and North Sea Port. This allows the existing installations to exchange and valorise residual flows, such as CO_2, H_2 and residual heat. The Flemish Climate Strategy 2050 capitalises on this asset and, through a cluster approach, aims for industrial symbiosis in which residual flows are exchanged and valorised to the maximum extent possible.

Flemish Moonshot "Flanders $_{CO2}$ neutral"

In 2019, the so-called Flemish Moonshot "Flanders $_{CO2}$ neutral" was launched, the innovation spearhead in Flemish energy and climate policy with the objective of research and innovation to make Flemish industry carbon circular and low-carbon by 2050. In concrete terms, innovative research within this Moonshot will contribute to the development of breakthrough technologies in Flanders by 2040 to implement new and improved processes that can be used to produce new and unique low-carbon products. The Moonshot consists of four essential and closely linked **research tracks**:

18. bio-based chemistry that leads to unique high-quality products,
19. circularity of carbon in materials,
20. electrification and radical transformation of processes, and
21. energy innovation.

The ETS Innovation Fund, which will provide European support for the demonstration of innovative low-carbon technologies, will become one of the main funding channels for innovative investments in the industrial and energy sectors.

To support the framework for the Moonshot innovation programme, the study 'Towards a carbon-circular and low-carbon Flemish industry' was published in November 2020 on behalf of the Agency for Innovation & Entrepreneurship (VLAIO). Four thematic **transition paths** were defined, which are in line with the themes of the Moonshot innovation programme:

1. the use of biomass (waste) as energy and raw material,
2. circularity, mainly involving the reuse of plastics,
3. electrification and increased use of hydrogen (H2), and
4. the capture, storage and reuse of CO2 (CCUS).

Table 14-1: Indicative sectoral contributions (in Mton CO2-eq) as laid down in the Flemish Climate Strategy 2050

	1990	2005	2017	2030	2050
Elektriciteit	17,4	18,7	10,7	Onder EU ETS	Onder EU ETS
Industrie – ETS[1]	29,3	24,3	21,0	Onder EU ETS	Onder EU ETS
Industrie – niet-ETS		4,4	5,7	3,6	1,2
Transport	12,8	15,9	16,0	12,2	0
Gebouwen	14,1	15,7	12,2	9,4	2,3
Landbouw	9,6	7,4	7,5	5,5	3,5
Afval[2]	3,2	2,9	2,4	1,4	0,1
Totaal niet-ETS		**46,1**	**43,5**	**32,2**	**7,1**

[1] Voor de ETS industrie schrijven we ons in binnen de context van een dalend emissieplafond dat wordt vastgelegd op EU niveau. In lijn met de recent aangenomen EU doelstelling om klimaatneutraal te zijn tegen 2050, voorziet de Commissie in haar 1,5LIFE scenario een reductie van -95% tegen 2050 t.o.v. 2005 voor alle stationaire ETS sectoren (dus elektriciteit + ETS industrie).

[2] Sector afval wordt in voorliggende visie toegelicht onder het hoofdstuk industrie omwille van de beleidsmatige link met circulaire economie.

14.3 Construction phase

As indicated above, the construction phase has already been partially completed (see schedule in sections 3.1 and 3.2). Therefore, where appropriate, we indicate below which items have already been implemented or realised. However, the entire project is included in the assessment within the climate chapter. We do explain which parts are already being implemented or have been implemented.

This chapter assesses the direct and indirect effects of the construction phase of the project (= construction works) on the climate. This includes the nature and extent of greenhouse gas emissions.

The division of climate impacts into direct and indirect emissions, with a further subdivision into 'scope 1, 2 and 3 greenhouse gas emissions' launched under the Greenhouse Gas Protocol, cannot simply be applied in the context of environmental impact reporting. This is because the inclusion of these emissions goes beyond the assessment of the direct and indirect effects of the project that is the subject of this EIA and is in line with the EIA Climate Manual.

14.3.1 Carbon balance

14.3.1.1 Change in land use (already implemented in 2022-2023)

14.3.1.1.1 Scope

This chapter calculates the carbon balance for vegetation removal, topsoil excavation, conversion to industrial land use and legally required forest compensation under the Forestry Decree:

- The area where vegetation removal, topsoil excavation and levelling works took place covered 90.29 ha:
  - The total area to be deforested was 39.31 ha.
  - After mechanical deforestation, milling work was carried out to remove the roots from the soil.
  - The vegetation was also removed from the remaining 50.98 hectares of land (grassland, scrub, rough terrain).
  - Prior to levelling the site, the top layer of soil was excavated and removed. This involved a total volume of 228,500 m³. This was topsoil containing organic residues that could not be reused for levelling.
  - Finally, levelling work was carried out to make the site suitable for further development.
- Following these preparatory works, Project One will permanently occupy 85.0 hectares of the site: forest and grassland will be taken over for industrial use by Project One. There will also be a temporary occupation of 5.29 hectares during the construction phase.
- Project One has a legally required forest compensation of 28.49 hectares.

14.3.1.1.2 Methodology

14.3.1.1.2.1Current carbon stocks

Current carbon stock in soil and biomass

The calculation method for the carbon stock present at that time in the biomass (litter layer, dead wood and living biomass) in the project area is based on the national averages used in the 2023 National Inventory for Greenhouse Gas Emissions for LULUCF reporting[145] . For carbon storage in the soil, the organic carbon samples taken as part of the technical report for this project are used.

The carbon stock of the project area is estimated in four compartments: 1) mineral soil, 2) litter layer, 3) dead wood, and 4) living woody biomass.

5. After vegetation removal and prior to levelling the site, the top layer of soil will be excavated and removed. The carbon stored in the forest soils and grassland/scrub soils (in this case, the rest of the project area, including unpaved roads) will therefore also be released again. As part of the technical report for Project One, sampling was carried out across the project area, including sampling of the dry matter content and organic carbon content (approx. 330 soil samples in the top 30 cm, evenly distributed across the project area). For the project area, an average of 1.8 tonnes/m³, a dry matter content of 92.22% and a carbon content of 4.76 g organic carbon/kg dry matter is taken into account. This is a relatively low carbon content, due to the fact that the project area is a reclaimed site with a mainly sandy texture.
6. Dead organic material is also present in the forest in the form of litter, estimated at approximately 7.56 tonnes C/ha145.
7. Dead organic material is also present in the forest in the form of dead wood, with a characteristic value of approximately 1.9 tonnes C/ha145.
8. Deforestation in the project area results in an exemption for the amount of carbon stored in the existing woody living biomass. Below is an estimate of the amount of CO_2 stored in the living biomass in the existing forest. This takes into account an average stock volume of standing living wood of 100 m³/ha. The conversion factors for deciduous trees from the 2019 National Inventory of Greenhouse Gas Emissions are also used in the calculation.

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[145] Belgium's greenhouse gas inventory 1990-2021. (15/04/2023). National Inventory Report. Submitted under the United Nations Framework Convention on Climate Change.
[146] 100 m³ of wood per hectare has been estimated based on the fact that most trees in the project area are birch with some willow. Trees thicker than 30-40 cm in diameter are rare. Most birch trees are quite thin, less than 20 cm in diameter.

- BEF 2 (biomass expansion factor) (ratio of total above-ground biomass volume to roundwood volume): 1.4
- R (root to shoot ratio) (ratio of volume of below-ground biomass to above-ground biomass): 0.21
- Wood density: 0.55 tonnes of dry matter/m³
- Carbon fraction of dry matter: 0.5 tonnes C/tonne dry matter
- Total carbon storage: 46.6 tonnes C/ha, of which:
  - 27.5 tonnes C/ha in roundwood;
  - 11 tonnes C/ha in branches and leaves (above-ground biomass excluding roundwood);
  - 8.1 tonnes C/ha in below-ground biomass.

Deforestation and conversion to industrial land use also cause the disappearance of the forest's CO2 storage function through the growth of new biomass. The potential of a forest ecosystem (or other ecosystem containing woody vegetation) to produce wood depends mainly on soil fertility, tree species composition and the age of the trees present. Vandekerkhove et al. (2014) provide an overview of the annual growth for the various combinations of tree species classes and soil texture and drainage classes (see Table 14-2) in their study on the ecosystem service of wood production.

Anthropogenic soil has been present in the project area since the early 1960s. The soil has a sandy texture and no profile structure to a depth of 4 to 5 m below the current ground level. The project area has drainage classes b/d/i. Taking into account the values in Table 14-2 for multifunctional deciduous wood, sandy soil and the specified drainage classes b/d/i, an average growth of approximately 6 m³ wood/ha/year can be assumed. Calculated using the conversion factors for deciduous trees from the 2019 National Inventory of Greenhouse Gas Emissions, the average growth is 3 tonnes C/ha/year.

On average, grassland stores between 0.5 and 1 tonne of carbon per hectare per year.

[147] Source: Opportunities for carbon storage under grassland and arable land in Flanders. ILVO Communication 231, July 2017.

Table 14-2: Overview of the growth figures used (m³/ha/year) for the various combinations of texture, drainage and tree species classes used in the potential supply map for the ecosystem service of wood production (Source: Vandekerkhove et al., 2014)

Productieloofhout (= cultuurpopulier	a	b/c	d/e/h	f/g/i
Z/V/X	0	0	9	6
S/P	0	9	12	11
A/L/M/G	0	10	18	9
E/U	0	13	20	7
Multifunctioneel loofhout	a	b/c	d/e/h	f/g/i
Z/V/X	4	6	6	5
S/P	5	8	8	6
A/L/M/G	3	11	10	7
E/U	3	9	10	6
Productienaaldhout	a	b/c	d/e/h	f/g/i
Z/V/X	11	14	10	3
S/P	11	14	12	2
A/L/M/G	9	15	10	2
E/U	9	8	8	0
Multifunctioneel naaldhout (Ps)	a	b/c	d/e/h	f/g/i
Z/V/X	7	9	7	2
S/P	8	10	8	2
A/L/M/G	4	10	7	2
E/U	4	8	6	0
Ander hooggroen	a	b/c	d/e/h	f/g/i
Z/V/X	4	6	6	5
S/P	5	8	8	6
A/L/M/G	3	11	10	7
E/U	3	9	10	6

14.3.1.1.2.2Future carbon stocks

Accurate estimation of future carbon stocks through planned forest compensation over time must take into account various parameters, such as soil type and fertility, initial soil carbon stock, tree species, undergrowth, management (plant density, thinning regimes), nutrient status and moisture supply, functional soil biodiversity, etc. It is therefore particularly difficult to accurately estimate the development of future carbon stocks through planned forest compensation. In this EIA, the figures provided in the study by Muys et al. (2002). The INBO is currently working on a dynamic carbon model that calculates CO_2 sequestration when afforesting new land, based on soil type, initial soil C stock, tree species, management, etc. In the future, this model can be used to determine how (quickly) a deforestation project can be offset in a climate-neutral way and to optimise the carbon balance of projects.

In the study by Muys et al. (2002), a simulation was made of the potential carbon stock of newly planted multifunctional forest (based on oak) on different soil textures (Z = sand; S = sandy loam; P = light sandy loam; L = sandy loam; A = loam), starting from agricultural land (Figure 14-4 and Table 14-3). The calculation of the carbon balance does not take into account any losses of carbon stock due to periodic harvesting of wood (periodic harvesting of wood gives rise to the jagged profile in Figure 14-4).

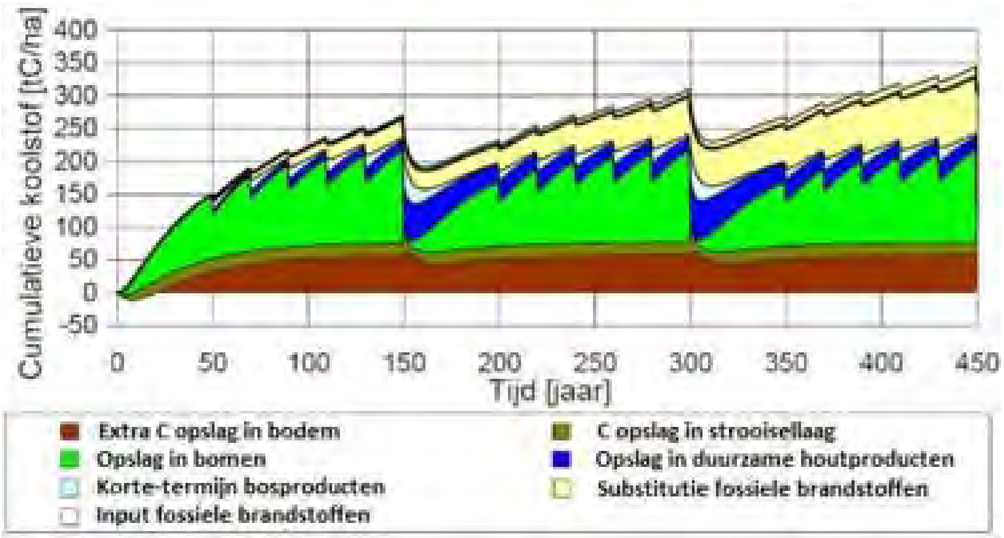

Figure 14-4: Conceptual model of a carbon balance (in tonnes C/ha) over time of carbon that is stored net in a multifunctional forest based on oak starting from agricultural land (according to Muys et al., 2002). The jagged profile shows the decline in carbon storage in biomass due to periodic harvesting of wood.

Table 14-3: Simulation of CO2 sequestration in newly planted forest on various soil textures (Source: Muys et al., 2002)

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

This EIA takes into account the average values of the soil textures considered: after 10 years, a total biomass of 159 tonnes of CO2/ha on average can be accumulated, and after 20 years, an average of 241 tonnes of CO2/ha. The net storage in soil and litter averages 6.40 tonnes of CO2/ha/year.

14.3.1.1.3 Carbon balance

The carbon balance is shown in Table 14-4.

This carbon balance provided an estimate of the current amounts of carbon stored in the biomass and soils of the project area. The amounts of carbon stored in the new forest plantations under the legally required forest compensation scheme were estimated in the carbon balance after a growth period of 10 years.

Below is a classification of the activities as carbon sources or carbon sinks (>0 emissions; <0 storage):

- Deforestation, removal of grassland and scrub vegetation, excavation of the topsoil and land use in the project area will release approximately +14,698 tonnes of stored CO_2 into the atmosphere and reduce CO_2 capture from the atmosphere by approximately +590 tonnes per year.
- After 10 years, the new forest will, under the legally required forest compensation scheme, result in the sequestration of approximately -6,616 tonnes of CO_2, abstracting from wood yield. This means that during the first 10 years, -662 tonnes of CO2 per year can be sequestered by the new forest.
- The actual carbon debit after X years basically consists of the carbon stock after X years in the project area if it were left untouched. The actual carbon debit therefore takes into account both the carbon stock and the carbon storage capacity of the area. The actual carbon debit after 10 years is
+ 13,980 tonnes of CO_2.

Table 14-4: Carbon balance of vegetation removal, topsoil excavation, legally required forest compensation and mitigation scenario for carbon storage in wood panels

	Key figures Carbon balance	Source	Area	Carbon reservoir		Carbon sequestration	
			ha	tonnes of CO	tonnes of CO2	tonnes C/year	tonnes CO2/year
Current carbon stock in soil and biomass Project One							
Deforestation of deciduous forest – removal of woody living biomass (above and below ground)	47tonnesC/ha	National inventory for greenhouse gas emissions (2019)	**39.31**	1,831	6,715	110	403
	3 tonnes C/ha/year	Vandekerkhove et al. (2014)					
Deforestation – removal of dead wood C/ha	1.9 tonnes	National inventory for greenhouse gas emissions (2019)	**39.31**	75	274		
Deforestation – removal of litter layer	7.56 tonnes C/ha			297	1,090		
Removing grassland/scrub/undergrowth	0.5 to 1 tonne C/ha/year	ILVO Communication 231 (July 2017)	**50.98**			51	187
Excavation and levelling of mineral soil (to approx. 30 cm below ground level)	1.8 tonnes/m³	Sampling results technical report earthworks Project One	**228,500 m³**	1,805	6,620		
	92.22% DS						
	4.76 gOC/kgDS						
Carbon reservoir and carbon storage capacity total project area			**90.29**	**4,009**	**14,698**	**161**	**590**

	Key figures Carbon balance	Source	Area	Carbon reservoir		Carbon sequestration	
			ha	tonnes C	tonnes $_{CO2}$	tonnes C/year	tonnes CO2/year
Future carbon stock through forest compensation							
Reforestation in accordance with legally required forest compensation	After 10 years: 159 tonnes CO2/ha in forest biomass; 7.4 tonnes CO2/ha/year in soil and litter	Muys et al. (2002)	**28.49**	**After 10 years: 1 804**	**After 10 years: 6 616**	**First 10 years: 180**	**First 10 years: 662**
Actual carbon balance after 10 years (>0 emissions; <0 storage)				**3,813**	**13,980**		

14.3.1.2 Timber removal and soil removal and delivery (largely carried out in 2022-2023)

14.3.1.2.1 Scope and methodology

Road transport of timber was taken into account. Based on approximately 100 m³ of timber per hectare and approximately 39.31 hectares to be deforested, approximately 3,931 m³ of timber will need to be transported. Taking into account a load capacity of approximately 50 m³ per lorry, an average of 21 working days per month and a deforestation period of two months, this corresponds to approximately 2 x 79 lorry movements or 2 x 2 lorry movements per day. A conservative assumption of 100 km per lorry movement was used for the carbon balance. The transport medium for timber removal depended on the location of the chosen company for conversion into wood products and on the choice of biomass plant for the residual flows.

The earthworks during the construction phase were divided into three phases:

- Volumes to be excavated and removed during the excavation of the topsoil;
- Volumes to be excavated, partly removed and partly replenished during the levelling of the sub-base;
- Volumes to be excavated, partly removed and partly replenished as part of the construction work itself.

For an overview of the volumes and a detailed description of the various earthworks, please refer to § 3.2.5.

The removal and delivery of soil will mainly take place via the Kanaaldok B2. Specifically contaminated soil may have to be transported to a separate processor by road. Approximately 90% of the soil will be removed by water and 10% by road.

The emission factor of the greenhouse gas CO_2 (in g/tonne-km) is considerably lower for the transport of bulk goods by inland waterway than by lorry[148] . For inland waterway transport, the emission factor of the greenhouse gas CO_2 (in g/tonne-km) is also significantly lower for the transport of bulk goods via 4-barge push convoys than via regular inland vessels (Kempenaar type, Rhine-Herne Canal vessel). As a mitigating measure, it is stipulated that the supply and removal of soil must be carried out by inland waterway transport (the type of inland vessel is not yet known). This will limit the CO2 emissions from the supply and removal of soil by water.

As a conservative assumption, an average distance of 100 km round trip between the project area and the relevant soil processing centres or soil stocks is assumed.

14.3.1.2.2 Carbon balance

The estimated CO2 emissions from timber removal due to deforestation are shown in Table 14-5. The estimated CO2 emissions from the removal and delivery of soil during the construction phase are shown in Table 14-6.

The transport of soil is carried out as much as possible by water. The transport of soil is carried out by inland waterway transport. This limits the CO2 emissions associated with the transport of soil. This is in line with the policy for the transport sector in the Flemish Energy and Climate Plan 2021-2030.

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[148] Source: https://co2emissiefactoren.be

Table 14-5: Carbon balance of timber removal from deforestation

	Number of lorries	Number of kilometres to destination and return	CO2 emission factor (kgCO2/km)	Total CO_2 emissions (tonnes CO2-eq)
Wood removal deforestation	79	100	1.10[149]	9

Table 14-6: Carbon balance of soil removal and supply

	Volume (m^3)	Quantity (tonnes)[150]	CO_2 emission factor (g/tonne km)[151]	Number of kilometres round trip	Total CO_2 emissions (tonnes CO2-eq)
Soil removal and supply – topsoil excavation, levelling works and construction works					
Inland waterway transport (90%)	433,350	780,030	41	100	3,198
Lorry with trailer (10%)	48150	86,670	82	100	711
Total	**481,500**	**866,700**			**3,909**

14.3.1.3 Construction machinery during construction phase (limited implementation in 2022-2023)

14.3.1.3.1 Scope and methodology

The impact of the fuel consumption of the construction machinery on the carbon balance was determined in the Air discipline. For a detailed description of the principles underlying the calculation, please refer to Appendix 6.1 of this EIA.

Specific emission factors were used for each engine class for the greenhouse gases CO_2, CH_4 and NMVOCs (non-methane volatile organic compounds). These emission factors are based on the following sources: US EPA420-R-05-019 Exhaust Emission Factors for Nonroad Engine Modelling NR-010e and EMEP/EEA air pollutant emission inventory guidebook 2023, Non-road mobile sources and machinery. The heating of the site huts is considered to have a negligible impact on the carbon balance of the construction phase and is therefore not budgeted separately.

14.3.1.3.2 Carbon balance

Figure 14-5 shows greenhouse gas emissions during the construction phase. CH_4 and NMVOC (non-methane volatile organic compounds) emissions can be considered negligible compared to CO_2 emissions. The cumulative CO2 emissions for the 3-year and 8-month construction phase of Project One (2022-2026) are estimated at approximately 136,516 tonnes, or an average of approximately 37,230 tonnes of CO_2 per year during the construction phase. The largest sources of emissions are mobile cranes, diesel generators and dumpers.

[149] Source: https://www.milieubarometer.nl/CO2-footprints/co2-footprint/velopa-bv-2015/
[150] 1.8 tonnes/m^3
[151] Source: https://co2emissiefactoren.be

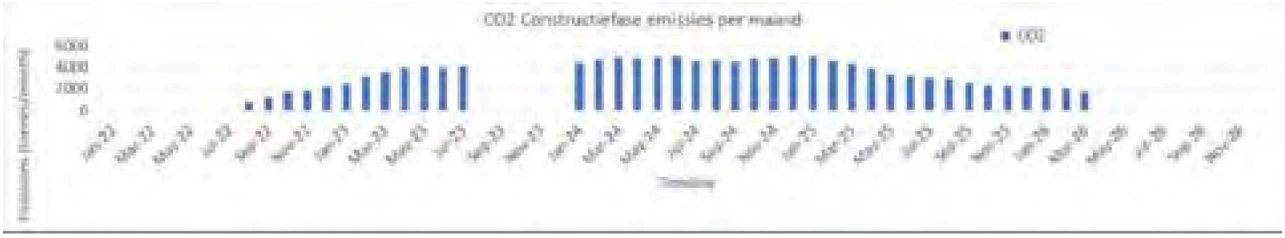

Figure 14-5: Greenhouse gas emissions from construction machinery during the construction phase (with interruption due to permit revocation)

14.3.1.4 Transport of materials and commuting by workers

14.3.1.4.1 Transport of materials

As described in Chapter 10 Mobility, a number of measures are being taken to limit emissions from the transport of materials. These measures are briefly outlined below; for a detailed description, please refer to Chapter 10 Mobility:

- Reducing transport
    - Working with modules
    - Bulk material by ship
    - Use of transhipment sites
- Shifting transport mode (shipping instead of freight traffic)

14.3.1.4.2 Commuting for shipyard personnel

During the construction phase, the transport of site personnel will be bundled as much as possible in buses and minibuses. Personnel on site are encouraged to cycle to the site. Carpooling is also encouraged. For a detailed description of these measures, please refer to Chapter 10 Mobility.

14.3.1.4.3 Scope, methodology and carbon balance

It is not easy to accurately estimate the CO2 emissions resulting from the commuting of site personnel and the transport of materials, as this requires detailed data on the number of kilometres travelled per transport and the quantities transported per transport. It is particularly difficult to obtain detailed information on the transport of materials. At the time of writing the EIA, we have made the following assumptions.

The carbon balance of the commuting of site personnel during the construction phase is determined on the basis of the modal split for site personnel from Chapter 10 Mobility and the emission factors per vehicle (Table 14-7). A conservative assumption of 50 km per trip or 100 km per day and 250 working days per year is used. The construction phase will last approximately 3 years and 8 months.

The number of freight transports per day was estimated in Chapter 10 Mobility, including for bulk material concrete (Table 14-8). During the peak period at the construction site, the total number of freight transports is calculated at 162 per day. A conservative assumption for the carbon balance is 50 km per freight transport or 100 km per day and 250 working days per year. The construction phase will last 3 years and 8 months.

For the number of shipments of materials by ship, it is assumed that steel is the most important material transported by ship (Table 14-9). Data on the origin of this steel is not known, but the calculation conservatively assumes that this steel comes entirely from Asia (longest transport distance). CO2 emissions are only taken into account for the outward journey, as the return journey for such transports is usually linked to another economic transport operation outside Project One for economic reasons. The return journey is therefore not part of the project and should not be included in the budget.

Emissions from commuting by site personnel and freight and shipping traffic for the transport of materials for Project One amount to approximately 68,495 tonnes of CO2 equivalent, or an average of approximately 17,124 tonnes of CO2 equivalent per year for the approximately four-year construction phase of Project One (Table 14-10).

Table 14-7: Carbon balance of commuting by shipyard personnel

Vehicle	Modal split	Site personnel/day	Number of vehicles/day	Number of kilometres/day	CO_2 emission factor[152]	CO2 emissions (tonnes CO2-eq/year)	Total CO2 emissions (tonnes of CO2 equivalent)
Bicycle	2%	51			0	0	0
Buses (45 passengers)	50%	1,268	29	100	109 gCO2/passenger km	3,455	12,646
Minibuses (8 passengers giers)	15%	380	48	100	287 gCO2/vehicle km	344	1261
Car (1.15 passengers) giers)	33%	837	727	100	193 gCO2/ vehicle km	3,508	12,838
Total		2,535	804			7,307	26,745

Table 14-8: Carbon balance for freight transport of materials (including concrete)

	Number of vehicles/day	Number of kilometres/day	CO_2 emission factor (kgCO2/km)	CO_2 emissions (tonnes CO2-eq/year)	Total CO2 emissions (tonnes CO2-eq)
Freight traffic (including concrete)	162	100	1.10[153]	4,455	17,820

Table 14-9: Carbon balance of shipping traffic transporting steel

	Quantity (tonnes)	Number of kilometres	CO2 emission factor (g/tonne km)[154]	Total CO2 emissions (tonnes CO2-eq)
Shipping traffic (steel)	44,000	22,000	22	21,296

[152] Source: https://co2emissiefactoren.be, the emission factors used were updated (March 2024)
[153] Source: https://www.milieubarometer.nl/CO2-footprints/co2-footprint/velopa-bv-2015/
[154] Source: https://co2emissiefactoren.be, the emission factors used were updated (March 2024)

Table 14-10: Summary carbon balance for commuting by site personnel and transport of materials

	Total CO_2 emissions (tonnes CO2-eq)
Commuting by site personnel	26,745
Freight transport of materials (including concrete)	17,820
Shipping traffic for transporting steel	21,296
Total	**65,861**

14.3.1.5 Use of materials

The extraction and production of building materials also has an environmental impact. Concrete and steel are mainly used for the construction of the installations. Consequently, an estimate will be made of the impact of material use on the carbon balance based on these two materials, as shown in Table 14-11. The CO_2 emission factors are taken from the French database of ADEME[155] (Agence de la transition écologique). These emission factors are valid for industrial installations and include indirect emissions related to the extraction and production of building materials. These emissions are then averaged over the estimated 50-year useful life of Project One.

Table 14-11: Carbon balance of materials used in the construction phase

Floor slab/ foundation	Concrete	155,000 m³	50	0.396 tonnes CO2-eq/m³	61,380	1,228
Piping/ structures/…	Steel	44,000 tonnes	50	3.19 tonnes CO2-eq/tonne	140,360	2,807
Total					201,740	4,035

14.3.2 Conclusion

The (largely completed) works involving changes in land use through deforestation, removal of other vegetation, excavation of the topsoil and conversion to industrial land use are assessed as follows:

- The project area functioned as a carbon sink (forest area, grassland, scrub and thickets) when it was overgrown, but lost this function due to the conversion of land use to industrial land use. The actual carbon debit after X years basically consists of the carbon stock after X years in the project area if it were left untouched. The actual carbon debit therefore takes into account both the carbon stock and the carbon storage capacity of the area. It was calculated that the change in

[155] Source: https://www.bilans-ges.ademe.fr/docutheque/docs/guide%20finalis%C3%A9e%20FNTP%20avril%202015.pdf

land use in the project area and the legally required forest compensation, a real carbon debit of + 13,980 tonnes of CO_2 after 10 years.

Emissions from transport media for the removal of timber, the delivery and removal of soil, the commuting of site personnel and the transport of materials, as well as emissions from site machinery during the construction phase, are summarised in Table 14-12 and amount to an average of 56,365 tonnes of CO2 equivalent per year for the construction phase (3 years and 8 months).

Table 14-12: Carbon balance of emissions from transport and site machinery during the construction phase

	Total CO_2 emissions (tonnes CO2-eq)
Wood removal deforestation	9
Soil removal and supply	3,909
Construction machinery	136,516
Commuting of construction site personnel	26,745
Freight traffic transporting materials (including concrete)	17,820
Shipping traffic transporting steel	21,296
Total transport and construction machinery	**206,295 tonnes CO2-eq or 56,365 tonnes CO2-eq/year**

Taking into account a 50-year lifespan for Project One, the CO2 equivalent emissions from the consumption of concrete and steel materials in Project One were estimated at 4,126 tonnes CO2 equivalent/year.

14.3.3 Recommendations and mitigation measures

Project-integrated mitigation measures:

- The supply and removal of soil is mainly carried out by inland waterway transport. This limits the CO2 emissions associated with the supply and removal of soil.

14.4 Operational phase

This chapter assesses the direct and indirect effects of the project's operation (= the operation of the installations) on the climate. This includes the nature and extent of greenhouse gas emissions, as well as the project's vulnerability to climate change.

The division of climate impacts into direct and indirect emissions, with a further subdivision into 'scope 1, 2 and 3 greenhouse gas emissions' launched under the Greenhouse Gas Protocol, cannot simply be applied in the context of environmental impact assessment. Including these emissions goes beyond the assessment of the direct and indirect effects of the project that is the subject of this EIA and is in line with the EIA Climate Manual.

14.4.1 Project One

Project One will market ethylene; the production capacity of the ECR is shown in Table 14-13. Ethylene is produced by steam cracking ethane in the ethane cracker (ECR). The ECR is designed for highly selective production of ethylene. Propylene, pyrolysis oil, C4 and C5+ hydrocarbons are formed in limited quantities as by-products in the ECR. Significant quantities of hydrogen are formed during the cracking process. The hydrogen-rich fuel gas is used as fuel for the cracking process and is an important technique for reducing CO2 emissions. Hydrogen is therefore not extracted as HVC for sale on the market.

The products of Project One's ECR fall under the category of "*high-value chemicals*" (HVCs). The ECR's annual HVC production capacity is 1.563 Mtonnes of HVCs, or 3.3% of the current annual HVC production capacity in Europe (47.6 Mtonnes of HVCs; IEA (2018)).

The raw material supply for Project One is shown in Table 14-13. The ethane cracker will be fed with ethane from the US, where it is largely produced as a by-product of shale gas extraction. Ethane will come from various suppliers in the north-east of the US and the Gulf Coast. Ethane will be shipped from the US to the port of Antwerp in liquid form, deep-chilled, using ethane tankers (VLEC, Very Large Ethane Carriers). The ethane tankers for Project One use a small portion of the ethane they transport as transport fuel, keeping transport emissions low. Other sources of ethane are not currently considered realistic for the operation of Project One due to availability and cost.

*Table 14-13: ECR HVC production capacity**

Product	Mton/year
ECR	
Ethylene	1,450
Other HVCs	0.113
Total HVC	**1,563**

*Different from the total Project One production capacity shown in Section 3.4.2.1, which also includes products that do not fall under the heading of HVCs.

Table 14-14: Project One raw material supply

Raw material	Mton/year
Ethane	1.910

14.4.2 Carbon balance

14.4.2.1 Process-related emissions

14.4.2.1.1 Carbon balance ECR and supporting infrastructure

14.4.2.1.1.1Scope

This chapter presents the expected carbon balance of both the operation of the ECR and the supporting infrastructure. The carbon balance of the ECR allows the specific emissions for HVC production of Project One to be assessed against the product benchmark of the EU ETS system. Both the direct (emissions from combustion processes) and indirect CO2-equivalent emissions (import of electricity and export of steam) from all production processes and associated utilities of Project One are calculated.

14.4.2.1.1.2 Methodology

The carbon balance is the result of a bottom-up analysis of the energy flows of the various entities of Project One and is based on the mass and energy balances of the licensor and the configuration of the site infrastructure.

The carbon balance of the ECR is first determined separately in order to be able to test it against the product benchmark of the EU ETS system, taking into account fuel consumption, electricity imports and steam exports.

The methodology used to calculate the carbon balance complies with the 2006 IPCC guidelines[156] and allows for verification against the product benchmark of the EU ETS system. Emissions were determined based on the most recent licence data for the ECR, which incorporated the remaining requirements for the supporting infrastructure. Detailed fuel compositions were used to derive corresponding emission factors for ECR fuel gas and natural gas.

The total carbon footprint of the ECR and the supporting infrastructure was calculated by adding the additional emissions from the supporting infrastructure and subtracting the steam exports from the supporting infrastructure.

A total of 8,760 production hours per year are taken into account. The emission factors used for steam, electricity and natural gas are shown in Table 14-15. The following comments should be made with regard to electricity:

- The specific emission factor for electricity production from renewable energy sources in Flanders is 0 CO2tonCO2-eq/MWh and from non-renewable energy sources 0.195 ton CO2-eq/MWh. However, in order to be able to test against the product benchmark for HVC production of the EU ETS system, the specific emission factor for electricity consumption from the 4th GHG Emission Trading Data must be used, namely 0.376 ton CO2-eq/MWh. This emission factor is an ETS region-wide emission factor and is independent of where and how the electricity was produced.
- This means that the reduction in indirect emissions at the start of Project One through the green electricity purchase agreement (PPA or power purchase agreement) with two energy suppliers is not shown in the calculation of the ECR's carbon footprint or in the assessment against the product benchmark of the EU ETS system. However, the impact of the green electricity purchase agreement is shown in the carbon balance of the ECR and supporting infrastructure as a whole.

Table 14-15: Specific emission factors for steam, electricity and natural gas

	CO2-eq emission factor	Reference
Steam production	0.056 tonnes CO2-eq/GJp	4th GHG Emission Trading data[157]
Electricity consumption	0.376 tonnes CO2-eq/MWh	4th GHG Emission Trading data[157]
Natural gas consumption	0.202 tonnes CO2-eq/MWh	IPCC. 2006 IPCC Guidelines for National Greenhouse Gas Inventories

14.4.2.1.1.3 Process-integrated energy-saving and emission-reducing measures

The ECR is designed for selective and efficient ethylene production. Project One uses state-of-the-art technology for ethane cracking, and best available techniques (BAT) and energy integrations are consistently applied to achieve high energy and production efficiencies. Table 14-16 provides an overview of the process-integrated energy-saving and emission-reducing measures, as identified in the in-house energy study for the ECR and the steam boilers.

When designing the ECR, important CO2 emission reduction measures were implemented, including cold ethane feed to reduce the energy demand of the separation step, H_2 fueling and air preheating to increase the thermal efficiency of the combustion installations. Cold ethane feed with energy integration and air preheating reduce the ECR's energy consumption by 6 to 7%. H_2 fuelling reduces direct CO2 emissions by 60%.

[156] IPCC 2006, 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan.
[157] 4th GHG Emission Trading Data, Steam Cracker Data Collection, 2017

Table 14-16: Process-integrated energy-saving and emission-reducing measures of Project One

Effect of the measures	Measures per component ECR	Steam boilers
Carbon efficiency	Selective process choice/raw material choice for ethylene production	Efficient combustion of natural gas and H_2 fuelling via fuel gas
Reduction of CO_2 emissions	H_2fueling, Air preheating, steam integration	H_2 fuelling, air preheating, steam integration
Increasing energy efficiency	Cold integrations, air preheating, BAT, steam integration	Air preheating, BAT, steam integration

14.4.2.1.1.4 ECR

14.4.2.1.1.4.1 Carbon balance for product benchmark EU ETS

Table 14-17 shows the energy consumption for the ECR. Table 14-18 shows the derived carbon balance for testing against the EU ETS benchmark. Most ECR CO2 equivalent emissions are direct emissions resulting from the combustion of fuel gas in the furnaces. The energy requirements of the ethane cracker are almost entirely met by the hydrogen-rich fuel gas generated as a by-product of the cracking process. The use of hydrogen-rich fuel gas for the cracking process is an important technique for reducing CO2 emissions. The ECR is also a highly heat-integrated unit. As a result, a significant amount of hydrogen-rich fuel gas is exported to the steam boilers, enabling the production of steam and electricity with a smaller carbon footprint compared to natural gas. Under normal circumstances, therefore, no natural gas is consumed in the ECR. Only when insufficient hydrogen-rich fuel gas is generated in the ECR is natural gas consumed to meet the remaining energy requirements in the cracking furnaces.

Table 14-17: Energy consumption ECR

		Volume (kton/jaar)	C-inhoud (wt%)
ECR	Stookgas	-272	45
	Netto stoomexport (naar OSBL)	GJ/jaar -1349874	
	Elektriciteitsimport (van OSBL)	GWh/jaar 215	

Table 14-18: Carbon balance ECR for assessment against EU ETS benchmark

	Unit	ECR
Direct emissions	ktonCO2eq/year	449
Indirect emissions (balance of steam exports and electricity imports)	ktonCO2eq/year	5
Total	ktonCO2eq/year	454
HVC production	kton/year	1,563
Specific CO2eq emissions ECR	tonnes **CO2eq/tonnes** HVC	**0.29**

14.4.2.1.1.4.2 Test against product benchmark EU ETS

The product benchmark for HVCs in phase 4 of the EU ETS system (2021-2025) is 0.681 tonnes CO2-eq/tonne HVC [158,159] for steam cracking (ECR). A product benchmark is based on the average greenhouse gas emissions of the 10% best-performing installations producing the product in question in the EU and EEA-EFTA countries. This means that the methodology does not vary according to the technology or fuel used, the size of an installation or its geographical location. There are 39 existing steam crackers under the EU ETS system, 38 of which were used to update the EU ETS benchmark.
It can therefore be concluded that only 3.8 steam crackers meet the EU ETS benchmark value for HVC production. The 10% best-performing steam crackers under the EU ETS system had average specific emissions of 0.693 tonnes CO2-eq/tonne HVC in 2016 and 2017[159] . It can therefore be deduced that, in order to determine the benchmark for 2021-2025, a reduction factor of 1.73% was applied to the average specific emissions of the 10% best-performing steam crackers in 2016-2017. The average specific emissions of all steam crackers under the EU ETS system in 2016/2017 amounted to 0.891 tonnes CO2-eq/tonne HVC. In the period 2016/2017, an average of 31,393,609 tonnes CO2-eq of emissions were covered by the benchmark each year and thus allocated free of charge to steam crackers under the EU ETS system. The European Commission estimated the provisional free allocation of emission allowances covered by the benchmark for the year 2021 at 22,816,634 tonnes CO2-eq[159] , which represents a decrease of approximately 27% compared to 2016/2017.

The specific process emissions of the Project One ethane cracker amount to 0.290 tonnes CO2-eq/tonne HVC, or only 42% of the current EU ETS benchmark value, and are therefore well below the current EU ETS benchmark value.

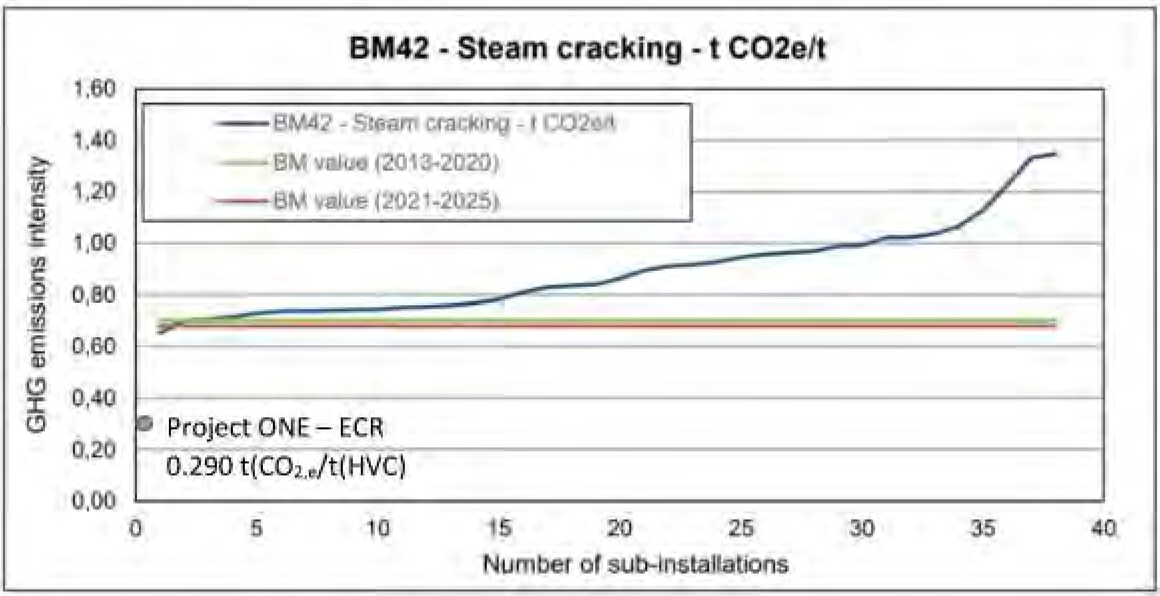

Figure 14-6: Specific greenhouse gas emissions (in tonnes CO2-eq/tonne HVC) for existing steam crackers under phase 4 of the EU ETS system (Source: European Commission, dated 15/06/2021159)

[158] Annex to the Commission Implementing Regulation establishing revised benchmark values for the free allocation of emission allowances for the period from 2021 to 2025 pursuant to Article 10a(2) of Directive 2003/87/EC of the European Parliament and of the Council/87/EC of the European Parliament and of the Council
[159] European Commission Directorate-General Climate Action. Update of benchmark values for the years 2021 – 2025 of phase 4 of the EU ETS. Benchmark curves and key parameters. 15/06/2021.

Project One will exploit the best performing steam cracking technology in terms of carbon efficiency in Europe. Project One implies a tightening of the EU ETS benchmark value for HVC production. This means that steam crackers under the EU ETS system that do not meet the benchmark value will have to purchase more additional emission allowances or credits to cover emissions or implement more emission-reducing measures compared to the current situation. Below, it is calculated that Project One implies a tightening of the EU ETS benchmark value for HVC production to approximately 0.577 $_{\text{tonnes CO2-eq/tonne HVC}}$. This is a decrease of approximately 15% compared to the current benchmark value for HVC production (0.681 $_{\text{tonnes CO2-eq/tonne HVC}}$).

Taking into account the current annual HVC production capacity in Europe of 47.6 Mton HVCs (IEA (2018)), this means that approximately 4.95 Mton of additional emission allowances must be paid or avoided annually by existing steam crackers for HVC production under the EU ETS system. Such a quantity of emission allowances corresponds to approximately 267 million euro/year, taking into account the current price (mid-February 2024) of 54 $_{\text{euro/tonne CO2}}$ under the EU ETS system. Part of this additional revenue for the EU ETS system will be used to support innovation and modernisation projects in energy-intensive industrial sectors and the energy sector.

The benchmark values will be tightened for each allocation period based on the observed improvement in greenhouse gas intensity in the 10% most efficient installations. The benchmark values will be tightened again for the period 2026-2030 to take into account technological improvements, among other things. As performance data for 2021-22 will be used to derive the benchmarks for 2026-30, Project One's ECR is likely to have an impact on the benchmark for phase 5 of the EU ETS system (from 2031), as activities will start in 2026.

Phase 5 (2031) EU ETS system

Tightening of EU ETS benchmark value for HVC production by Project One =

(2.8 x 0.693 $_{\text{tonnes CO2-eq/tonne HVC}}$ + 0.290 $_{\text{tonnes CO2-eq/tonne HVC}}$) / 3.8 x (1 – reduction factor) = 0.577 $_{\text{tonnes CO2-eq/tonne HVC}}$

(This assumes that Project One's steam cracker will push the highest-emitting steam cracker out of the group of the 10% best-performing steam crackers in the EU ETS system and that the reduction factor will remain constant at 1.73%.)

Additional purchase or avoidance of CO2 emission allowances for existing steam crackers EU ETS system by Project One =

(0.681 $_{\text{tonnes CO2-eq/tonne HVC}}$ - 0.577 $_{\text{tonnes CO2-eq/tonne HVC}}$) x 47.6 Mtonnes HVC/year = 4.95 Mtonnes CO2/year

4.95 MtonCO2/year x 54 $_{\text{euro/tonCO2}}$ = 267 M euro/year

14.4.2.1.1.4.3 Potential reduction in CO2 footprint of INEOS group

The ethylene produced in Project One is sold on the market. Most existing installations are currently fed with ethylene from European naphtha crackers, which are often outdated and have significantly higher specific CO2 equivalent emissions than the new ECR in Project One. These plants can purchase the ethylene produced by Project One and reduce their CO2 equivalent emissions. As an example, it has been calculated that the reduction in the carbon footprint of the customers would amount to approximately 2 Mton CO2-eq/year if the customers were to use the ethylene produced in Project One.

Table 14-19: Potential reduction in customers' carbon footprint when using Project One ethylene

		Average European naphtha cracker	ECR Project One
Ethylene production	kton/year	1,450	1,450
CO_2-eq emissions per tonne of HVC	tonnes CO_2-eq/tonne HVC	0.891	0.290
CO_2-eq emissions per tonne of ethylene	tonnes CO_2-eq/tonne ethylene	1.74	0.31
Total CO_2-eq emissions	kton CO_2-eq/year	2,523	454

* European Commission, dated 15/06/2021[159]

**Based on data from Ren et al. (2006) and IEA (2018)

14.4.2.1.1.5 Total ECR and supporting infrastructure

14.4.2.1.1.5.1 Green electricity imports

Project One's electricity demand amounts to 140,160 MWh per year. Two power purchase agreements (PPAs) have been concluded with energy suppliers Engie and RWE for the supply of a total of 509,600 MWh per year of green electricity (offshore wind energy) for a period of 10 years. This means that when Project One starts in 2026, the external electricity demand will be covered by green electricity. The carbon balance of the ECR and supporting infrastructure will therefore eliminate the indirect emissions resulting from the import of electricity.

No electrification is used for the ECR cracking furnaces. Electrification of cracking furnaces is currently still in the research and development phase and there is currently no established or cost-competitive technology. At present, no proven concept has been reported. For example, the Linde pilot electric cracking furnace (6 MW) was scheduled to be mechanically completed by the end of 2023, so there is still no experience with performance, reliability, upscaling, etc., even at this pilot plant size. The current emphasis is on adapting existing furnaces of smaller sizes in the range of 20 to 30 MW heat load. The furnaces of Project ONE have a capacity of approximately 113 MW. Electrification of the cracking furnaces can be evaluated once the technology is sufficiently developed. ECR cracking furnaces produce a fairly large volume of combustion gases as a 'by-product' of the cracking process, consisting mainly of hydrogen and methane. These combustion gases can be put to good use by burning them to utilise their energy content. Due to its high hydrogen content, this fuel gas is highly combustible and results in significantly lower CO_2 emissions than natural gas. By using the fuel gases directly to heat the cracking furnaces, with recovery of the remaining heat through steam production, this energy content is recovered on site. If the cracking furnaces were to be heated electrically, the same amount of fuel gas would be produced, which could then no longer be used to heat the cracking furnaces. Another use for the combustion gas would have to be found, such as using it for steam production for use in the process units or for generating electricity, whereby the energy content of the combustion gas is less efficiently recovered. Larger steam boilers would have to be built for such use of the fuel gas. However, in order to avoid direct CO_2 emissions when using the fuel gas, an application must be found for the methane stream in the fuel gas without burning methane.

14.4.2.1.1.5.2 Carbon balance

This chapter also includes emissions from the supporting infrastructure required for the operation of the ECR. Table 14-20 shows the energy consumption for the supporting infrastructure. Table 14-18 shows the carbon balance for the ECR and supporting infrastructure as a whole. At the start of Project One in 2026 – with external electricity demand of 140,160 MWh/year covered by green electricity with two PPAs of 509,600 MWh/year – the total emissions of the ECR and supporting infrastructure will decrease by approximately 7% compared to the project without the import of green electricity, specifically from 708 ktonCO2-eq/year to 655 ktonCO2-eq/year.

Table 14-22 shows the carbon efficiency of raw materials for the ECR and supporting infrastructure. Of the raw material ethane, 81% of the carbon is captured in ethylene.

Table 14-20: Energy consumption of supporting infrastructure

			Volume (kton/year)	C content (wt%)
OSBL	In	Natural gas	67	75
		Heating gas	13	45
		Electricity	GWh/year 140	

Table 14-21: Carbon balance ECR + supporting infrastructure

	Unit	ECR + supporting infrastructure without green electricity imports	ECR + supporting infrastructure with green electricity imports covering 100% of electricity demand = Project One
Total direct emissions	ktonCO2eq/year	655	**655**
Total indirect emissions from electricity imports	ktonCO2eq/year	53	**0**
Total emissions	ktonCO2eq/year	708	**655**

Table 14-22: Raw material carbon efficiency ECR + supporting infrastructure

Carbon efficiency					
		Hydrocarbons kton/year	**C content** wt %	**Carbon** kton/year	**CO2 emissions** kton/year
Raw materials (in)	Ethane	1,910	80.0	1,528	0
Products (from)	Ethylene	1,450	85.7	1,243	0
	Other (C3, C4 and C5+)	175	89.6	157	0
Tail gas (off, used as fuel gas)		285	45.0	128	470
Raw material carbon efficiency ethylene production		**81**			

14.4.2.1.2 Future prospects: reduction of emissions

Project One currently has a number of possible future prospects for further reducing the direct CO2 emissions of the ECR. These future prospects are discussed below.

The INEOS Group is committed to achieving the EU's 2050 climate and energy targets and reducing net CO2 emissions to zero. Project One has been designed with *net zero* CO2 emissions in mind and aims to be the first CO2-neutral cracker in Europe, playing a role in Antwerp's sustainable industrial future. Project One is currently confident that it is feasible to achieve this within 10 years of the cracker's start-up. INEOS is also taking into account the EU's ambition to reduce greenhouse gas emissions to at least 55% below 1990 levels by 2030.

To achieve these objectives, INEOS is working on drawing up a roadmap. The roadmap will contain an action plan on how INEOS can reduce emissions by using green electricity, hydrogen and recycled or bio-based raw materials and by increasing the energy and raw material efficiency of its production sites. Although the focus is on avoiding CO_2 emissions rather than waiting for a technology to store CO_2, CO_2 storage is also part of the roadmap. To this end, INEOS can draw on its experience with existing CO_2 capture installations at its sites in Zwijndrecht, Tavaux, Lavera and Cologne.

Currently, approximately 100,000 tonnes of CO_2, which is produced as a by-product of the ethylene oxide process in Zwijndrecht, is captured, purified, liquefied, sold and reused. INEOS was also involved in the 'Power to Methanol' demonstration project in the Port of Antwerp for the production of methanol from CO_2 on a technical scale (see § 14.4.2.1.2.1.2 below). However, this project has been discontinued. The Power to Methanol industrial consortium is scrapping its plan to produce fuel from green hydrogen and captured CO_2 in the Port of Antwerp. The project is 'financially unviable'.

14.4.2.1.2.1 *Post-combustion* reduction of direct emissions through CO2 capture

CO_2 can be captured from point sources, after which the captured CO_2 is stored deep underground (CCS) or used in other production processes (CCU).

14.4.2.1.2.1.1 CO_2 capture Project One

Technology availability

INEOS Group has been operating carbon capture installations for some time in certain processes with high concentrations of CO2 in flue gases. Based on this knowledge, it also supports the development of new carbon capture technologies for applications with lower CO2 concentrations, such as Project ONE.

Project One analysed various existing *post-combustion* technologies (CO2 capture after combustion) for the relatively low-concentration CO2 streams from the ECR and steam boilers, see Table 14-23. The current mature, commercially available and relevant post-combustion technology for Project One uses a solvent, monoethanolamine (MEA), to absorb CO_2 from flue gases at atmospheric pressure. The solvent is regenerated by heating it in a stripper, which breaks the weak chemical bond between the amine and the CO_2. The CO_2 that is released is compressed and dried and then exported via a pipeline for reuse (CCU) or geological storage (CCS). This technology has up to 90% CO2 capture efficiency. An example of the layout of a CO2 capture installation is given in Figure 14-7 and Figure 14-8.

Although INEOS can draw on experience with existing CO2 capture installations at the INEOS sites in Zwijndrecht, Tavaux, Lavera and Cologne, it should be noted that the current state-of-the-art technology for post-combustion CO2 capture is still under development. At present, there are only a few examples in operation on a (semi-)industrial scale worldwide. At this stage, the technologies have not yet been technically proven for flue gases with a low CO2 concentration and/or on the scale required by Project One.

[160] PDC. Project One – Plot-space estimate for carbon capture. Dated 14/04/2020. Commissioned by Ineos.

Figure 14-7: Layout of the CO2 capture installation at the Petra Nova coal-fired power station in Texas (USA) (Source: U.S. Energy Information Administration)

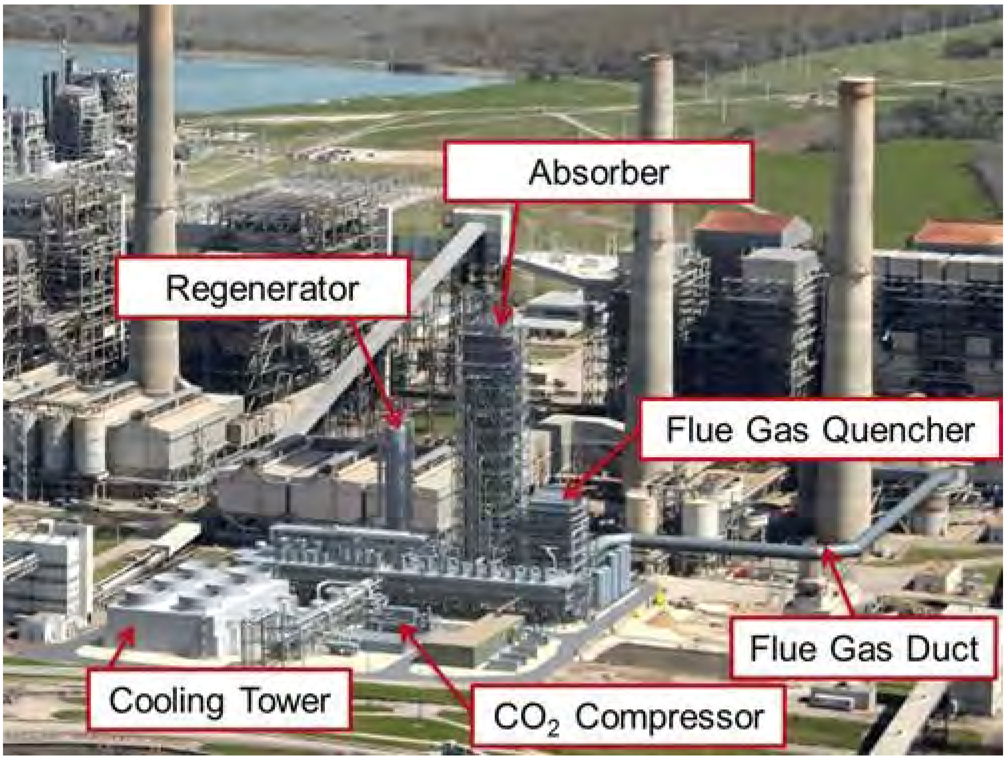

Figure 14-8: Detail of the layout of the CO2 capture installation at the Petra Nova coal-fired power station in Texas (USA) (Source: Mitsubishi Heavy Industries)

Table 14-23: Analysis of post-combustion CO_2 capture technologies (Source: IOB)

Minimum criteria and technology used (yes✓ /no ✗)	Aminesolvent	Chilled ammonia solvent	Physical solvent	Potassium carbonate solvent	Cryogenic	Adsorption	2-stage membrane
CO2 capture (>90%)	90%	Up to90%	CO2 partial pressure too low	Up to 90%	✗ Prior concentration step required. Minimum concentration of 50% required in flue gas	90	90% (theoretical)
CO2 purity (>95%)	>99% (dry)	>99% (dry)	Low	>99% (dry)		>99%	95% (theoretical)
Technology Readiness Level (TRL) (>8)[161]	8-9	7	N/A	5-6		5-6	6-7

161 The European Commission has established the definitions of TRLs as follows:
1. Basic principles observed
This phase is characterised by fundamental research. The basic principles of the technology have been observed and assumptions have been made about the operating principles of this technology. However, no experimental evidence is yet available.
2. Technology concept formulated
The technological concept and its potential scope of application have been formulated.
3. Experimental proof of concept
The initial laboratory tests have been completed, resulting in a proof of concept.
4. Technology validated in lab
The proof of concept is validated in a laboratory environment, often using low-fidelity prototypes on a small scale.
5. Technology validated in relevant environment
The technology has been tested and validated in a relevant environment. Functional and refined (high-fidelity) prototypes are often used for this purpose.
6. Technology demonstrated in relevant environment
The technology's operation is demonstrated in a relevant environment. The prototype's performance has not yet been optimised for the operational environment. This demonstration is used to demonstrate the technical operating principle.
7. System prototype demonstration in operational environment
The technology has been integrated into the final operational environment. The focus is now on matters such as production and certification.
8. System complete and qualified
The technology is performing as expected and the latest production issues have been resolved.
9. Actual system proven in operational environment
The technology is technically and commercially ready. The next steps are production and market introduction.

Minimum criteria and selected technology (yes ✓ /no ✗)	Aminesolvent	Chilled ammonia solvent	Physical solvent	Potassium carbonate solvent	Cryogenic	Adsorption	2-stage membrane
Existing installation	1.4 million tonnes/year ktonnes/year	< 100	✗ Proven technology in natural gas/syngas applications. Not a developed technology as post-combustion CO2 capture technology.	Pilot scale (< 10 kton/year)		Pilot plant (10 ktonnes/year)	Pilot plant (7 ktonnes/year)
	✓	✗ No proven advantages compared to amine solvent technology		✗ Low TRL. Risk of upscaling		✗ Low TRL. Risk of upscaling	✗ Low TRL. Risk of upscaling
HSE (Health, Safety and Environment)	Toxic degradation products with conventional amine, including the formation of heat-stable salts.	Solvent volatility. Risk of solid formation. No toxic degradation products.		Solvent does not degrade and has no toxic emissions.		Waste production from adsorbents. No toxic material.	Non-toxic product. High-pressure operation.
Amine technology is the only mature and relevant technology for low-concentration CO2 streams (post-combustion capture technologies).							

Project One CO_2 capture ready

Project One is being made 'CO2 capture-ready' for the application of *post-combustion* CO2 capture with technological flexibility on the ECR and the steam boilers. The term 'CO2 capture-ready' refers here to the fact that sufficient space is reserved in the project area for the application of CO2 capture and that the design already takes into account future retrofitting of the site and installations.

The CO2 concentration in the flue gases (3.6 mol%) when burning the current hydrogen-rich fuel gas in the cracking furnaces is too low to apply CO2 capture efficiently. After all, current state-of-the-art technology uses flue gases that contain at least 14 mol% CO_2. This means that the ECR would be modified to produce pure H_2 as the end product. The fuel gas used in the furnaces would then consist mainly of methane, supplemented with natural gas, so that the CO2 concentration in the chimney of the cracking furnaces would be high enough to allow efficient CO2 capture.

If Project One builds and operates a carbon capture facility in the future, Project One will:

9. The hydrogen released in the ECR's process installations (approx. 13 tonnes/hour or 114 ktonnes/year), which is used as fuel in the initial situation, must be extracted from the fuel gas (using a PSA unit; *pressure swing adsorption*) and that hydrogen must be put to a separate use (export it for the production of chemicals or use it in a specific combustion plant). It should be noted that the furnaces are optimised for a high hydrogen content in the fuel gas. As a result, the output of the furnaces will have to be reduced by approx. 15% or the furnaces will have to be converted to limit production losses.
10. use the remaining combustion gas (mainly methane) together with purchased natural gas (approx. 20 tonnes/hour or 175 ktonnes/year) as fuel, applying CO2 capture to the flue gases. This brings the CO2 concentration in the flue gases to approx. 9 mol%, which is still low. Absorption takes place at the ECR installations and the steam boilers themselves. Solvent regeneration and CO2 compression are carried out centrally.

Carbon balance and energy requirements

Table 14-24 shows the results of the PDC energy study [162], which calculated the impact on the carbon balance of the ECR and supporting infrastructure of implementing a *post-combustion* CO2 capture installation based on MEA absorption for the ECR and steam boilers:

- A CO2 capture installation for the ECR and the steam boilers means an additional steam demand of approximately 197 MW_{th} and compensation in natural gas for the export of hydrogen gas. This requires approximately 628 MW of additional natural gas consumption for the steam boilers and the ECR combined. The direct emissions from the ECR and supporting infrastructure will initially increase from 655 ktonCO2-eq/year to approximately 1,710 ktonCO2-eq/year. Taking into account a CO2 capture efficiency of 90% for emissions from the ECR and steam boilers, approximately 1,539 ktonCO2-eq/year can be captured, leaving approximately 171 ktonCO2-eq/year in direct CO2 emissions for the ECR and supporting infrastructure. Compared to the baseline project (without CO2 capture), this means that approximately 484 ktonCO2-eq/year of direct CO2 emissions will be avoided. In addition to the additional steam demand of approximately 197 MW_{th}, there is also an additional demand for cooling water of approximately 255 MW_{th} and an additional electricity demand of approximately 24 MW_e (it is assumed that this will be covered by green electricity from the two PPAs of Project One).
- A CO2 capture installation for the ECR and steam boilers means a total carbon footprint of approximately 171 ktonCO2-eq/year. This represents a reduction of approximately 74% compared to the CO2 equivalent emissions of the base project (without CO2 capture).

[162] PDC. Project One – CO_2 capture and CO_2 avoidance. Dated 07/05/2021. Commissioned by Ineos.

Cost

The investment costs for the future CO2 capture installation at the ECR and the steam boilers with MEA absorption technology (current state-of-the-art) were calculated in the PDC[162] energy study and amount to roughly 630 million euros. The annual operating costs for the future CO2 capture installation on the ECR and the steam boilers amount to roughly 190 million euros. The cost of avoiding CO2 emissions is therefore roughly 393 euros per tonne of direct CO2 emissions avoided. By way of comparison, the current price (mid-February 2024) per tonne of CO2 emission allowances is €54 under the EU ETS system.

Space requirements

The space requirements for the future CO_2 capture plant with MEA absorption technology (current state-of-the-art) with 90% CO_2 capture efficiency were calculated in a study by PDC[163].

The total space requirement for the future CO2 capture installation for the ECR and steam boilers was calculated by PDC to be approximately 8,000 m². PDC's estimate is based on internal reference information relating to CO2 capture using current state-of-the-art MEA technology. This total area is divided as follows:

- The 'pre-treatment and absorption' section of the ECR installation requires a plot of approximately 1,900 m² (including the space required for the cooling tower cells).
- The centralised CO_2 capture installation (stripper, CO_2 compressor, cooling tower cells for the stripper and CO_2 compressor, and storage tanks for auxiliary chemicals) requires a plot of approximately 5,400 m². This area includes 1,000 m² for storage tanks.

Conclusion

The above analysis of the CO2 capture installation using current state-of-the-art technology based on MEA absorption shows that this technology has a substantial steam demand, which significantly increases the natural gas consumption of the steam boilers and also means additional electricity and cooling demand. CO2 capture means a significant reduction of approximately 74% compared to the CO2 equivalent emissions of the base project (without CO2 capture). The cost of this CO2 capture technology is very high. Based on the above elements, it is concluded that CO2 capture using current state-of-the-art MEA technology is not justified at this time. Project One will be made 'CO2 capture-ready' with technological flexibility, so that CO2 capture can be implemented at the project site in line with expected developments in CO2 capture technologies.

The timeline for implementation of this technology depends, among other things, on:

- The availability of efficient, mature technology for capturing the relatively low-CO2 flue gases from Project One, which is not currently available;
- A guaranteed market for the hydrogen gas produced (approx. 13 tonnes/hour or 114 ktonnes/year);
- Guaranteed sales of the CO2 produced (transport, storage and/or reuse) (approx. 1,539 ktonnes/year);
- The evolution in the price of CO2 emission allowances under the EU ETS system.

This future outlook will be the subject of further research as part of INEOS' roadmap to achieve net zero CO2 emissions for all its sites in the Port of Antwerp by 2050 at the latest. Project One is currently convinced that it is feasible to complete this journey within 10 years of the cracker's start-up.

[163]PDC. Project One – Plot-space estimate for carbon capture. Dated 14/04/2020. Commissioned by Ineos.

Table 14-24: Future prospects: carbon balance ECR and supporting infrastructure at CO2 capture installation

	Unit	ECR and supporting infrastructure without CO2 capture	ECR and supporting infrastructure with CO2 capture
Total direct emissions ECR and supporting infrastructure	ktonCO2eq/year	655	Approx. 1,710
Total CO2 capture	ktonCO2eq/year	-	Approx. 1,539
Remaining direct CO2 emissions after CO2 capture	ktonCO2eq/year	-	Approx. 171
Avoided direct CO2 emissions	ktonCO2eq/year	-	Approx. 484

14.4.2.1.2.1.2 CCUS in the Port of Antwerp

IOB is a partner in the Antwerp@C project and is therefore involved in the development of the external infrastructure that will be needed to transport CO2 to storage locations. The Antwerp@C project is investigating the possibilities for CCUS in the Port of Antwerp. The consortium of participating companies is investigating the technical and economic feasibility of a CO_2 infrastructure for CCUS. The CO_2 infrastructure would be of the 'open access' type and could therefore be used by the entire industrial port community. In the first phase, the partners will conduct studies into the technical and economic feasibility of CO_2 infrastructure to support CCUS. Belgium does not have a suitable subsoil for offshore CO_2 storage. International cooperation will therefore be necessary. In 2019, the port of Antwerp submitted two project applications for recognition by the European Commission as Projects of Common Interest. Both projects offer the opportunity to investigate the development of cross-border CO2 transport infrastructure, towards Rotterdam (CO2TransPorts project) and Norway (Northern Lights project) respectively. Both projects were recognised as Projects of Common Interest at the end of 2019. In the first phase, emission sources with highly concentrated CO2 flows will be captured. The aim is then to capture emission sources with more diluted CO2 flows.

When applying CO2 capture and PSA units at Project One in a future perspective, both CO_2 and hydrogen gas will become available at the Project One site. This opens up an important perspective for the (re)use of CO_2 and hydrogen gas in the future in the Port of Antwerp. For example, Inovyn, a company adjacent to Project One, is part of the seven-member consortium that would set up the 'Power to Methanol' demonstration project for the production of methanol from CO_2 on a technical scale (planned production of 8,000 tonnes of methanol per year). However, the project has not been rolled out further. The Power to Methanol industrial consortium is scrapping its plan to produce fuel from green hydrogen and captured CO_2 in the Port of Antwerp. The project is 'financially unfeasible'.

14.4.2.1.2.1.3 CCUS Project Greensand

INEOS investigated how CO_2 can be stored in depleted oil fields in the North Sea. The project within INEOS that is investigating the possibilities for transporting and injecting CO_2 has been named 'Greensand'.

INEOS has already acquired an almost depleted oil field (Siri Area) off the Danish coast. The idea is to eventually transport CO_2 captured from flue gases by ship to Denmark and inject it into the depleted oil fields there. The aim is to be able to store up to 4 million tonnes of CO_2 per year. A successful trial carried out in 2023 involved capturing, compressing and transporting CO_2 over a distance of 500 km, across the border, to the Nini offshore oil field in the Danish North Sea. More information is available at https://projectgreensand.com.

[164] Commission Delegated Regulation (EU) 2016/89 of 18 November 2015 amending Regulation (EU) No 347/2013 of the European Parliament and of the Council as regards the Union list of projects of common interest

14.4.2.1.2.2 *Pre-combustion* reduction of direct emissions through 100% H2 content in fuel gas

As an alternative to reducing CO_2 emissions from the ECR using *post-combustion* CO_2 capture technology, the possibility of using *pre-combustion* technology was investigated, whereby the hydrogen content in the fuel gas supplied to the ECR and steam boilers is increased to 100%. In this case, direct CO_2 emissions from the process are reduced to zero. In this case too, a PSA unit will have to separate the fuel gas into its hydrogen and methane fractions. The hydrogen fraction will then be recovered to the furnaces and must be supplemented with additional green hydrogen (produced from renewable energy sources) or blue hydrogen (produced via steam *reforming* (of methane) combined with CO_2 capture), approximately 100 ktonnes/year. For this scenario, more limited modifications to the furnaces will be required to allow this, and no loss of production is expected, in contrast to the alternative scenario with CO_2 capture. With a 100% hydrogen content from green hydrogen in the fuel gas, a solution must be found for the remaining methane fraction. This can be done by injecting it into the natural gas network or by valorising it, e.g. as a raw material for blue hydrogen production via steam *reforming* of methane combined with CO_2 capture.

There are two options for the additional supply of green hydrogen of approximately 100 ktonnes/year:

- Purchase of green hydrogen from the grid: The implementation of this option depends on the availability of a sufficient quantity of green hydrogen on the market (approximately 100 ktonnes/year), which is not currently available.
- Production of green hydrogen with green electricity in Project One: The implementation of this option depends on the availability of sufficient green electricity. After all, this option requires approximately 500 to 600 MW of additional green electricity, which is currently not available for Project One.

The production of blue hydrogen has an advantage over CO_2 capture on existing cracking furnaces in that the steam *reforming* process has a high CO_2 concentration in the chimney, which is more efficient for CO_2 capture.

Project One is currently convinced that it is feasible to achieve *net zero* CO_2 emissions within 10 years of the cracker's start-up, using one or more of the techniques described in this EIA.

14.4.2.1.2.3 *Pre-combustion* reduction of direct emissions through partial electrification of the furnaces in combination with 100% H2 content in fuel gas.

Another possibility for reducing the CO_2 emissions of the ECR is partial electrification of the ECR's cracking furnaces, with the rest of the furnaces running on 100% hydrogen in the fuel gas.
The electrification of coking ovens is currently still in the research and development phase, and there is currently no established or cost-competitive technology. It is not yet known what this technology will look like in concrete terms, but it will probably require a far-reaching retrofit of the ECR. This technology requires approximately 300 to 400 MW of green electricity, which is not currently available for Project One. The future availability of mature technology and sufficient green electricity is difficult to predict.

In this case, the direct CO_2 emissions from the process are reduced to zero. Here too, a PSA unit will be required to separate the fuel gas into its hydrogen and methane fractions. The hydrogen fraction will then be recovered for use in the furnaces. A new market will need to be found for the remaining methane fraction.

Project One is currently convinced that it is feasible to achieve *net zero* CO_2 emissions within 10 years of the cracker's start-up, using one or more of the techniques described in this EIA.

14.4.2.2 Administrative building

Passive techniques such as thorough insulation and passive solar gain, climate and lighting controls, and renewable energy techniques (heat pump) are integrated into the design of the administrative building. PV panels are installed on the warehouses. The energy-efficient design was implemented by the architectural firm commissioned by Project One. The administrative building will comply with the Energy Performance Regulations.

As part of this study, an assessment was also carried out on the BREEAM International New Construction 2016 Scheme for the administrative building. BREEAM stands for Building Research Establishment Environmental Assessment Method and is a sustainability label for the construction of sustainable buildings with minimal environmental impact. Under BREAAM, the third highest score was achieved on a scale of 1 to 5 (rating 'very good').

Taking into account the energy-efficient techniques used, the indirect CO2 emissions of the administrative building amount to approximately 300 tonnes of CO2 per year. Given that the external electricity demand will be covered by green electricity, these indirect emissions from the administrative building will therefore be eliminated.

14.4.2.3 Commuting by employees

In Chapter 10 Mobility, it is calculated that approximately 533 people will need to travel to the Project One site.

In Chapter 10 Mobility, the modal split was determined, as shown in Table 14-25. Based on this modal split and emission factors per vehicle, the carbon balance of employees' commuting during the operational phase is determined. A conservative assumption of 50 km per trip or 100 km per day and 250 working days per year is used.

Chapter 10 Mobility sets out measures and recommendations to improve the modal split and the sustainability of commuting, including encouraging cycling, public transport, carpooling, limiting the availability of parking spaces and promoting electric vehicles. These measures and recommendations are, of course, also relevant to Chapter Climate in order to limit CO2 emissions from commuting.

Table 14-25: Carbon balance of employee commuting Project One

Vehicle	Modal split	Number of employees/visitors per day	Number of kilometres/day	CO_2 emission factor[165]	CO_2 emissions (tonnes CO2-eq/year)
Bicycle	17	91		0	0
Collectivetransport I-bus	8	43	100	109 gCO2/passenger km	117
Engine	4	21	100	146 gCO2/vehicle km	77
Carpool (2 passengers per car)	6	32	100	193 gCO2/ vehicle km	154
Car	64	341	100	193 gCO2/vehicle km	1,637
Total		533			1,985

[165] Source: https://co2emissiefactoren.be (updated in March 2024)

14.4.2.4 Transport of raw materials

Ethane will be shipped from the US to the Project One site in Antwerp using the latest generation of VLEC (*Very Large Ethane Carriers*) vessels. These vessels have the following characteristics:

- These ships are designed with state-of-the-art technology and efficiency;
- The ships mainly use ethane as fuel, in addition to fuel oil in situations where no or insufficient ethane is available. Ethane offers the advantage of being a cleaner fuel than marine diesel oil or heavy fuel oil.

The carbon balance is shown in Table 14-26.

Table 14-26: Carbon balance for raw material transport Project One

Ethane transport VLEC-ship	Fuel	tonnes/ethane transport*	tonnes CO_2-eq/tonne	tonnes CO_2-eq/ethane transport*	tonnes ethane/transport	tonnes CO_2-eq/tonnes ethane supply	tonnes ethane supply/year	tonnes of CO_2 equivalent emissions /year
	Ethaan	891	2.93	2,611	51,600	0.055	1,910,000	105,050
	Stook-oil	77	3.19	246				

***Ethane transport: sum of loaded transport to Antwerp and ballast transport back to the US**

14.4.2.5 Transport products

Ethylene is transported directly from the process installations via pipelines. The CO2 emissions from the pumps used to operate the pipelines are included in the calculation of the total process-related emissions from Project One.

14.4.3 Climate adaptation

14.4.3.1 Flooding

In its current state, the 90.29-hectare project area is virtually unpaved. In the planned state, approximately 33.53 hectares will be paved with concrete, asphalt and buildings.

The available flood risk maps (pluvial, fluvial and from the sea) show that the only possible flood risk is due to surface runoff and not to flooding from the Scheldt. It should be noted, however, that the flood map for flooding from the sea does not currently take into account the effect on the Scheldt (see below).

The available forecast for 2050 is used as a basis for the future climate.

The pluvial flood map under the current climate (Figure 14-9) shows the simulated floodable area for a rainfall event with a return period of 10 years (T10), 100 years (T100) and 1,000 years (T1000) for the existing situation. The pluvial flood map under the high-impact climate scenario (Figure 14-10) shows the simulated floodable area for a T10, T100 and T1000 storm under the high-impact climate scenario in 2050. Please note: Figure 14-10 does not take into account the planned land use conversion in the present project. The plans show that the northern part will be raised to 7.6 mTAW during the works. The level of the southern part will vary between 7 and 9 mTAW. As in the current situation, the flood-prone area will remain rather limited.

The design of the rainwater drainage, collection and reuse system, as well as infiltration and buffering, will comply with the regional rainwater regulations as a minimum.

By providing the necessary water management measures within the framework of the regional regulation on rainwater, the effects of flooding are expected to be largely mitigated in the current climate.

However, in light of climate change, an increase in annual precipitation and more frequent (very) heavy rainfall in our region is expected. The design of the rainwater management system therefore also took into account a changed precipitation pattern under the influence of climate change. A storm with a return period of 100 years (T100) was simulated under the high-impact climate scenario (HighS – high summer scenario) for Flanders from VMM for the year 2050. The high summer scenario takes into account flooding as a result of summer convective showers. This is the most extreme and therefore conservative scenario. The design objective is that, in the event of a T100 storm in 2050 under the high summer scenario, the water level will remain at least below the floor slab of the foundations of the industrial installations and below the floor level of buildings. In this way, the project area will be made more resistant to increased flood risks as a result of climate change.

In the future climate, sea levels are expected to rise along the Belgian coast. This rise in sea level not only increases the risks along the Belgian coast, but also the risks along the estuaries connected to the North Sea. This is the case, for example, along the Scheldt estuary, along which the project area is located.

The fluvial flood maps (Figure 14-11, Figure 14-12) and coastal flood maps (Figure 14-13) are also shown below, both for the current and future climate. These maps show no flood risk for the project area.

It is beyond the scope of this EIA to investigate the impact on the water level of the Scheldt. This investigation is being carried out at policy level. For the impact of sea level rise on the Scheldt estuary, reference can be made to the study commissioned by the Flemish-Dutch Scheldt Commission (VNSC) in 2019. This study proposed conducting research in the period 2020-2023 to answer, among other things, the question 'what measures should be taken to maintain functional uses (safety, accessibility, naturalness) in the event of accelerated sea level rise? (VNSC, 2019, Work Plan 2020-2023 Research and Monitoring Scheldt.). This research programme has now been completed and points for attention for the 2024-2028 work plan have already been formulated.

The water level of the Scheldt is also subject to preconditions and measures taken at policy level. Reference can be made, for example, to the SIGMA plan, which includes measures to prevent flooding, such as reinforcing and raising dykes, creating controlled flood areas and depoldering areas. (https://www.sigmaplan.be/nl/themas/veiligheid)

It should also be noted that the project provides for procedures for both planned shutdowns of the installation and emergency shutdowns. These procedures are designed to shut down the installation safely in the event of an emergency or planned maintenance.

Figure 14-9: Pluvial flood map under the current climate. High probability: rainfall event with a return period of 10 years (T10); medium probability: return period of 100 years (T100); low probability: return period of 1000 years (T1000) (Source:www.waterinfo.be/overstromingsrichtlijn)

Figure 14-10: Pluvial flood map – flood-prone area under the high-impact climate scenario (high summer) 2050. High probability: precipitation with a return period of 10 years (T10); medium probability: return period of 100 years (T100); low probability: return period of 1000 years (T1000) (Source:www.waterinfo.be/overstromingsrichtlijn)

Figure 14-11: Areas susceptible to river flooding under the current climate

Figure 14-12: Areas susceptible to river flooding under the future climate

Figure 14-13: Flood-prone areas from the sea under the current climate and the future climate (modelling has only been carried out along the Belgian coast)

14.4.3.2 Water supplies

14.4.3.2.1 Water balance Project One

For a detailed description of Project One's water balance, please refer to Chapter 9 Water of this EIA. Project One's total water consumption averages 720 m³/h, with municipal water and demineralised water being the largest incoming water flows:

- Project One's municipal water consumption averages 367 m³/h. Municipal water accounts for approximately 54% of the cooling water demand in the cooling towers, which totals an average of 673 m³/h.
- Project One's demineralised water consumption averages 333 m³/h. Demineralised water accounts for approximately 43% of the cooling water demand.
- Project One's rainwater and drainage water consumption averages 20 m³/h. This water accounts for approximately 3% of the cooling water demand.

Approximately 90% of the water used leaves the site through evaporation, mainly via the cooling systems.

The municipal water and demineralised water required for Project One will be sourced from external water suppliers.

The water company concerned has a production capacity of 640,000 m³/day **of municipal water** and supplies 40% of the drinking water in Flanders, divided across three segments: residential, industrial and other water companies. Project One's drinking water consumption represents an average increase of 3% in the external water supplier's drinking water supply.

The raw water source for the water company's municipal water supply is currently the River Meuse, whose water flows via the Albert Canal to the intake points. In the current climate, there are no problems with the water supply. However, during dry periods, the Flemish Waterway takes preventive measures to avoid water shortages. This was also the case for the Albert Canal in June 2023.

The VMM, together with the water company concerned, has developed a strategic plan for water supply in view of increasing consumption and reduced water availability during periods of drought due to climate change (VMM, 2021, Strategic plan for water supply in Flanders). This plan stipulates that 3 m³/s (approx. 260,000 m³/day) of alternative water sources must be available for the robust supply of water to industrial and residential customers by 2050, for 5 to 6 months per year, in addition to the traditional sources of drinking water (surface water and groundwater). In addition to reduced water availability during droughts, the deteriorating water quality of existing alternative sources during future drought periods was also taken into account. For example, it is assumed that by 2050, during a prolonged drought, the conductivity in the Antwerp harbour docks could rise to 24,000 µS/cm (brackish - salt water).

In a study conducted by the water company concerned, various options were defined as part of a pre-engineering study, including the production of drinking water during periods of drought using water from the Albert Canal downstream of the lock in Wijnegem (where there is a gradual transition from fresh to brackish water) and the construction of an additional reservoir near the Albert Canal from which water can be consumed during periods of drought. This reservoir is then refilled during the winter period when high Meuse flows are available. In addition, better cooperation and interaction between the various water companies will reduce dependence on the Albert Canal. The Albert Canal currently provides a large part of the water supply for the water company concerned. The conclusion of this study is that there are several possible solutions for making an additional 3 m3/s available from alternative sources during prolonged droughts. There is no simple solution; a combination of different options is needed. However, producing drinking water from alternative sources during periods of drought does lead to an increase in energy consumption compared to traditional sources of drinking water (groundwater and surface water).

In order to reduce pressure on water consumption, two options were studied and weighed up:

- Initially, the installation of a Reverse Osmosis (RO) system on the Project One site was investigated. This would allow part of the discharge from the cooling water circuits and part of the rainwater to be treated. The RO system would produce purified water that could be used as supplementary water for the cooling circuit (replacing municipal water). An assessment was made of whether an RO system could be fed with dock water and/or residual water flows from the installations. This system was thoroughly investigated but proved to be energy-inefficient and therefore also cost-inefficient.
- To reduce pressure on the city's water supply, an external supply of **demineralised water** was chosen instead of an RO installation. The water company involved uses brackish dock water as a raw water source, which reduces pressure on the city's water supply. The use of demineralised water to replace city water means that Project One's city water consumption is roughly halved.

14.4.3.2.2 Impact of drought on Project One

Flanders has one of the lowest levels of water availability per capita. With the exception of three countries, Flanders and Brussels have the lowest water availability per capita of all OECD (Organisation for Economic Co-operation and Development) countries. This is due to a combination of high population density and a relatively limited supply of surface water and groundwater. Climate change is upsetting this fragile balance (Climate Portal, VMM).

Water plays an essential role in the Flemish economy. In 2019, the Flemish Knowledge Centre for Water (Vlakwa) published an updated study on the socio-economic importance of water in Flanders. The study was conducted in collaboration with VITO. The sectors most affected by rising water prices (i.e. sectors with high water costs in relation to gross value added and low gross value added in relation to operating income) include food, beverages, petroleum and coke, chemicals and paper. The Flemish Environment Agency developed a decision-support reactive assessment framework for priority water consumption during droughts. This reactive assessment framework was presented to the five Flemish provinces in 2021 and is currently being refined. Within this framework, two threshold levels have been defined:

- Threshold level 1: imminent water scarcity
- Threshold level 2: effective water scarcity

To determine this level, drought indicators are provided (e.g. water level, soil moisture, etc.). The water balance (the balance between supply and demand) was determined for each sub-area. Based on this water balance, measures were defined that can be taken in certain situations and at certain locations. A number of principles and conditions were also applied for this purpose. This resulted in an area-specific assessment framework.

To reduce the pressure on the city's water supply, it was decided to use an external supply of demineralised water. The water company involved uses brackish dock water as a raw water source, which reduces the pressure on the city's water supply. Using demineralised water to replace city water means that Project One's city water consumption is roughly halved, which is a significant reduction.

Project One's urban water consumption represents an average increase of 1% of total urban water consumption in Flanders compared to 2021 (Table 14-27) or an increase of 4% of total urban water consumption in the industrial sector in Flanders compared to 2021.

Project One's urban water consumption can be considered significant. In the current climate, there are no problems with the water supply at the water company involved. Project One's municipal water consumption falls within the strategic plan of the water company concerned to make alternative water sources available in order to guarantee the supply of drinking water to industrial and residential customers in the future during periods of drought, even in a changed climate. The water company's drinking water supply to Project One will remain guaranteed in the future, even under a changed climate. This mitigates the risk of water scarcity for Project One during periods of drought. However, producing drinking water from alternative sources during periods of drought does lead to an increase in energy consumption compared to traditional sources of drinking water (groundwater and surface water).

Table 14-27: Urban water consumption in Flanders (2021) (Source: VMM) and contribution of Project One

	Urban water consumption 2021 (m³)	Urban water consumption Project One* (%)
Flanders – total for the energy, trade & services, households, industry and agriculture sectors	352,439,000	1
Flanders – total for the industry sector	81,678,000	4

*Project One's urban water consumption amounts to 367 m³/hour or 3,214,920 m³/year, based on 8,760 production hours per year.

In addition, reference can be made to the legal obligations of water companies under the Integrated Water Policy Decree (DIW) with regard to the operation, maintenance and development of the water distribution network and the provision of services (Article 2.5.1.1 DIW).

These obligations are further elaborated in an implementing decree and mean that the water company must:

- Must use all appropriate means to ensure the continuity of water supply at all times
- takes appropriate measures to meet future water needs
- draws up long-term supply plans.

In addition, under certain conditions, the minister, governor or mayor has the power to impose temporary restrictions on the use of drinking water. (Articles 24 and 27 of the Decree of the Flemish Government of 20 January 2023 on the quality, quantity and supply of water intended for human consumption.)

It should also be noted that the project provides for procedures for both planned shutdowns of the installation and emergency shutdowns. These procedures are designed to shut down the installation safely. This can be done in the context of an emergency, planned maintenance or in the event of water scarcity.

14.4.3.3 Climate resilience of industrial installations

When establishing the basic values for temperature, relative humidity and wind for the design (BEDD = basic engineering design data) of Project One (including the cooling systems and compressors), historical climate data was taken into account, with a conservative margin built in. The simulated parameters were then checked against the VMM's medium and high climate scenarios for Flanders for the year 2050. The conclusion was that the BEDD data could be retained, and the consequences of expected extreme weather conditions as a result of climate change were also better mapped out. Climate resilience has been integrated into the operation of Project One's industrial installations.

14.4.3.4 Heat stress

Heat stress is expressed in heatwave degree days. Heatwave degree days are a measure of the heat stress to which residents are exposed, and are the sum of the exceedances of the daily maximum and minimum temperatures above the threshold values for heatwave days in the period from 1 April to 30 September in a given year. We speak of a heatwave when a heat episode lasts at least three days, the daytime temperature rises above 29.6 °C and remains above 18.2 °C at night. The threshold for heat stress is considered to be 60 heatwave degree days. Heat stress due to rising temperatures is mainly seen in built-up areas, less so in rural areas.

In the project area, 90.29 hectares can currently be considered entirely green and unpaved space, of which 39.31 hectares is forest area. Green space has the capacity to cool the ambient temperature during the day as a result of the evapotranspiration of vegetation (trees, grass, shrubs, etc.), or to keep it cool by providing shade. A lawn is cooler during the day than a concrete surface. A forest is even cooler than a lawn.

A forest cools more effectively during prolonged heat waves because trees evapotranspire more water and have deeper roots than grasses and lower vegetation. Due to the difference in temperature with the surrounding area, the coolness spreads to the immediate vicinity. The influence of this cooling plume depends on the orientation of the streets, any blockages, etc. Some key figures[166]:

- Green spaces larger than 3 ha are significantly cooler than the urban environment;
- Green elements must be at least 5 hectares in size to have a temperature effect on the surrounding area.
- The average daytime temperature difference (air temperature) between a park and the surrounding built-up area is between 1 and 4.7°C;
- With a permeable soil seal, rainwater can penetrate the soil more easily, which evaporates through the vegetation in hot weather, lowering the ambient temperature. The average surface temperature drops by 1 °C when 10% of the paved and built-up area is replaced by unpaved surface. The reverse is also true. On a smaller scale (street level), the cooling effect can be greater; upright plants (like other forms of vegetation) actively cool their surroundings during the day through evaporation via the stomata of their leaves - evapotranspiration. A tree can evaporate around 400 litres per day in summer. The energy/heat extracted from the environment results in a local cooling of the air temperature. Trees also have an important shading effect, so that surfaces such as soil, facades and paving can absorb less heat.

In its current state, the project area has a noticeable cooling effect on the immediate surroundings. This cooling and buffering effect is mainly important for the natural values present in the project area itself and, to a lesser extent, for humans, given that only industrial functions are present in the immediate surroundings. This cooling effect in its current state is shown in Figure 14-14 and Figure 14-15, which show the number of heatwave degree days and the number of heatwave days for the project area and its surroundings, respectively. These maps are taken from the VMM Climate Portal. Note also the significant cooling effect of the Scheldt and the Canal Dock. In the existing situation, the threshold for heat stress (60 heatwave degree days) is not exceeded for the project area and its surroundings.

Figure 14-16 shows that the threshold for heat stress (60 heatwave degree days) is exceeded by less than twice for the project area, and between twice and three times in the vicinity of the project area in VMM's high-impact climate scenario for the year 2050. Figure 14-17 shows that in 2050, in the high-impact climate scenario, there will be 7 to 8 more heatwave days in the project area compared to the current situation. For the area surrounding the project area, the increase in the number of heatwave days in the high-impact climate scenario for 2050 compared to the current situation is up to 15 days.
Please note: Figures 14-16 and 14-17 do not take into account the planned land use conversion in this project. Note also the continuing important cooling effect of the Scheldt and the Canal Dock.

From the above, it can be concluded that climate change will lead to a noticeable increase in the number of heatwave days and the degree of heat stress in 2050. Due to the removal of vegetation and the conversion of green and unpaved land use to industry, the cooling and buffering effect in the project area and its immediate surroundings will disappear. Given the change in land use (industrial installations), this will have no effect on the living environment. Moreover, the cooling effect of the Scheldt and the Canal Dock on either side of the project area is greater than that of the project area in the current situation and for the future climate. This cooling effect will be maintained.

[166] Source: Technum, 2015. Climate adaptation and qualitative and quantitative guidelines for spatial planning. Commissioned by Ruimte Vlaanderen.

Figure 14-14: Heat stress (number of heatwave degree days) in project area (black pins): existing situation 2017 (Source: Climate Portal Flanders VMM)

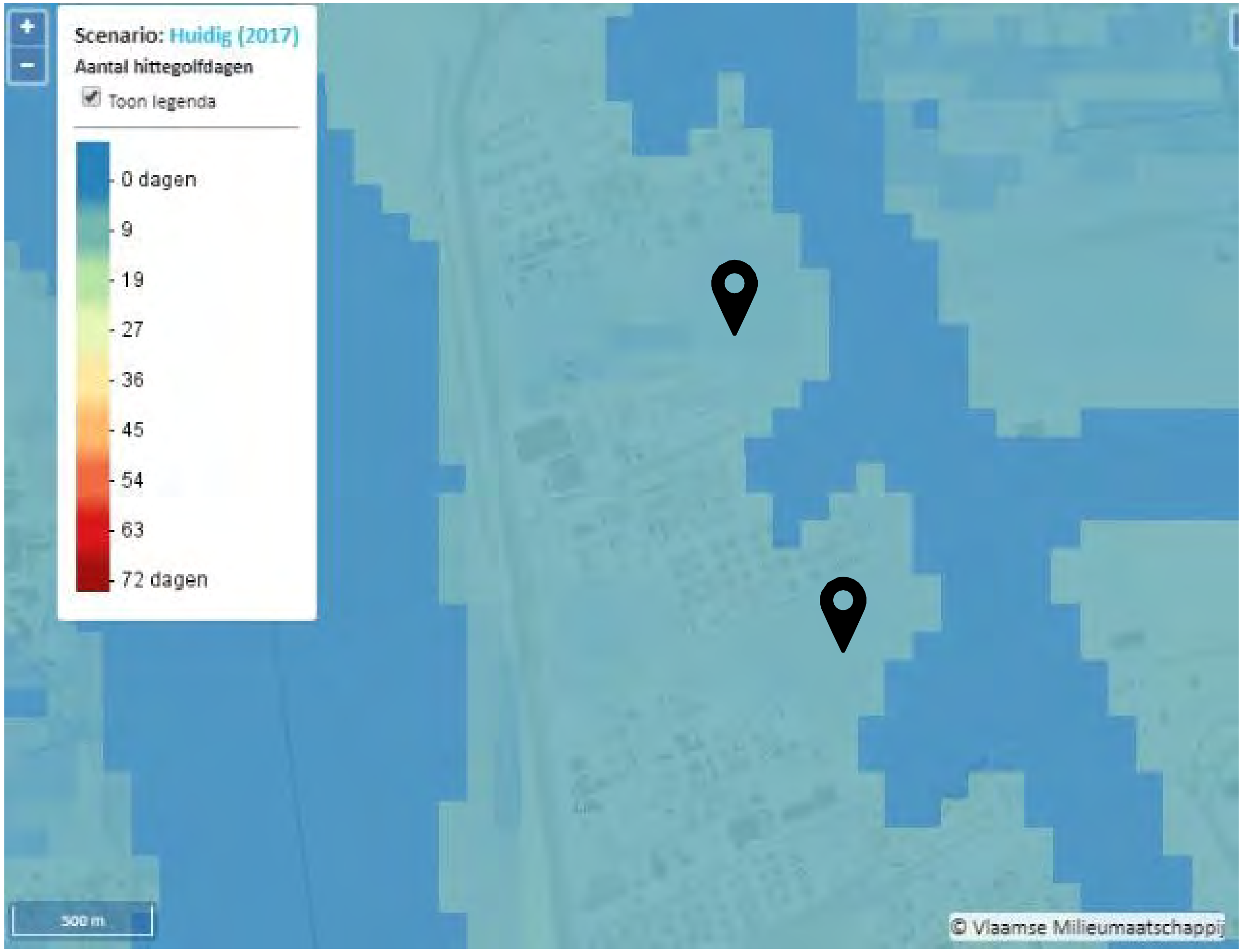

Figure 14-15: Number of heatwave days in project area (black pins): existing situation 2017 (Source: Climate Portal Flanders VMM)

Figure 14-16: Heat stress (number of heatwave degree days) in the project area (black pins): high-impact climate scenario 2050 (Source: Climate Portal Flanders VMM)

Figure 14-17: Increase in the number of heatwave days in the project area (black pins): high-impact climate scenario 2050 vs. current situation 2017 (Source: Climate Portal Flanders VMM)

14.4.4 Conclusion

14.4.4.1 Carbon balance

The **process-related emissions** of the ECR and supporting infrastructure are estimated as follows:

- The total carbon balance of the ECR and supporting infrastructure is calculated as 655 ktonCO2-eq/year:
  - Project One uses state-of-the-art technology for cracking ethane, and the best available techniques (BAT) and energy integrations are consistently applied to achieve high energy and production efficiencies.
  - The ECR is designed for selective and efficient ethylene production. Of the raw material ethane, 81% of the carbon is captured in ethylene. Project One will operate the best-performing steam cracking technology in terms of carbon efficiency in Europe.
  - The specific process emission of Project One's ECR is 0.290 $_{\text{tonnes CO2-eq/tonne HVC}}$, or only 42% of the current EU ETS benchmark value of 0.681 $_{\text{tonnes CO2-eq/tonne HVC}}$. It has been calculated that Project One implies a tightening of the EU ETS benchmark value for HVC production to approximately 0.577 $_{\text{tonnes CO2-eq/tonne HVC.}}$ This is a decrease of approximately 15% compared to the current benchmark value for HVC production (0.681 $_{\text{tonnes CO2-eq/tonne HVC}}$).
  - The ethylene produced in Project One is sold on the market. Most existing installations are currently supplied with ethylene from European naphtha crackers, which are often outdated and have significantly higher specific CO2 equivalent emissions than the new ECR of Project One. These installations can purchase the ethylene produced by Project One and reduce their CO2 equivalent emissions. As an example, it has been calculated that the reduction in the carbon footprint of the customers would amount to approximately 2 Mton CO2-eq/year if the customers were to use the ethylene produced in Project One.
  - Two power purchase agreements (PPAs) were concluded with energy suppliers Engie and RWE for the supply of a total of 509,600 MWh per year of green electricity (offshore wind energy) for a period of 10 years. This means that when Project One starts in 2026, the external electricity demand of 140,160 MWh/year will be covered by green electricity. This will reduce the total emissions of the ECR and supporting infrastructure by approximately 7% compared to the project without the import of green electricity, specifically from 708 ktonCO2-eq/year to 655 ktonCO2-eq/year.

The **emissions from the administrative building**, the **emissions from transport for employees' commuting, transport for raw materials** and **transport for products** in the operational phase are estimated as follows:

- Passive techniques such as thorough insulation and passive solar gain, climate and lighting controls, and renewable energy techniques are integrated into the design of the administrative buildings. Under BREAAM, the rating 'very good' has been achieved (^{3rd} highest score on a scale of 1 to 5). Taking into account the energy-efficient techniques used, the (indirect) CO2 emissions of the administrative building amount to approximately 300 tonnes of CO2/year. As the external electricity demand will be covered by green electricity, these emissions from the administrative building will therefore be eliminated.
- A total of approximately 533 employees and visitors will need to travel to the Project One site every day. The **commuting** of Project One **employees** will result in emissions of approximately 1,985 tonnes of CO2-eq/year.
- **The raw material** ethane is transported using efficient VLEC ships. The total carbon balance for the transport of ethane for Project One by ship is 105,050 tonnes of CO2-eq/year.
- The **transport of** ethylene from the process plant is carried out directly via pipelines. The CO2 emissions from the pumps used to operate the pipelines are included in the calculation of Project One's total process-related emissions.

14.4.4.2 Climate adaptation

The consequences of climate change may have an impact on the project area itself:

- **Flooding**: The available flood hazard maps (pluvial, fluvial and coastal) show that the flood risk is due to surface runoff and not to flooding from the Scheldt.

It should be noted that the flood map for flooding from the sea does not currently take into account the effect on the Scheldt. When designing the rainwater management system, account was taken of a changed precipitation pattern under the influence of climate change under the high-impact climate scenario (HighS – high summer scenario) for Flanders from VMM for the year 2050. The high summer scenario takes into account flooding as a result of summer convective showers. This is the most extreme and therefore conservative scenario. In this way, the project area is made more resistant to increased flood risks as a result of climate change.

- **Water supply**:
  - Project One's urban water consumption represents an average increase of 1% of total urban water consumption in Flanders compared to 2021. Project One's urban water consumption represents an average increase of 4% of total urban water consumption in the industrial sector in Flanders compared to 2021.
  - To reduce the pressure on the city's water supply, it was decided to use an external supply of demineralised water. The water company involved uses brackish dock water as a raw water source, which reduces the pressure on the city's water supply. Using demineralised water to replace city water means that Project One's city water consumption is roughly halved, which is a significant reduction.
  - Project One's urban water consumption can be considered significant. In the current climate, there are no problems with the water supply at the water company involved. Project One's municipal water consumption falls within the strategic plan of the water company concerned to make alternative water sources available in order to guarantee the supply of drinking water to industrial and residential customers in the future during periods of drought, even in a changed climate. The water company's drinking water supply to Project One will remain guaranteed in the future, even under a changed climate. This mitigates the risk of water scarcity for Project One during periods of drought. However, producing drinking water from alternative sources during periods of drought does lead to an increase in energy consumption compared to traditional sources of drinking water (groundwater and surface water).
- **Climate resilience** of **industrial installations**: When establishing the basic values for temperature, relative humidity and wind for the design (BEDD = basic engineering design data) of Project One (including the cooling systems and compressors), a comparison was made with the medium and high climate scenarios for Flanders from VMM for the year 2050. The conclusion was that the BEDD data could be retained, and the consequences of expected extreme weather conditions as a result of climate change were also better mapped out. Climate resilience has been integrated into the operation of Project One's industrial installations.
- Heat **stress**: The project area can currently be considered entirely green space. In its current state, the project area has a cooling effect on the immediate surroundings. This cooling and buffering effect is mainly important for the natural values present in the project area itself and less so for humans, given that the immediate surroundings mainly consist of industrial functions. Deforestation and the removal of other vegetation will cause this cooling and buffering effect to disappear. Given the change in the use of the space (industrial installations), this will have no effect on the living environment. Moreover, the cooling effect of the Scheldt and the Canal Dock on either side of the project area in its current state and for the future climate is greater than that of the project area. This cooling effect will be retained.

14.4.5 Mitigation measures and recommendations

Project-integrated mitigating measures for the operational phase of Project One are:

- The ECR is designed for selective and efficient ethylene production. Project One uses state-of-the-art technology for ethane cracking. Best available techniques (BAT) and energy integrations are consistently applied to achieve high energy and production efficiencies. Key process-integrated energy-saving and emission-reducing measures are applied in the design of Project One.
- Two power purchase agreements (PPAs) were concluded with energy suppliers Engie and RWE for the supply of green electricity (offshore wind energy) for a period of 10 years. This means that when Project One starts in 2026, external electricity demand will be covered by green electricity.
- Project One currently has three possible future prospects for further reducing the CO2 emissions of the ECR in the future:

1. *post-combustion* CO_2 capture technology or;
2. a *pre-combustion* CO2 reduction technology with 100% green and/or blue hydrogen in the fuel gas supplied to the ECR or;
3. a *pre-combustion* CO2 reduction technology with partial electrification of the ECR's cracking furnaces, with the rest of the furnaces operating on 100% hydrogen in the fuel gas.

Project One has the necessary technological flexibility on the ethane cracking furnaces (ECR) and steam boilers for the first two scenarios. Sufficient space has been reserved in the project area for these scenarios, and the design already takes into account future retrofitting of the site and installations. Electrification of cracking furnaces, the third scenario, is currently still in the research and development phase and there is currently no established or cost-competitive technology. Electrification of the cracking furnaces can be evaluated once the technology is sufficiently developed. The three possible future scenarios will be the subject of further research as part of INEOS' roadmap to achieve net zero CO2 emissions.Project One is currently convinced that it is feasible to achieve *net zero* CO2 emissions within 10 years of the cracker's start-up, using one or more of the techniques described in this EIA.

- The administrative building is designed to be energy efficient. Passive techniques such as thorough insulation and passive solar gain, climate and lighting controls, and renewable energy techniques are integrated into the design. Under BREAAM, it achieves the third highest score on a scale of 1 to 5 (rating 'very good'). Given that the external electricity demand will be covered by green electricity, the emissions from the administrative building will therefore be eliminated.
- Ethane will be transported using efficient VLEC ships.
- Ethylene is transported via pipelines.
- In order to reduce the pressure on the city's water supply, it was decided to use an external supply of demineralised water. The water company involved uses brackish dock water as a raw water source, which reduces the pressure on the city's water supply. The use of demineralised water to replace city water means that Project One's city water consumption is reduced by approximately half.

14.5 Life Cycle Thinking ethylene

14.5.1 Scope

Life Cycle Thinking (LCT) is based on a systemic framework with a holistic view of the production and consumption of a product or service, assessing its environmental impact throughout its entire life cycle. This starts with the extraction and processing of raw materials, followed by production and distribution, and ends with use and/or consumption. It ends with the reuse of materials, energy recovery and final disposal. LCT goes beyond the traditional focus on a specific production location and a specific production process. Emissions resulting from the use of raw materials and products upstream and downstream of the project should therefore not be analysed in an EIA.

However, the climate chapter goes further than what is required under the relevant regulations. The decision has been made to apply Life Cycle Thinking. A project EIA, as defined by European and Flemish regulations, deals with the effects of a project and not those of a product. That is why this chapter on Life Cycle Thinking will discuss the climate effects that occur during the life cycle of ethylene – upstream and downstream of Project One – in a qualitative and informative manner. The application of Life Cycle Thinking is valuable, given that production and consumption influence each other due to the reality of complex, interconnected value chains.

Project One will bring ethylene to market. Ethylene is an important intermediate in the chemical industry. Greenhouse gas emissions occur throughout the entire life cycle of end products derived from ethylene:

11. extraction of raw materials and fuels upstream of Project One,
12. production of ethylene in Project One,
13. production of ethylene derivatives downstream of Project One,
14. conversion of derivatives into consumer products downstream of Project One,
15. use phase of products downstream of Project One,
16. end-of-life (EoL) phase downstream of Project One.

The purpose of this chapter is to identify the main sources of greenhouse gas emissions from ethylene throughout its entire life cycle and to indicate where the main challenges and opportunities lie in terms of emission reductions related to the efficient use of raw materials and products, in line with European and Flemish climate policy. It is also important to note that the use of ethylene applications in itself leads to significant reductions in greenhouse gas emissions in the various end-user sectors.

This chapter describes the sustainability measures that are being or could be taken by Project One and the INEOS Group, both upstream and downstream of the project. It is important to note at which stages of the life cycle of end products derived from ethylene Project One and the INEOS Group play a role and where they do not:

- Project One selects the type and suppliers of raw materials and fuels for the production of ethylene, but is not directly involved in the extraction of these raw materials and fuels.
- Project One produces ethylene. Project One is not involved in the production of ethylene derivatives, the conversion to end-use products, or the end-of-life phase of these products downstream of ethylene production.
- The INEOS Group is actively involved in the production of certain ethylene derivatives and conversions into consumer products.

14.5.2 Raw materials and production routes for ethylene

Ethylene is produced worldwide mainly from fossil raw materials such as petroleum (naphtha), natural gas or coal. These are the so-called conventional production routes for ethylene, which are described below. A variety of carbon- and hydrogen-containing materials can replace oil, natural gas and coal as chemical raw materials (IEA, 2018; World Economic Forum, 2016). Alternative production routes are based on biomass and greenhouse gases, among other things. Two alternative production routes for ethylene are described below, but this list is not exhaustive.

Next, we will discuss the chosen production route for Project One and the upstream raw material extraction for Project One.

14.5.2.1 Ethylene production routes

Based on naphtha or ethane

The current leading technology for the production of olefins (alkenes) is steam cracking (SC), based on petroleum or natural gas (Amghizar et al., 2017).

Naphtha, a petroleum derivative, is the primary raw material for global olefin production and is also the most widely used raw material for ethylene production in Europe. After crude oil is extracted from the ground, it is transported to a refinery. The oil refining process produces, among other things, naphtha, a mixture of hydrocarbons that can be converted into olefins through a process called steam cracking. Olefins can also be produced directly by fluidised catalytic cracking in oil refineries, although this process is less common.

Ethane is also an important raw material for the production of ethylene and is the chosen production route for Project One (albeit significantly optimised in terms of reduced CO2 emissions). Once extracted from natural gas in a fractionation plant, ethane is processed into ethylene in an ethane steam cracker (ECR). Due to the related structure between ethane and ethylene, the conversion is accompanied by high selectivity. While naphtha cracking produces ethylene, propylene and other HVCs, ethane crackers are designed to produce ethylene very selectively.

Based on coal

Coal is also used to produce olefins, although the process is significantly less cost-efficient and energy- and carbon-efficient than olefin production from oil and gas (Amghizar et al., 2017; IEA, 2018). Coal can be converted into synthetic natural gas (syngas) through the process of coal gasification.

After gasification, this syngas, a mixture of CO and H_2, can be converted into methanol, which can then be converted into olefins (principle of *methanol-to-olefins* or MTO). This process is sometimes also referred to as *coal-to-olefins* (CTO).

The greatest gains for HVC production in terms of process-related energy demand and CO2-equivalent emissions can be achieved by switching from solid raw materials (coal) to gaseous or liquid raw materials (IEA, 2018).

Based on methane

The abundance of methane from shale gas or stranded gas reserves has led to increased interest in the development of processes to valorise methane into higher hydrocarbons or chemicals (Amghizar et al., 2017). Methane can also be produced from biomass (waste) streams. Several of these processes have been identified as potential alternatives to steam cracking: *methanol-to-olefins* (MTO), Fischer-Tropsch synthesis (FTS) and oxidative coupling of methane (OCM).

Methanol-to-olefins, or MTO, is one of the technologies that can be used to produce basic petrochemical products. Methanol is mainly produced catalytically from syngas, a valuable gas mixture of hydrogen and carbon monoxide. Methanol is used in large quantities for the production of a wide variety of basic chemicals. Syngas can be obtained from various carbon-containing sources by gasification of natural gas, coal or biomass. However, the lowest production costs and highest carbon efficiency of syngas production are based on methane. High carbon selectivity towards ethylene and propylene is achieved. In addition, the process conditions can be modified to promote the formation of propylene. The main process challenge, however, is the rapid deactivation of the catalyst (Amghizar et al., 2017).

Fischer-Tropsch synthesis, or FTS, is another technology that converts syngas into basic petrochemical products and mainly hydrocarbons for the fuel segment. FTS is a mature technology, but significant challenges remain in improving product selectivity and catalyst design (Amghizar et al., 2017).

The above-mentioned technologies (MTO and FTS) can be used to convert methane into higher hydrocarbons, but only indirectly; that is to say, they require the production of syngas as a first step. This first step to produce syngas represents an inherent inefficiency. Oxidative coupling of methane, or OCM, is one of the most promising direct routes for converting methane into ethylene and higher hydrocarbons. The main challenges for the economic success of OCM are catalyst development and reactor design (Amghizar et al., 2017).

Alternative steam cracking technologies must be economically and technically viable. Both the FTS and MTO processes are proven technologies, with several plants already operational worldwide. Despite the maturity of these technologies, both are inherently inefficient due to the syngas production step. Furthermore, FTS is not selective enough to produce only light olefins and produces a significant amount of fuel hydrocarbons. However, improvements to these processes are still possible, particularly with regard to catalyst design. For OCM, major research efforts on catalyst and reactor design are still required before it can be considered an alternative to steam cracking (Amghizar et al., 2017).

Alternative steam cracking technologies must also be viable from an environmental perspective. In this context, it is important to evaluate the CO2 emissions associated with the various technologies discussed above. Figure 14-18 shows the expected CO2 emissions per tonne of HVC production. A distinction is made between CO2 emissions resulting from the energy requirements of the process (i.e. fuel combustion) and the chemical CO2 emissions generated by the reaction. Figure 14-18 clearly shows that steam cracking is still the best performing technology in terms of CO2 emissions. The process produces almost no chemical CO_2, and the energy efficiency of the process has been optimised to such an extent that the energetic CO2 emissions are very low compared to those of the other technologies. OCM also looks promising, as it has the lowest energetic CO2 emissions. However, due to its relatively low ethylene selectivity, the chemical CO2 emissions for this technology are still quite high.

As expected, coal-based technologies generate high CO_2 emissions, both energetically and chemically (Amghizar et al., 2017).

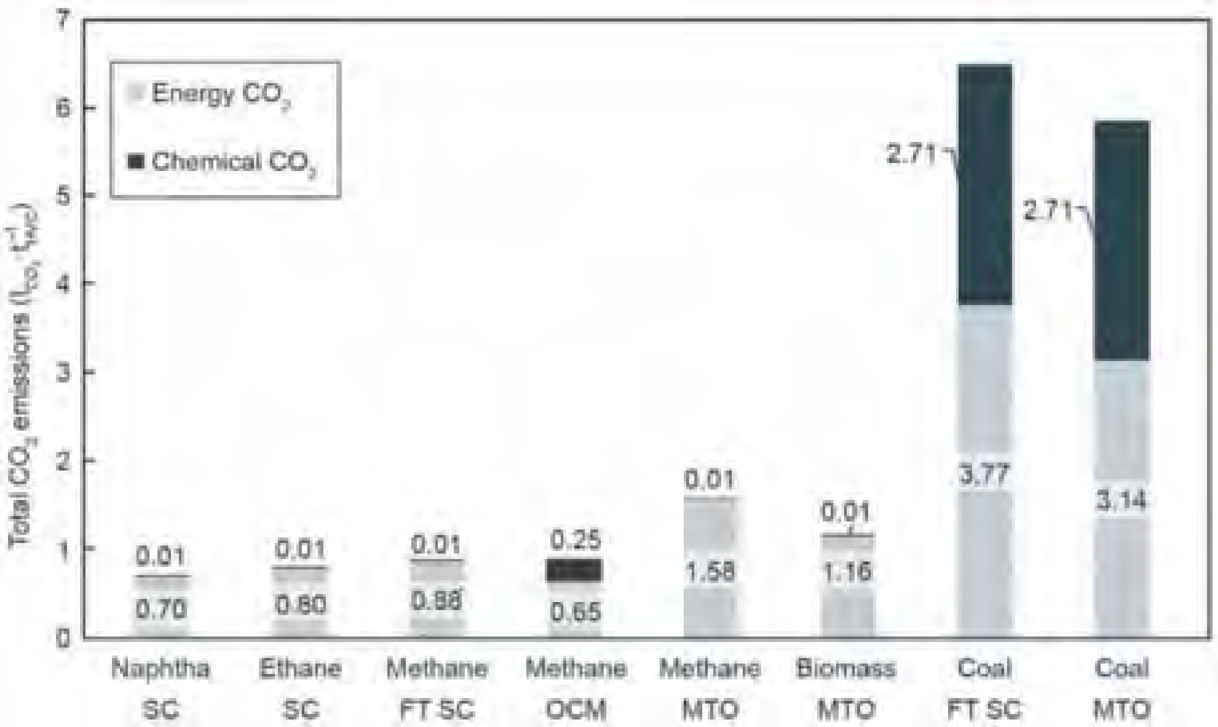

*Figure 14-18: Total CO2 emissions per tonne of HVC production (tonnes CO2/tonne HVC) for different technologies – at global level (Source: Amghizar et al., 2017)**

*This graph is not representative of the specific CO2 emissions of Project One's ECR.

Based on bioethanol

Ethylene is produced on an industrial scale from bioethanol derived from sugar cane and other bioenergy crops. So-called bioethylene is produced by dehydration (the removal of water) from ethanol in a well-developed process. This technology is generally only economically viable in areas where bioethanol can be produced at competitive economic costs, based on good local availability of bio-raw materials. Brazil, which derives large quantities of ethanol from the fermentation of sugar cane, accounts for 50% of global bioethylene production capacity. This is a so-called first-generation bio-based raw material, where direct and indirect land use changes in certain cases have a negative impact on the overall carbon footprint compared to conventional production routes based on fossil raw materials.

Based on CO_2

CO_2 can be used to produce synthetic olefins. Although there is some diversity in the available processes, it can generally be said that CO_2 is combined with hydrogen in the presence of a catalyst. Hydrogen gas can be produced using water and electricity through electrolysis. Electrolysis is already widely used in industry for the production of metals such as aluminium and lithium. The reaction between electrolysis-based hydrogen and CO_2 results in methanol. Methanol can then be converted into olefins via MTO (*methanol-to-olefins*).

14.5.2.2 Selected ethylene production route in Project One

14.5.2.2.1 Steam cracking of ethane in Project One

The ECR in Project One is fed with ethane. Project One achieves significant gains in terms of process-related CO2 equivalent emissions compared to naphtha-dominated HVC production in Europe. The ECR is designed for selective and efficient ethylene production.

Of the raw material ethane, 81% of the carbon is captured in ethylene. Project One will exploit the best performing steam cracking technology in terms of carbon efficiency in Europe.

It has been calculated that Project One implies a tightening of the EU ETS benchmark value for HVC production to approximately 0.577 tonnes CO2-eq/tonne HVC. This is a decrease of approximately 15% compared to the current benchmark value for HVC production (0.681 tonnes CO2-eq/tonne HVC). Taking into account the current annual HVC production capacity in Europe of 47.6 Mton HVCs (IEA, 2018), this means that approximately 4.95 Mton of additional emission allowances must be paid or avoided annually by existing steam crackers for HVC production under the EU ETS system. Such a quantity of emission allowances corresponds to approximately 267 million euro/year, taking into account the current price (mid-February 2024) of 54 euro/tonne CO2 under the EU ETS system. Part of this additional revenue for the EU ETS system will be used to support innovation and modernisation projects aimed at reducing CO2 emissions in energy-intensive industrial sectors and the energy sector. The ECR of Project One is likely to have an impact on the benchmark for phase 5 of the EU ETS system (from 2031), as activities will start in 2026.

The ethylene produced in Project One is sold on the market. Most existing installations are currently supplied with ethylene from European naphtha crackers, which are often outdated and have significantly higher specific CO2 equivalent emissions than the new ECR of Project One. These installations can purchase the ethylene produced by Project One and reduce their CO2 equivalent emissions. As an example, it has been calculated that the reduction in the carbon footprint of the customers would amount to approximately 2 Mton CO2-eq/year if the contractors were to use the ethylene produced in Project One.

14.5.2.2.2 Raw material extraction upstream of Project

One 14.5.2.2.2.1General

The ECR of Project One is fed with ethane from the US, where it is largely produced as a by-product of shale gas extraction. Shale gas (natural gas) consists mainly of methane, although heavier hydrocarbons in the form of natural gas liquids (NGLs) are also produced from gas wells. The most common NGLs are ethane and propane. These NGLs are (partially) removed from the natural gas stream for safety, operational or economic reasons.

Ethane will come from various INEOS-approved suppliers in the north-east of the US and the Gulf Coast. Ethane will be shipped from the US to the port of Antwerp in liquid form, deep-chilled, using ethane tankers (VLEC, Very Large Ethane Carriers). The main factor determining the choice of production routes for HVCs is the availability and cost of raw materials, which varies greatly between regions (IEA, 2018). Other sources of ethane are not currently considered realistic for the operation of Project One due to availability and cost.

Conventional natural gas was the dominant form of natural gas produced in the 20th century. Until this century, shale gas could not be developed commercially on a large scale. The use of a new combination of technologies in the 21st century – high-precision directional drilling, high-volume hydraulic fracturing and drilling platforms with clustered multiple horizontal wells – has changed this. In recent years, global shale gas production has increased by a factor of 14, from 31 billion m^3 per year in 2005 to 435 billion m^3 per year in 2015, with 89% of production in the United States and 10% in western Canada. The US Department of Energy predicts rapid further growth in global shale gas production, to 1,500 billion m^3 per year in 2040 (EIA, 2016).

14.5.2.2.2.2Fugitive emissions

During the extraction, processing, conversion and transport of all types of fossil fuels to the point of end use, hydrocarbons may be released. Volatile methane emissions are particularly significant in this regard. Methane is a powerful greenhouse gas, with a global warming potential (GWP) that is 84 times higher over a period of 20 years and 28 times higher over a period of 100 years than that of CO2. This is why even small methane leaks are significant.

The IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels (Rogelj et al., 2018), it is stated that limiting warming to 1.5°C means that global net CO2 emissions must be reduced to zero by around 2050 and that, at the same time, emissions of non-CO2 greenhouse gases, in particular methane, must be significantly reduced.

Chapter 7 on "Energy Systems" by Working Group III in the IPCC's Fifth Assessment Report (AR5) (Bruckner et al., 2014), it is stated that the rapid development of hydraulic fracturing and horizontal drilling techniques since AR4 (2007) has led to an increase and diversification of gas supply and that a more extensive switch from coal to gas for electricity and heat production has become possible; which is a major reason for the reduction in greenhouse gas emissions in the United States.

At the same time, the increasing use of natural gas has raised the issue of volatile methane emissions from both conventional and shale gas production. Methane is the main component of natural gas. Central emission estimates from recent analyses show that methane accounts for around 2%–3% (+/-1%) of the gas produced. Emissions from conventional and unconventional gas are comparable (Bruckner et al., 2014). The recent review paper on 'The Global Methane Budget 2000-2017' by Saunois et al. (2020) states that the increase in gas production in the US will almost certainly lead to an increase in absolute methane emissions, but that the global impact of the rapidly growing shale gas activities in the United States on atmospheric methane concentrations still needs to be accurately determined. A mix of affordable technological solutions, mandates and emissions pricing instruments is needed to control methane emissions, recognising the need to maintain the competitiveness of natural gas relative to coal (World Economic Forum, 2020).

In recent years, the US has introduced a series of performance standards and requirements for shale gas extraction that build on the best available techniques and practices to minimise fugitive methane emissions and methane emissions from venting and flaring. The US has also introduced LDAR (Leak Detection and Repair) programmes, regular equipment and infrastructure inspection programmes, and methane emissions monitoring and reporting programmes.

14.5.2.2.2.3Measures Project One

In addition to emission-reducing techniques and regulatory measures, voluntary, industry-led emission reduction programmes are also important. Project One is taking the following emission-reducing measure in relation to the supply of ethane:

- INEOS's largest current ethane suppliers – notably Antero and EQT – were affiliated with emission reduction programmes such as the OneFuture Coalition or the US EPA's Natural Gas STAR programme (US EPA, 2021). In doing so, they committed to setting targets and publicly reporting their performance. According to data reported in 2019[167], methane emissions below 0.04% of natural gas production, down from 0.09% methane emissions from natural gas production in 2017. Antero and EQT report similar levels of methane emissions. Antero states in its sustainability report[168] that their specific methane emissions in 2019 amounted to 0.046% of natural gas produced. These emissions are significantly lower than the average emission levels reported in §14.5.2.2.2.2 from (Bruckner et al., 2014). In 2022, the EPA partially discontinued the Natural Gas STAR Partnership. The partnership agreements and annual reporting elements of the programme were terminated. However, the emphasis remains on technology transfer and stakeholder engagement. Through the Methane Challenge Partnership, the EPA continues to collaborate with operators. Affiliated partners must report transparently on systematic and comprehensive actions to reduce their methane emissions. In doing so, they follow a strategy based on emission reduction targets rather than a technology-based strategy.
- MiQ is an independent non-profit organisation that seeks to achieve a rapid reduction in methane emissions from the oil and gas sector.

[167] Source: Range Resources 2020 Corporate Sustainability Report: https://csr.rangeresources.com/wp-content/uploads/2020/09/Range_resources_CSR_report.pdf
[168] Source: Antero Resources 2020, Sustainability, https://www.anteroresources.com/sustainability/founders-message

This is achieved through independent certification of gas producers in the natural gas chain. Each certificate, with a unique identification code, proves where and when the gas was produced and what the methane intensity of the production is. Range Resources obtained the 'A-grade MiQ certificate' from MiQ. EQT is seeking to obtain MIQ certification.

14.5.2.3 Applications of ethylene

Project One's ECR will bring ethylene to the market, specifically 1.45 Mton of ethylene per year. Propylene, C4, C5+ hydrocarbons and pyrolysis oil will be generated as the main by-products in the ECR in limited quantities. Together, these by-products account for 0.113 Mton per year of HVC. Figure 14-19 provides an overview of the various derivative products of these HVCs. The ethylene produced by Project One is sold and supplied to anyone who purchases it and could be used in the INEOS group's installations, which could significantly reduce the carbon footprint of its customers.

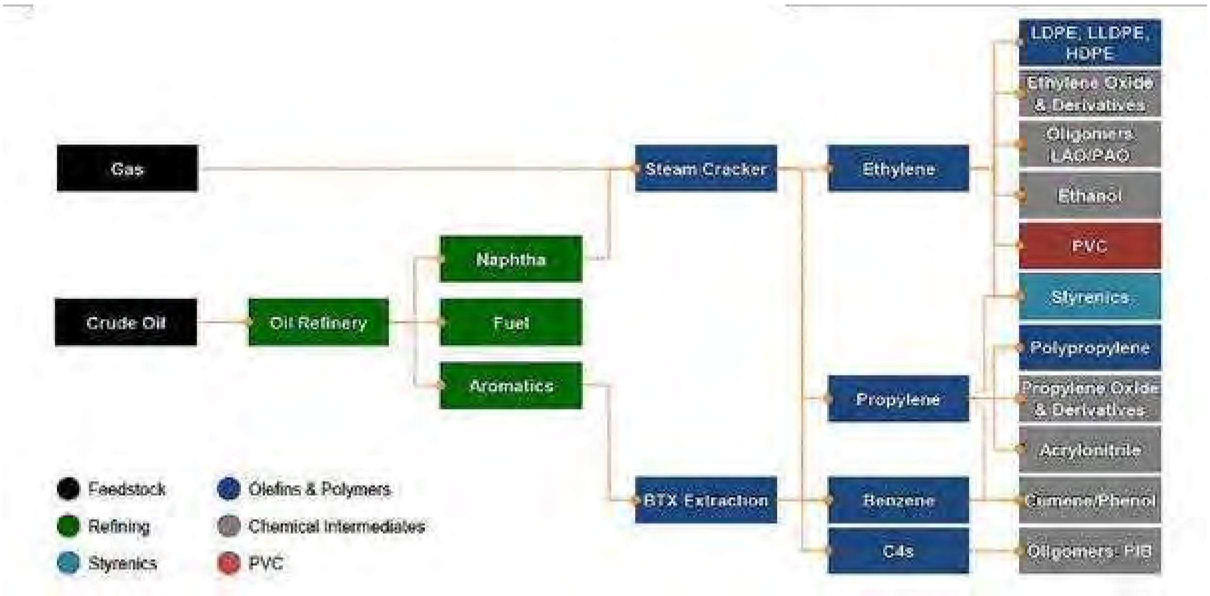

Figure 14-19: The value chain derived from HVC production in Project One (Source: INEOS)

Globally, approximately 90% of ethylene production is used for plastic applications. The largest derivative product of ethylene is polyethylene, which accounts for almost two-thirds of global demand for the monomer ethylene. Globally, approximately 70 to 80% of the by-product propylene is used for plastic applications. The derivative product polypropylene again accounts for nearly two-thirds of global demand for the monomer propylene. The other by-products have a wider range of downstream applications.

More than 30 types of plastics are in common use, with different properties and applications in numerous sectors. The most important applications and types of plastics can be distinguished by looking at the largest volume flows. The data below is taken from the report "Production, use, and fate of all plastics ever made" by Geyer et al. (2017):

- Figure 14-20 (above): Packaging accounts for 36% of global plastics production. This segment includes both consumer packaging and packaging used for business-to-business transactions and in industry in general. Synthetic textiles account for 12% of global plastics production. The construction sector represents 16% of global plastics production. Consumer products, including toys and utensils, account for 10% of global plastics production.
- Figure 14-20 (below): Mass-produced plastics include polymers, synthetic fibres and additives. Although there are many types of plastics, the most common polymers are polyethylene (PE), polypropylene (PP), polyethylene terephthalate (PET), polyvinyl chloride (PVC), polystyrene (PS) and polyurethane (PUR); and the most common synthetic fibres are polyester, polyamide and acrylic (PP&A) fibres.

The largest group of polymers (PE, PP, PET, PVC and PS) accounts for more than three quarters of all plastics production by weight. Ethylene is the primary raw material for PE, PET, PVC and PS.

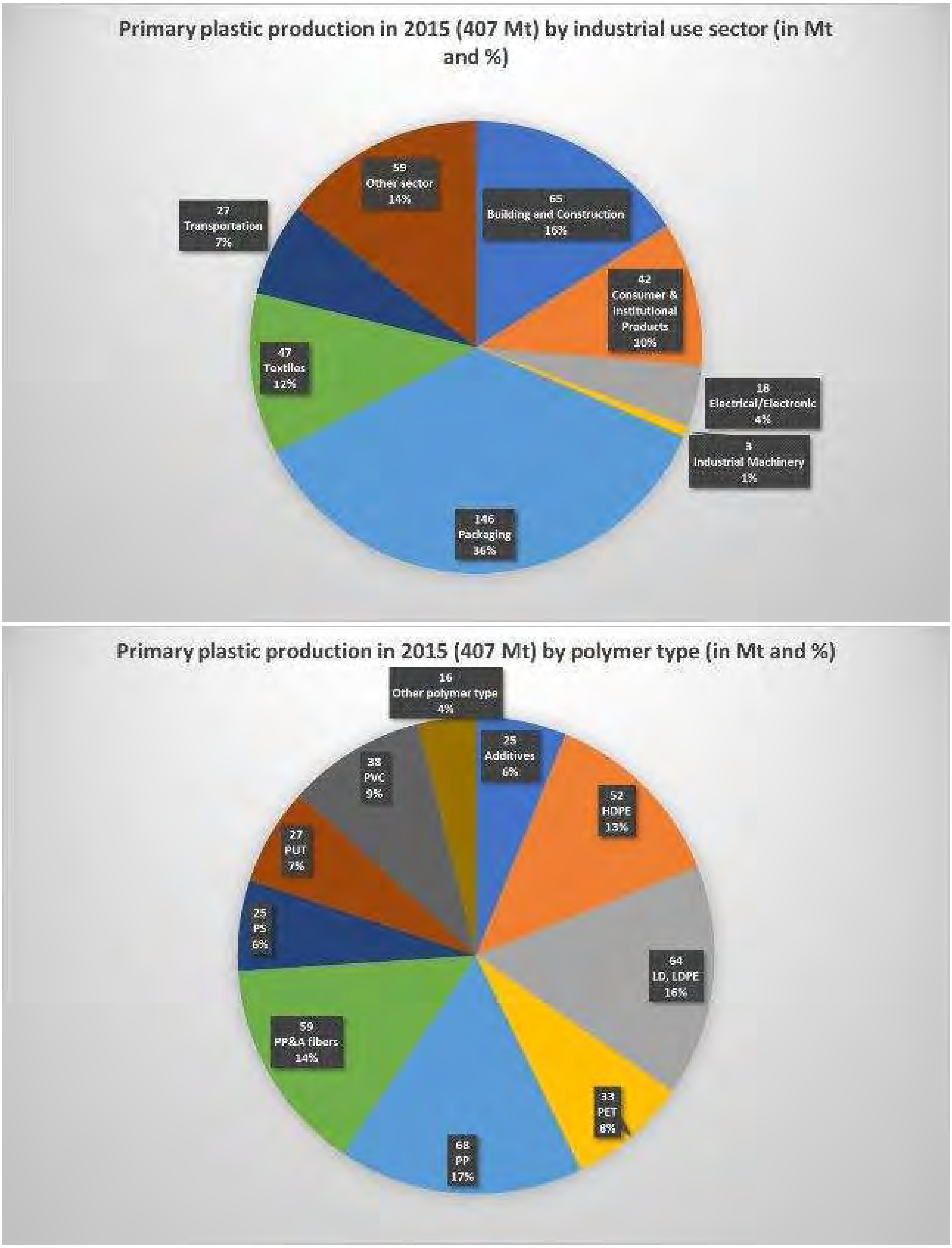

Figure 14-20. Global primary plastic production by application segment (top) and by plastic type (bottom) in 2015 (in Mtonnes and in %) (Geyer et al., 2017)

14.5.2.4 Carbon footprint of the global life cycle of plastics

Demand for plastics exceeds that for all other bulk commodities (such as steel, aluminium or cement) and has nearly doubled since the beginning of the millennium. The combination of a growing global economy, a growing world population and technological developments will translate into increasing demand for petrochemical products. Plastics are identified as the most important factor in the growth of the petrochemical sector (IEA, 2018).

Plastics, or synthetic organic polymers, are increasingly used throughout the economy and serve as key components for sectors such as packaging, construction, transport, healthcare and electronics. Plastics have brought significant economic benefits to these sectors, thanks to their combination of low cost, versatility, durability and high strength-to-weight ratio (World Economic Forum, 2016).

It is also important to note that the use of plastics directly or indirectly leads to a reduction in CO2 emissions in various sectors, as described below (non-exhaustive list) (Plastics Europe, 2021). The CO2 savings during the use phase depend on the application:

- The use of plastics in vehicles and aeroplanes, instead of metal, reduces their weight, resulting in lower fuel consumption and consequently lower CO2 emissions.
- The use of plastic bottles instead of glass bottles reduces the weight per bottle, which also reduces the weight during transport and thus leads to lower fuel consumption and lower CO2 emissions.
- The use of plastic packaging gives food a longer shelf life. This results in less food waste, which in turn leads to lower CO2 emissions.
- The use of plastic as insulation material directly contributes to lower CO2 emissions through reduced fuel consumption.
- Due to lower melting temperatures, recycling plastics requires less energy than recycling metal and glass, and therefore consumes less fuel.
- It is possible to convert residual energy in plastic waste into electricity.
- Replacing wood with plastic in the construction industry, for example for window frames, reduces the number of trees that need to be felled.
- The use of plastic water pipes instead of metal pipes results in fewer leaks and therefore less waste of drinking water. Lower pressure losses in the pipes also mean less energy consumption by pumps;
- The use of plastic gas pipes reduces natural gas emissions because they are less prone to leaks than metal pipes.

A recent study published in Nature Climate Change (Zheng & Suh, 2019) conducted a global analysis of the carbon footprint of the global life cycle of plastics (i.e. not just ethylene-based plastics). Greenhouse gas emission data were collected for three stages of the life cycle:
(1) the production phase, which covers all activities from cradle to factory gate for the production of polymers;
(2) the conversion phase, which includes the manufacturing processes that convert polymers into plastic end products; and (3) the end-of-life phase, which relates to the processing and disposal of plastic waste. Emissions and direct and indirect CO2 savings during the use phase of plastics were not taken into account.

The study by Zheng & Suh (2019) calculated that the global amount of plastics produced in 2015 (407 Mt; Geyer et al., 2017) corresponds to emissions of 1.8 GtCO2 equivalents over the entire life cycle of production, conversion to end-of-life phase of plastics, excluding carbon credits from recycling. The production phase accounts for the majority of emissions (61%), followed by the conversion phase (30%). The end-of-life phase accounts for 9% of emissions over the entire life cycle, excluding carbon credits from recycling. The carbon footprint of plastics over their entire life cycle corresponds to 3.8% of global CO2 equivalent emissions in 2015. A study by Material Economics (2018) found a similar carbon footprint for the life cycle of plastics as in the study by Zheng & Suh (2019).

Based on the expected growth in plastics, the cumulative amount of greenhouse gas emissions over the life cycle of plastics could increase globally to 56 GtCO2-eq between 2015 and 2050. This represents 13 to 10% of the total remaining carbon budget, corresponding to a $^{2/3}$ to $^{1/2}$ chance, respectively, of limiting global warming to 1.5°C (Shen et al., 2020). It is important to note that future projections of the impact of plastic production on the remaining global carbon budget are highly dependent on, among other things, developments in the growth of plastic production, the energy mix used, developments in carbon capture, storage and reuse technologies, end-of-life management of plastics and the mix of raw materials, and are therefore highly uncertain.-of-life management of plastics and the mix of raw materials, and are therefore highly uncertain.

The study by Zheng & Suh (2019) found that the production phase (which includes all activities from cradle to factory gate for the production of polymers) accounts for the majority of emissions in the life cycle of plastics.

Project One achieves significant gains in terms of process-related $_{CO2}$ equivalent emissions. To illustrate: according to the study by Zheng & Suh (2019), the global average specific CO2 equivalent emission for HDPE production (*high density polyethylene;* one of several possible derivatives of ethylene) is 1.949 $_{\text{tonnes CO2-eq/tonne HDPE}}$ (from cradle to factory gate). A study by Vlachopoulos (2009) states that monomer production accounts for approximately 80% and polymer production for approximately 20% of the total energy demand of the production phase. Taking this into account, the average CO2 equivalent emissions for the production phase of HDPE with ethylene from Project One amount to approximately 0.679 $_{\text{tonnes CO2-eq/tonne HDPE}}$. This is a reduction of approximately 65% compared to the global average HDPE production, and Project One therefore achieves a significant reduction in this area.

In the study commissioned by VLAIO (2020), which is also in line with the Flemish Climate Strategy 2050, four thematic transition paths were defined to achieve a carbon-circular and low-carbon Flemish industry:

17. the use of biomass (waste) as energy and raw material,
18. circularity, mainly through the reuse of plastics,
19. electrification and increased use of hydrogen ($_{H2}$), and
20. the capture, storage and reuse of $_{CO2}$ (CCUS).

The study concludes that the future will be a combination of the four transition paths. There is no 'single solution' for achieving a carbon-circular and low-carbon industry. Focusing on just one of the four paths is not enough; all four are needed.

Below, we discuss in more detail how Project One fits into each of the four thematic transition paths of the study "Towards a carbon-circular and low-carbon Flemish industry" commissioned by VLAIO (2020).

14.5.2.4.1 Substitution of fossil raw materials by bio-based raw materials

A variety of carbon- and hydrogen-containing materials can replace oil, natural gas and coal as chemical raw materials (IEA, 2018; World Economic Forum, 2016). Alternative production routes are based on biomass, biomethane and $_{CO2}$, among other things.

The main advantage of alternative raw materials is that they can offer a net reduction in CO2 emissions compared to conventional fossil raw materials. The reduction stems from the fact that these materials would otherwise have remained unused (even if they are originally extracted from fossil raw materials), or because they are renewable and therefore do not contribute to the accumulation of $_{CO2}$ in the atmosphere (in the long term).

A study by Amghizar et al. (2017) on “New Trends in Olefin production” states that the enormous capital invested in current production facilities suggests that steam cracking of hydrocarbons will remain the leading technology for ethylene production. The large number of projects coming onto the market as a result of the shale gas revolution in the US will lead to a significant expansion of capacity for ethylene producers. As a result, technologies for alternative raw materials will have to become even more competitive than before.
Investments in alternative processes and raw materials are yet to come; the lack of economic viability of such processes in an uncertain raw materials market threatens their large-scale application.

Nevertheless, it will ultimately be necessary to utilise biomass and waste streams, although this shift will need to be stimulated by global regulatory bodies, as the contribution of these streams will remain marginal in the coming five years. Drop-in feedstocks for the current generation of steam crackers would be a first step (Amghizar et al., 2017).

Currently, it is not possible to supply renewable raw materials to Project One. Project One's ECR processes ethane and up to 20% propane, regardless of the source. In principle, the ECR can therefore also process biogas – if technologically and commercially available on an industrial scale:

- Biopropane: The ECR can process up to 20% propane as a raw material. Biopropane can be produced from the inedible parts of palm oil, animal fats and waste streams such as used cooking oil (Johnson, 2017). In this case, biopropane can be considered a second-generation bio-based raw material, as it is made from agricultural residues or waste. Second-generation bio-based raw materials have the advantage that no additional fertiliser, water or land is needed to grow them. Biopropane is not currently produced on an industrial scale.
- Bioethane: There is currently no technology available for the production of bioethane.

14.5.2.4.2 Circular use of materials

In March 2020, the European Commission proposed a new action plan for a circular economy. Specifically for the plastics sector, the European Commission will propose mandatory requirements for recycled content and waste reduction measures for products such as packaging, construction materials and vehicles. Among other things, the European Commission will develop a policy framework on the production, labelling and use of bio-based plastics. The European Commission also ensures the timely implementation of the new directive on single-use plastics.

Sustainable use of materials requires a shift from linear use (single use) to circular use. In concrete terms, this should lead to a reduction in primary production and primary raw material consumption through the increasing application of the following measures, in order of priority:

- Reuse: particularly plastic packaging, and associated with this, the design of plastic applications for long-term and sustainable reuse of plastics and the implementation of reuse systems. Elimination/reduction of the production of single-use plastic applications;
- Design of lighter polymer applications;
- Improvements in recycling. From a technical perspective, there are three key factors that are slowing down the production of high-quality secondary plastics (Material Economics, 2018):
  - Mixed and contaminated streams: High-quality recycling requires plastics to be separated by type. This is currently hampered by product design and current collection systems, in which different types of plastics are mixed with other materials, such as paper or metal. This requires costly sorting of materials, which can make effective separation impossible.
  - Additives. Plastics often contain additives such as colourants, stabilisers or flame retardants. These are difficult to trace or remove and can contaminate plastics or make them unsafe or impossible to reuse in products.
  - Contamination. Plastics can also be contaminated by the substances they contain, leading to stains or odours and low-quality recycling, or they can be contaminated with harmful chemicals or medical waste that make recycling completely impossible.

The above measures are outside the scope of Project One. The INEOS Group is responding to the transition to a circular economy through the following developments in recycling:

INEOS has set itself four targets to be achieved by 2025:

1. To offer a range of polyolefin products for packaging applications in Europe that contain 50% or more recycled material;
2. Use an average of 30% recycled material in products intended for polystyrene packaging in Europe;
3. Process at least 325 kt/year of recycled material in products;
4. Ensure that 100% of polymer products can be recycled:

- Design for recyclability: Develop solutions to promote better recyclability of packaging, to make consumer products easier to recycle and reduce waste. INEOS' available knowledge and expertise for further developments in this area:
  - Single-material packaging that offers the same/acceptable functionality as multi-materials;
  - Avoid materials that are difficult to recycle and contamination with OPA (oriented polyamide), OPET (oriented polyethylene terephthalate) and aluminium in multi-layer film structures;
  - Avoid inseparable paper/plastic combinations (sleeves, labels);
  - Avoid black carbon, fillers, pigments where possible, colours/inks that cannot be removed in the recycling process;
  - Design packaging so that it can be completely emptied.
  - Focus on polyolefins as the material of choice for recyclable packaging.
- Mechanical recycling: INEOS offers a Recycl-IN polymer range, which contains up to 50% post-consumer recycled plastic (PCR) alongside primary polymers. Recycled plastics lose some of their physical strength and performance with each recycling cycle. By incorporating recycled plastics, the Recycl-IN range meets consumer demand for increased use of recycled materials while maintaining the properties and high performance requirements needed for the products. The range includes rigid and flexible products for use in non-food contact applications.
- Advanced recycling (chemical recycling): Advanced recycling introduces circularity into the production of plastics, whereby plastic waste can be used to make new plastics, replacing raw materials derived from fossil-based products. Chemical recycling with pyrolysis produces naphtha/diesel fractions, and chemical recycling with gasification produces syngas. The process creates value for plastic waste to be recycled as a raw material, thus preventing it from being landfilled, incinerated or released into the environment. INEOS is working with Plastic Energy on a new advanced recycling plant to chemically recycle plastic waste that would normally be landfilled or incinerated into naphtha and process it in existing naphtha crackers to produce recycled polyethylene and polypropylene.

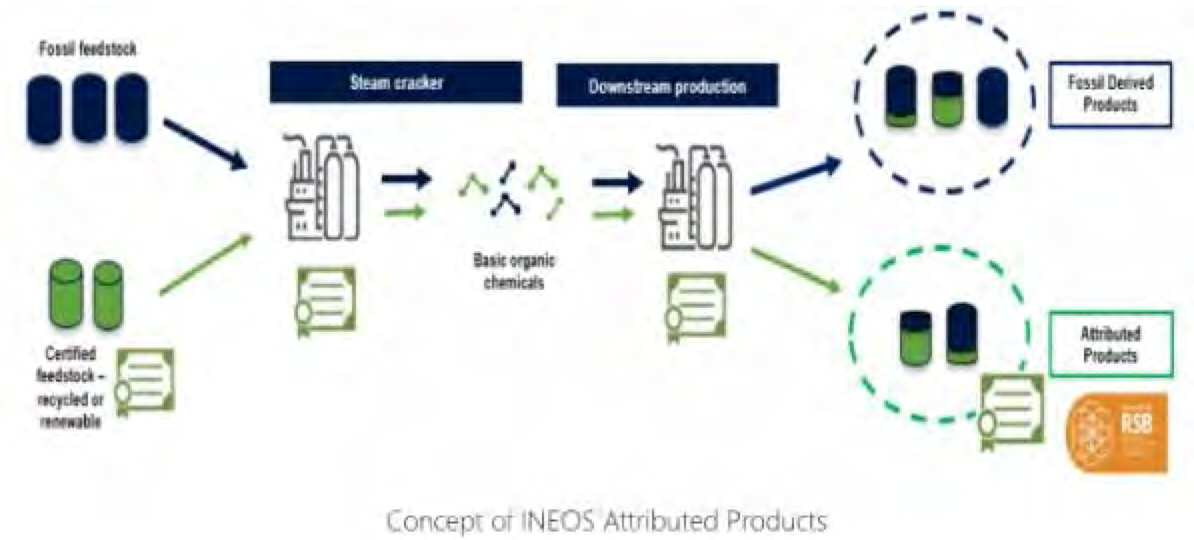

Figure 14-21: Conceptual sketch of the use of alternative raw materials in existing naphtha crackers or polymer production units of the INEOS group

The above pilot projects concerning the use of recycled raw materials from the INEOS group are not compatible with the ethane cracker of Project One. Mechanical and chemical recycling of plastics currently produces polymer fractions and naphtha/diesel fractions or syngas, respectively, which means that mechanically and chemically recycled raw materials are not suitable for use in Project One's ECR. After all, the ECR is only capable of processing ethane and up to 20% propane, regardless of the source. With the technologies currently available, it is not yet possible to produce recycled ethane and propane from plastic waste.

14.5.2.4.3 Electrification

Zheng & Suh (2019) demonstrate that the use of renewable energy for the production and conversion phase offers the greatest potential for reducing the carbon footprint of plastics.

When Project One commences in 2026, external electricity demand will be met with green electricity. This will reduce Project One's total emissions by approximately 7% compared to the project without the import of green electricity, specifically from 708 MtonCO2-eq/year to 655 MtonCO2-eq/year.

Electrification is not being used for ECR cracking furnaces, as this technology is currently still in the research and development phase. Electrification of cracking furnaces is currently neither an established nor a cost-competitive technology. At present, no proven concept has been reported. For example, the Linde pilot electric cracking furnace (6 MW) was scheduled to be mechanically completed by the end of 2023, so there is still no experience with performance, reliability, upscaling, etc., even at this pilot plant size. The current emphasis is on adapting existing furnaces of smaller sizes in the range of 20 to 30 MW heat load. The furnaces of Project ONE have a capacity of approximately 113 MW. Electrification of the cracking furnaces can be evaluated when the technology is sufficiently advanced. The future availability of mature technology and sufficient green electricity is difficult to predict.

14.5.2.4.4 The capture, storage and reuse of CO_2 and increased use of H_2

Project One will be made 'CO2 capture-ready' for *post-combustion* CO2 capture technology with technological flexibility on the ethane cracking furnaces (ECR) and steam boilers. This will allow the industrial installations to be retrofitted with post-combustion CO_2 capture technology without major changes to the existing process. To build the 'CO2 capture-ready' Project One, sufficient space will be reserved in the project area for the CO2 capture equipment and associated pipelines for CO2 transport, and the design already takes into account future retrofitting of the site and installations.

If the *post-combustion* CO2 capture technology is sufficiently developed for industrial application in Project One, both CO_2 and hydrogen gas will be available at the Project One site. This opens up important prospects for the (re)use of CO_2 and hydrogen gas in the Port of Antwerp in the future. For example, Inovyn (part of the INEOS group), a company adjacent to Project One, is part of the seven-member consortium that will set up the 'Power to Methanol' demonstration project for the production of methanol from CO_2 on a technical scale (planned production of 8,000 tonnes of methanol per year). However, the project has not been rolled out further. The Power to Methanol industrial consortium is scrapping its plan to produce fuel from green hydrogen and captured CO_2 in the Port of Antwerp. The project is 'financially unfeasible'. The timeline for implementing *post-combustion* CO_2 capture technology depends, among other things, on:

- The availability of efficient, mature technology for capturing the relatively low-CO2 flue gases from Project One, which is not currently available;
- A guaranteed market for the hydrogen gas produced;
- Guaranteed sales of the CO2 produced (transport, storage and/or reuse);
- The evolution in the price of CO2 emission allowances under the EU ETS system.

For a detailed description, please refer to § 14.4.2.1.2.1.

As an alternative to reducing CO2 emissions from the ECR using *post-combustion* CO2 capture technology, the possibility of using *pre-combustion* technology was investigated, whereby the hydrogen content in the fuel gas supplied to the ECR and steam boilers is increased to 100%. In this case, direct CO2 emissions from the process are reduced to zero. The cracking furnaces are currently designed for use with a mixture of hydrogen and methane, but the possible switch to pure hydrogen gas was included in the design. If only hydrogen gas is used as fuel gas, the residual methane fraction can be fed into the natural gas grid. No concrete timeline for the realisation of this alternative can be given due to the uncertainty of the future availability of sufficient green hydrogen and green electricity. For a detailed description, please refer to § 14.4.2.1.2.2.

14.5.3 Conclusion: assessment against European and Flemish policy

The 2015 Paris Climate Agreement stipulates that global warming must be limited to 1.5°C and implies that net CO2 emissions worldwide must be reduced to zero by 2050.

The INEOS Group has set itself the target of reducing net CO2 emissions to zero for all its sites in the Port of Antwerp by 2050 at the latest. To achieve these targets, INEOS is working on drawing up a roadmap. The roadmap will contain an action plan on how INEOS can reduce emissions by using green electricity, hydrogen and recycled or bio-based raw materials, increasing the energy and raw material efficiency of its production sites and applying CO2 capture. Project One is currently convinced that it is feasible to achieve *net zero* CO2 emissions within 10 years of the cracker's start-up.

Given the scale of Project One's production capacity, it is relevant to assess the operational phase of Project One against the relevant pillars of the 'European strategic long-term vision for a prosperous, modern, competitive and climate-neutral economy' (hereinafter: EU) and the vision for the industrial sector set out in the 'Flemish Climate Strategy 2050' (hereinafter: VL). Both policy documents are in line with the Paris Climate Agreement:

- EU: Making optimal use of the benefits of energy efficiency / VL: Continued commitment to efficiency improvements:
  - Project One uses state-of-the-art technology for cracking ethane, and the best available techniques (BAT) and energy integrations are consistently applied to achieve high energy and production efficiencies.
  - The ECR is designed for selective and efficient ethylene production. Of the raw material ethane, 81% of the carbon is captured in ethylene. Project One will operate the best-performing steam cracking technology in terms of carbon efficiency in Europe.
  - The specific process emissions of Project One ethane cracker amount to 0.290 $_{\text{tonnes CO2-eq/tonne HVC}}$, or only 42% of the current EU ETS benchmark value of 0.681 $_{\text{tonnes CO2-eq/tonne HVC}}$. It has been calculated that Project One implies a tightening of the EU ETS benchmark value for HVC production to approximately 0.577 $_{\text{tonnes CO2-eq/tonne HVC}}$. This is a decrease of approximately 15% compared to the current benchmark value for HVC production (0.681 $_{\text{tonnes CO2-eq/tonne HVC}}$). Taking into account the current annual HVC production capacity in Europe of 47.6 Mton HVCs (IEA (2018)), this means that approximately 4.95 Mton of additional emission allowances must be paid or avoided annually by existing steam crackers for HVC production under the EU ETS system. Such a quantity of emission allowances corresponds to approximately 267 million euro/year, taking into account the current price (mid-February 2024) of 54 $_{\text{euro/tonne CO2}}$ under the EU ETS system. Part of this additional revenue for the EU ETS system will be used to support innovation and modernisation projects in energy-intensive industrial sectors and the energy sector. Project One's ECR is likely to have an impact on the benchmark for phase 5 of the EU ETS system (from 2031), as operations will start in 2026.
  - The ethylene produced in Project One is sold on the market. Most existing installations are currently supplied with ethylene from European naphtha crackers, which are often outdated and have significantly higher specific CO2 equivalent emissions than the new ECR of Project One. These installations can purchase the ethylene produced by Project One and reduce their CO2 equivalent emissions. As an example, it has been calculated that the reduction in the carbon footprint of the customers would amount to approximately 2 Mton CO2-eq/year if the customers were to use the ethylene produced in Project One.
- EU: A competitive European industry and the circular economy as a crucial prerequisite for reducing greenhouse gas emissions / VL: A circular economy by 2050:
  - There are currently no alternative (recycled, greenhouse gas-based or bio-based) raw materials available for Project One's ECR, with the exception of biopropane:
    - Mechanical and chemical recycling of plastics currently produces polymer fractions and naphtha/diesel fractions or syngas, respectively, which means that mechanically and chemically recycled raw materials are not suitable for use in Project One's ECR. After all, the ECR is only capable of processing ethane and up to 20% propane, regardless of the source. The production of recycled ethane and propane from plastic waste is not yet possible with the technologies currently available. Ethylene production based on recycled raw materials is therefore currently carried out via production routes other than those that can be used in Project One's ECR.

    - Project One's ECR is not compatible with ethylene production based on greenhouse gases (methane or CO_2), as the ECR is only capable of processing ethane and up to 20% propane.
    - In principle, Project One's ECR can process bioethane. However, there is currently no technology available for the production of bioethane. Bioethylene is currently produced using production routes and raw materials other than those that can be used in Project One's ECR.
    - In principle, Project One's ECR can process biopropane. However, biopropane is not currently produced commercially on an industrial scale.
- EU: Optimising the deployment of renewable energy sources and the use of electricity to make Europe's energy supply completely carbon-free/ VL: Switching to renewable and climate-neutral fuels and raw materials:
  - Electrification and import of green electricity:
    - When Project One starts in 2026, the external electricity demand of 140,160 MWh/year will be covered by green electricity. This will reduce Project One's total emissions by approximately 7% compared to the project without the import of green electricity, specifically from 708 ktonCO2-eq/year to 655 ktonCO2-eq/year.
    - Electrification is not being applied to the ECR's cracking furnaces, as this technology is currently still in the research and development phase. Electrification of cracking furnaces is not yet an established or cost-competitive technology. Electrification of the crackers can be evaluated once the technology is sufficiently developed. The future availability of mature technology and sufficient green electricity is difficult to predict. This possible future prospect will be the subject of further research as part of INEOS' roadmap. Project One is currently convinced that it is feasible to achieve *net zero* CO2 emissions within 10 years of the cracker's start-up, using one or more of the techniques described in this EIA.
    - There is currently no supply of renewable raw materials possible in Project One. The ECR of Project One is only capable of processing ethane and up to 20% propane, regardless of the source. However, there is currently no technology available for the production of bioethane. Biopropane is not yet commercially produced on an industrial scale.
- EU: Tackling remaining CO2 emissions through carbon capture and storage / VL: CO_2 capture and reuse:
  - Project One is being made 'CO2 capture-ready' with technological flexibility, so that CO2 capture can be implemented at the project site in line with expected developments in CO2 capture technologies.
  - As an alternative to CO2 capture, it was examined whether the hydrogen content in the fuel gas to the ECR and the steam boilers could be increased to 100%. In this case, the direct CO2 emissions from the process would be reduced to zero. The cracking furnaces are currently designed for use with a mixture of hydrogen and methane, but the possible switch to pure hydrogen gas was included in the design. If only hydrogen gas is used as fuel gas, the residual methane fraction can be fed into the natural gas grid.
  - The above possible future scenarios will be the subject of further research as part of INEOS' roadmap. Project One is currently convinced that it is feasible to achieve *net zero* CO_2 emissions within 10 years of the cracker's start-up, using one or more of the techniques described in this EIA.
- EU: Developing adequate smart network infrastructure and interconnections / VL: Industrial symbiosis in clusters:
  - IOB is a partner in the Antwerp@C project, which is investigating the possibilities for CCUS in the Port of Antwerp. When applying CO2 capture and PSA units at Project One in the future (the timing of which is currently undetermined), both CO_2 and hydrogen gas will become available at the Project One site. This opens up significant prospects for the (re)use of CO_2 and hydrogen gas in the Port of Antwerp in the future.

14.6 Cumulative effects

14.6.1 Quay wall

The construction of the quay wall is not expected to have any climate effects that would have a cumulative effect with the effects evaluated in this EIA for Project One.

The EIA for the quay wall (PRMER3242) does not report any relevant effects for the Climate discipline. For example, the quay wall will not affect the water level of the canal docks and has been designed in such a way that climate- and energy-friendly mooring facilities can be installed if necessary.

15 Other effects and environmental aspects

15.1 Waste

For an overview of the raw materials used and products manufactured, please refer to Chapter 3 Project Description.

During the **construction phase,** the following waste materials account for the largest volume:

- rubble from excavated soil (hazardous/non-hazardous);
- rubble from demolition work (hazardous/non-hazardous);
- contaminated soil and topsoil (quality 999);
- waste wood from vegetation.

The **process-related waste streams** in the operational phase are relatively limited due to the nature of the process. As the production process mainly involves gaseous substances, only a limited amount of solid waste is generated in the processes. This mainly concerns:

- Coke separated during the decoking stage of the ECR;
- Used/replaced catalysts: The catalysts used in the process are replaced at the end of their service life. This replacement is carried out by specialised subcontractors, and the old catalysts are recycled;
- Resins used in dryers and polishers;
- Water treatment sludge: Water treatment sludge is produced during the water treatment process. This is dewatered on site to form a solid sludge that is transported off-site for external processing.

In addition to these process-related waste materials, more common types of waste will also be generated, such as kitchen waste, scrap metal, plastic (packaging, etc.), paper and cardboard. In accordance with agreements with waste collectors, these will be separated by type and transported for recycling.

Project One has an overarching philosophy for waste stream management, both during the construction phase and during the operational phase. This philosophy is aimed at preventing and limiting waste streams as much as possible, reusing or recycling as much as possible, and treating them in accordance with legal regulations and/or having them processed in recognised, licensed facilities.

15.2 Environmental safety

An Environmental Safety Report (ESR) was drawn up for Project One, in parallel with the EIA. The ESR is attached to the environmental permit application.

We refer to the OVR for a detailed evaluation of the safety aspects. We reproduce the conclusions of the OVR below.

Under the Seveso legislation, priority is given to accidents that could have immediate fatal consequences for people in the surrounding area and therefore outside the establishment. These accidents and their consequences are identified using a quantitative risk analysis. The risks to humans are then presented in two ways. On the one hand, a location-specific risk (also known as a site-specific risk) is determined, which, as the name suggests, reflects the risk at each location around the site. On the other hand, a group risk is also calculated, which reflects the probability that a group of people could simultaneously suffer fatal injuries as a result of such an accident. These risks are evaluated on the basis of criteria as described in the Risk Criteria Code. A qualitative analysis is also carried out with regard to surrounding installations containing hazardous substances, and a qualitative analysis is also carried out on substances that can cause major damage to the environment.

The location-specific risk of IOB complies with the Code of Good Practice on risk criteria for external human risks, with the exception of the $^{10-5}$ isorisico contour.

One of the measures taken by IOB for this purpose is the conclusion of written cooperation agreements, namely a safety information plan with the companies Bayer, ASA and Vesta.

The group risk falls below the criterion line. It is largely determined by the presence of personnel at the companies surrounding IOB. Close cooperation and the conclusion of a safety information plan with these companies is therefore of great importance.

Mutual effects between IOB installations and surrounding businesses cannot be completely ruled out. IOB itself is taking various measures to limit such effects as much as possible. Close cooperation with the above-mentioned businesses will further contribute to this.

With regard to environmental risk, it can be concluded that the environmental risk posed by IOB is adequately controlled.

15.3 Cross-border effects

15.3.1 Environment

The Project One site is located approximately 4 km from the Belgian-Dutch border as the crow flies. At this distance, cross-border effects are possible for some disciplines.

The assessment of these effects, as explained in detail in previous chapters, can be summarised as follows:

- **Chapter 6 – Noise**: The effects do not extend to the national border.
- **Chapter 7 – Air**: The effect at the national border, assessed against air quality standards, is considered negligible (0), both during the construction phase and the operational phase.
- **Chapter 8 – Soil**: The effects do not extend to the national border.
- **Chapter 9 – Water**:
  - **Construction phase:** The effects of groundwater drainage do not extend to the national border.
  - **Operational phase:** The impact of the discharge of treated waste water into the Scheldt is negligible (0) for all pollutants at the national border.
- **Chapter 10 – Mobility**: The relevant effects do not extend to the national border.
- **Chapter 11 – Biodiversity**:
  - The only aspect for which effects in nature areas across the national border are possible is nitrogen deposition as a result of NOx and NH_3 emissions. Based on scientific arguments, the effects on habitats in Dutch habitat directive areas are negligible (0).
  - Other effects on biodiversity, such as habitat loss, desiccation, and noise and light pollution, were also evaluated, but these effects do not extend beyond the national border.
- **Chapter 12 – Landscape**: The tallest structures on the site (tallest distillation columns, high flare) will be visible from certain vantage points in the Netherlands. These are locations from which the existing Antwerp port landscape is already clearly visible. The visual impact of the Project One installations from the Netherlands is assessed as negligible (0).

- **Chapter 13 – Human Health**:
  - The effect of exposure to air pollution resulting from Project One emissions is assessed as negligible (0) in residential areas in the Netherlands, both during the construction phase and the operational phase.
  - Other health effects such as Legionella and noise impact were also evaluated, but these effects do not extend to the national border.

- **Chapter 14 – Climate**: The climate aspects evaluated are not limited to the study area or national borders.

15.3.2 Environmental safety

The quantitative risk analysis in the Environmental Safety Report has shown that the effects on humans or installations do not extend to the Netherlands. Nor are any cross-border effects expected as a result of the possible release of environmentally hazardous products.

16 Gaps in knowledge

Below is an overview of gaps in knowledge and how these have been addressed in this EIA.

With regard to the discipline **of Sound,** the following gaps in knowledge have been identified:

- Noise emissions during the construction phase depend on the number and type of machines used, their operating regime, their emission profile, etc. This is part of the planning and organisation of the site, partly determined by the contractors on the instructions of Project One. For the various activities, assumptions have been made that are as realistic as possible regarding the number, type, electrical power and operating time of the construction site machinery.
- The sound power level representative of the entire site was compiled on the basis of the specified type, number and operating time of the site machinery for a maximum, but realistic, working day during the peak period of each site stage (the three most critical months of the approximately 44 months) (see also § 6.4.1).

  Since the layout and trajectories of the various machines during the construction phase are unknown, the acoustic transmission model simulated the noise emission for each construction stage as a flat source across the entire project area. This approach ensures that a realistic calculation of the noise propagation is performed.
- The exact location of the individual noise sources during the operational phase is not yet known. The noise emissions from these sources were therefore divided into clearly defined installation zones to be used as representative flat sources (rather than point sources) in the modelling. No buildings, silos or other obstacles within the installation zones were taken into account, which corresponds to maximum noise emission from these zones (worst-case evaluation).
- The sound power level for the flares was estimated by Project One based on the available technical data from suppliers and empirical formulas for maximum flare flow during an emergency (to ensure safety on site) and the start-up phase of the ECR, respectively. This is therefore a worst-case approach for both situations.
- The original ambient noise level at the reference points 200 m east of the project area boundary (in the Kanaaldok) is unknown. Based on continuous immission measurements carried out earlier (2018) on the vacant land 200 m east of the IMB site and based on the strategic noise pollution maps, the ambient noise can be estimated at between 50 and 55 dB(A).
- The current ambient noise (reference situation) is described on the basis of:
  - the immission measurements carried out (2019, 2021, 2023-2024) at four reference points;
  - the immission measurements carried out on the currently undeveloped northern project area 200 m east of IMB;
  - the strategic noise pollution maps of the Antwerp agglomeration (2016).

  In a few places, more specifically in the Opstalvallei nature reserve and in the industrial area 200 metres to the north, east and south of the project area, a reliable estimate of the current ambient noise has been made based on the data collected. This allows for an unambiguous determination of the VLAREM II limit values for all reference points, together with the impact assessment. At the reference point 200 m east of the project area, the impact assessment was carried out on the basis of the lower and upper limits of the original ambient noise.

With regard to the discipline **of Air,** the following gaps in knowledge have been identified:

- Evaluation of secondary effects on air quality:

  The EIA quantitatively assessed the primary effects on air quality, as well as several secondary effects for which a standard assessment method is available (NO_2 and fertilising deposition). Other secondary effects have not been quantitatively assessed (e.g. ozone formation or secondary particulate matter). For further details on each type of secondary effect, please refer to section 7.6.2.7.

With regard to the discipline **of Mobility,** the following gaps in knowledge have been identified:

- When drawing up mobility studies, future predictions are made on the basis of various assumptions and suppositions about the number of journeys per person, the choice of transport mode, the time of the journey, the origin and destination of the traffic, etc. These assumptions naturally involve logically involve uncertainties about future developments. For example, it is impossible to determine with certainty whether a particular distribution of transport mode choices will actually be achieved. (From the Guidelines Booklet on Mobility Impact Studies, Mobility Assessment and MOBER - 2018 - Mobiel Vlaanderen).

- The assumptions regarding routing, staff working hours and the modal split were provided by the client and are based on the client's own expertise (experience with similar sites) and on information in this regard in the broader context of the Port of Antwerp.
- Uncertain factors that may influence general travel behaviour include fuel prices, government tax policy on means of transport, etc. These factors may alter the traffic volume calculations used in the traffic models.
- Other projects (if not yet included in the traffic modelling) may change in size and/or timing and consequently have a different impact on the traffic network. The exact timing, sequence and possible interaction and overlap between certain works cannot be estimated at present and will require continuous planning and coordination between the various initiatives.

With regard to the discipline **of Climate,** the following knowledge gaps have been identified:

- The known climate scenarios and the uncertainties surrounding them are described in detail in § 14.2.1.1. It is important to note that no probability can be assigned to each of these possible future scenarios. However, it is assumed that – based on current scientific knowledge – the total range of potential impacts covered by the scenarios is highly likely to encompass the actual future evolution.
- There is no comprehensive guideline manual for the Climate discipline, as there is for the other EIA disciplines. However, there is a 'Climate Manual for EIA' (Department of Environment, Nature and Energy, 25/05/2018). The Climate chapter was drawn up after consultation with Team EIA on the basis of this Manual and the advice and public consultation responses obtained when the first EIA for Project One was submitted (see scoping advice from EIA PR3263).

There is a gap in knowledge in the discipline **of Soil**:

- Knowledge of soil quality is based on available samples and analyses, which always represent a snapshot in time. The actual, current situation may therefore differ to a certain extent from such a snapshot. Some contaminants are known but need to be investigated further in a descriptive soil investigation.

Knowledge of the **Water** discipline has the following gaps:

- Knowledge of (ground)water quality is based on available samples and analyses, which always represent a snapshot in time. The actual, current situation may therefore differ to a certain extent from such snapshots.
- The exact duration, flow rates, etc. of the drainage are not yet known. The groundwater model therefore uses substantiated worst-case assumptions.
- The VMM Excel calculation tool is used to assess the impact of drainage water on surface water quality. However, this tool is not suitable for determining the impact of PFAS. For more information, please refer to the Water chapter.
- The flow rates/discharge capacities of watercourses are subject to variations. For this purpose, characteristic flow rates determined by VMM are used for each watercourse.
- The exact composition of the wastewater is not yet known. In the EIA, the assessment was carried out on the basis of the maximum expected concentrations (worst-case assumptions), determined on the basis of the origin of the wastewater and the treatment techniques used.
- There are no quality objectives for chlorides, sulphate and conductivity due to the brackish nature of the transitional water in the Scheldt estuary (in accordance with the MKN VLAREM II); these parameters are therefore not evaluated in the EIA.

Knowledge of the discipline of **biodiversity** has the following typical gaps:

- Inventories of fauna and flora always provide a snapshot of the situation at a given moment and are therefore inherently incomplete. However, the EIA, the appropriate assessments and the enhanced nature assessment were drawn up on the basis of all available data on the surrounding nature areas, supplemented by extensive and repeated field research and observations within the project area, so that the effects can be evaluated with sufficient precision.

Knowledge in the field of **human health** has the following gaps:

- The Guideline System states, among other things, that the criterion "exposure to a mixture of chemical stressors with the same critical endpoint" is being investigated. Although synergistic effects have already been demonstrated in laboratory studies, research efforts in epidemiological studies are limited. Additional research is needed to determine the relative importance of certain pollutants when exposed to mixtures.
- Synergistic effects (possible synergy when exposed to a mixture of substances, whereby the final effect is greater than the mere sum of the effects of the substances individually) have already been demonstrated in laboratory studies, but this issue has only been investigated to a limited extent in epidemiological studies. Further research is needed to determine the relative importance of certain pollutants in exposure to mixtures and, if possible, to establish dose-effect relationships. These effects are therefore only mentioned qualitatively in the EIA. The assessment of health effects is mainly based on the effects of exposure per pollutant, for which dose-effect relationships and health-based guidance values are available.

17 Employment, investments and material flows

17.1 Employment

During the construction phase, a variable number of people will be working on the Project One site. During the busiest period of the project, this number could rise to approximately 2,500 people per day.

During the operational phase, Project One will employ approximately 450 people:

- Approximately 90 people at IOB in the production departments in a continuous shift system
- Approximately 210 people at IOB in other departments during normal working hours (administration, control, laboratory, maintenance, etc.)
- In addition, approximately 150 contractors are employed on site. Most of these

jobs require specific technical knowledge and training.

17.2 Investment

The investment for the entire project is estimated at 4 billion euros.

17.3 Material flows

For the main material flows, please refer to § 3.4.7.

18 Synthesis of effects, mitigation measures and monitoring

18.1 Effects

The various potential effects of Project One were evaluated in this EIA for each environmental discipline. Table 18-1 provides an overview of this. The table shows the following:

- The effects with the effect score (0 / -1 / -2 / -3).
  In many cases, these effects have already been mitigated by the project-integrated mitigation measures that Project One determined during the design and engineering of the project, in consultation with environmental experts, among others. The project-integrated measures are not listed in the table.
- The effects are listed per discipline and per phase of the project (construction phase and operational phase).
- For the main effects, additional proposed mitigation measures that can be taken are listed, along with the remaining effect when these are applied.
- The table does not include the various climate aspects that were explained and evaluated in this EIA. As climate effects do not occur at the local level, the climate aspects were not assessed using the impact scores used for the other disciplines. The evaluation of the climate aspects is summarised separately, outside the table.

We briefly explain the main environmental impacts below.

18.1.1 Noise

- **Noise emissions during the construction phase**:
  Noise emissions during the construction phase may have a (limited) negative impact (-1/-2) at close range, near the Galgenschoor nature reserve. In residential areas further away and in the Opstalvallei nature reserve, the impact is negligible (0).
  - The short-range impact mainly affects part of the Galgenschoor South nature reserve, located in the southern part of the project area, where there is a relatively higher level of construction activity close to the nature reserve than in the northern part of the project area. In Galgenschoor South, there is a limited negative effect (-1), up to a local and only during the most intensive construction period in the southern part of the project area (construction stage B), a negative effect (-2).
  - In the Galgenschoor North nature reserve, the effect is more moderate, with a limited negative score (-1) at the start of the construction phase (construction stage A), followed by a negligible score (0) later in the construction phase (construction stages B and C).
  - The negative effect (-2) in Galgenschoor south and limited negative effect (-1) in Galgenschoor north only occur on the Scheldt dyke, which is part of the nature reserve. In the lower-lying salt marsh area within the nature reserve between the dyke and the river, the effect is generally more limited due to the protective effect of the dyke.

- **Noise emissions during the operational phase**:
  The noise emissions from the installations and ships during the operational phase will have a negligible impact (0) on the surrounding residential areas and nature reserves. At 200 m east of the project area, in the Kanaaldok (industrial area), there will be a limited negative impact (-1). This impact is limited to the Kanaaldok area, Insteekdok 1 and, depending on the situation, Insteekdok 2, and does not extend to the surrounding residential and nature areas. Given the large scale of the project, this low impact is the result of a restriction on the noise emitted, which is imposed on the suppliers/manufacturers of the various equipment and installations.

- **Noise emissions from flares:**

  There are three flares that will only be used sporadically during an emergency (to ensure safety on site) or during the start-up/shutdown of a unit. Ground flares will be provided so that the tower flare needs to be used as little as possible, thereby minimising the impact (noise, light, possible smoke). The ground flares will be able to handle all operational scenarios and most safety scenarios without using the tower flare.
  - The noise emissions from the installations during the start-up phase of operation with the ECR ground flare in operation will have negligible effects (0) on nearby residential areas and nature reserves. Locally, 200 metres east of the project area in Kanaaldok B2 (industrial area), there may be a limited negative impact (-1).
  - The maximum operation of the ECR tower flare and the operation of the ground flares for tank storage only occur in very exceptional circumstances for safety reasons in the event of incidents. For the ECR, this involves the discharge of residual gas flows that are too large for the ground flare. This will be clearly audible at the nearest homes in Lillo and parts of the Galgenschoor nature reserve (briefly + 8 dB(A)). The effect will be limited or imperceptible (< 4 dB(A)) at the more distant homes in Berendrecht and the Opstalvallei nature reserve.

18.1.2 Air

- **Air emissions during construction phase**:
  The effect of air emissions from construction machinery during the construction phase is negligible (0) at the nearest residential area in Berendrecht. At shorter distances, there is a limited negative effect (-1) extending to 0.5 to 1 km from the site. At a very short distance (above Kanaaldok), the effect is negative (-2). This effect is mitigated by the fact that Project One requires the use of Stage IV or better machines (built in 2014 or later) for all types of machines above 56 kW and not the heaviest type of diesel generators (>560 kW).

- **Air emissions during the operational phase:**
  During the operational phase, the effect of the expected emissions for NO_2 is negligible (0) at the nearest residential area of Berendrecht. The zone with a limited negative impact (-1) extends to approximately 2 km from the ECR and does not affect any residential areas. There is a local negative impact (-2) at the Kanaaldok, which is partly determined by emissions from ships at the quay.
  For all other pollutants, there are only very localised negative (-1) to negligible (0) effects. These effects have already been mitigated in accordance with BAT by various project-integrated mitigation measures. For NOx emissions, the mitigation measures applied limit the emission level to values lower than those prescribed by BAT. A further reduction in the annual NOx emission load based on the best available techniques is not possible due to technical limitations of the available techniques. The alternatives investigated require efforts that are disproportionate to their effectiveness.

18.1.3 Soil

Provided that the usual and mandatory mitigating measures are applied to prevent soil contamination, Project One will have only negligible (0) to limited negative (-1) effects on the soil, both during the construction phase and during the operational phase.

18.1.4 Water

- **Groundwater**:
  - The main temporary effect on groundwater stems from the necessary drainage during the construction phase, spread across the entire site, for a period of approximately 24 months. By implementing preventive measures (such as installing sheet piling or equivalent technology), the effect of the drainage can be reduced to a limited negative effect (-1). A detailed drainage report will be included in the permit application, describing all relevant technical aspects of the drainage (purification, monitoring, etc.).
  - During the operational phase, the infiltration of rainwater into the groundwater will be limited by the presence of paved surfaces (limited negative effect (-1)). There are no other relevant effects on the groundwater.

- **Surface water**:
  - The drainage water will be discharged (after treatment) into the Kanaaldok. The worst-case impact of the discharge of drainage water based on the discharge standards is negligible (0).
  - Project One provides for extensive industrial water treatment during the operational phase, with the wastewater stream from the ECR undergoing separate pre-treatment. The effect of discharging the treated wastewater into the Scheldt is assessed as negligible (0) for all pollutants.
  - Although Project One (cooling systems) will represent a significant amount of water consumption, there are plans to use demineralised water in addition to municipal water. This will allow the cooling water to remain in use for longer, resulting in less waste water (discharge). In addition, the collected rainwater will mainly be reused as cooling water.

18.1.5 Mobility

- In terms of traffic, negative effects (-2) can be expected on traffic flow during the construction phase at the intersection at the Vopak entrance, which will also be the site entrance. These effects can be further mitigated to a limited negative effect (-1) by making the necessary adjustments (traffic lights) when designing this intersection as site access.
- In addition, both during the construction phase and the operational phase, there may be limited negative effects (-1) on road safety, which can also be mitigated by traffic lights.
- Finally, it has been established that the Scheldelaan x R2 intersection south of the project area is already virtually saturated during rush hour, which means that the additional traffic generated by Project One will have a limited negative (-1) to significantly negative (-3) impact, especially during the busiest periods of the construction phase. The application of contractually adjusted working hours (starting early and finishing early) and/or the implementation of more collective transport can reduce this considerably to a negative effect (-2).

18.1.6 Biodiversity

- The removal of vegetation from a large part of the project area during the first phase of construction resulted in local habitat loss, which is assessed as having a significant negative impact (-3). Measures were taken to protect protected species (relocation of plants and animals, etc.) and forest compensation took place outside the project area. The installations also create an additional barrier between existing nature areas. The pipeline corridors can function as an ecological connection if ecological management is applied, resulting in a limited negative impact (-1).
- For all other aspects of Project One, the effects on biodiversity are negligible (0) to slightly negative (-1).

18.1.7 Landscape

- In terms of landscape, deforestation is assessed as having a negative impact (-2) (changes to structure and relationships and changes to the landscape image and perception), which cannot be mitigated and is inherent to the designated use of the land (industrial area). The construction of industrial installations will also have a limited negative (-1) effect on the landscape image and perception in some locations.

18.1.8 People

- The impact on health and nuisance for local residents is assessed as negligible (0) to limited negative (-1) for most aspects.
- This is the case, for example, for noise nuisance during both the construction and operational phases. The limited impact is partly due to the reduction of noise emissions from the installations, especially during the operational phase.
- The current NO_2 concentration in the vicinity of the port of Antwerp is higher than the recommended health guideline value everywhere. The increase in exposure as a result of Project One during the construction phase is limited for Berendrecht, Lillo and Doel. Taking into account the background values present, the impact of NO_2 during the construction phase is assessed as limited negative (-1). Elsewhere, the impact is negligible (0). For the operational phase, taking into account the existing background values, the impact of NO_2 during the operational phase in the residential areas of Berendrecht, Zandvliet,

Lillo, Doel and parts of Stabroek are assessed as negative (-2) to slightly negative (-1). In other parts of the study area, the effect is assessed as negligible (0). In the Netherlands, the impact is also negligible (0).

- The current background concentrations of benzene and butadiene throughout the study area are associated with an additional cancer risk that is not negligible from a health perspective. For these substances, the contributions of Project One during the operational phase are very low. Taking into account the existing background values, the effect can be considered limited negative (-1) in Lillo and Berendrecht, as well as in part of Doel for the parameter benzene.
- For PM_{10}, the impact is negligible (0). In the worst case scenario, the $PM_{2.5}$ contribution is the same as that of PM_{10}. In that case, the impact in Berendrecht can be assessed as negative (-2) to slightly negative (-1). The negative assessment is partly due to the exceeding of the health advisory value for $PM_{2.5}$. Outside Berendrecht, the contribution for $PM_{2.5}$ is negligible (0).

18.1.9 Climate

For the **Climate** discipline, the assessment is not expressed in impact scores. We summarise the evaluation as follows:

- **Construction phase**:
  - The project area functioned as a carbon stock (forest area, grassland, scrub and thickets) when it was overgrown and lost that function due to the conversion of land use to industrial land use. The actual carbon debit after X years basically consists of the carbon stock after X years in the project area if it were left untouched. The actual carbon debit therefore takes into account both the carbon stock and the carbon storage capacity of the area. It was calculated that, due to the change in land use in the project area and the legally required forest compensation, the actual carbon debit after 10 years is + 13,980 tonnes of CO2.
  - Direct CO2 equivalent emissions during the entire construction phase from the use of fuels for all transport (materials and personnel) to and from the site and for the machinery that will be operating on site are estimated at 56,365 tonnes CO2 eq/year during the construction phase (3 years and 8 months). The CO2 equivalent emissions from the consumption of concrete and steel materials in Project One are estimated at 4,126 tonnes CO2 equivalent/year (spread over the 50-year lifespan of the installation).
- **Operational phase - Carbon balance**
  - The total carbon balance of the ECR and supporting infrastructure is calculated at 655 ktonCO2-eq/year.
  - Project One uses state-of-the-art technology for ethane cracking, and best available techniques (BAT) and energy integrations are consistently applied to achieve high energy and production efficiencies.
  - The specific process emissions of Project One's ECR amount to 0.290 tonnes CO2-eq/tonne HVC, or only 42% of the current EU ETS benchmark value of 0.681 tonnes CO2-eq/tonne HVC.
  - It has been calculated that Project One implies a tightening of the EU ETS benchmark value for HVC production to approximately 0.577 tonnes CO2-eq/tonne HVC. This is a decrease of approximately 15% compared to the current benchmark value for HVC production (0.681 tonnes CO2-eq/tonne HVC). Taking into account the current annual HVC production capacity in Europe of 47.6 Mton HVCs (IEA, I2018), this means that approximately 4.95 Mton of additional emission allowances must be paid or avoided annually by existing steam crackers for HVC production under the EU ETS system. Such a quantity of emission allowances corresponds to approximately 267 million euro/year, taking into account the current price (mid-June 2021) of 54 euro/tonne CO2 under the EU ETS system. Part of this additional revenue for the EU ETS system will be used to support innovation and modernisation projects in energy-intensive industrial sectors and the energy sector.
  - The ethylene produced in Project One is sold on the market. Most existing installations are currently supplied with ethylene from European naphtha crackers, which are often outdated and have significantly higher specific CO2 equivalent emissions than the new ECR of Project One. These installations can purchase the ethylene produced by Project One and reduce their CO2 equivalent emissions. As an example, it has been calculated that the reduction in the carbon footprint of the customers would amount to approximately 2 Mton CO2-eq./year if the customers were to use the ethylene produced in Project One.

- The total electricity demand of 140,160 MWh/year will be covered by green electricity. This will reduce Project One's total emissions by approximately 7% compared to the project without the import of green electricity, specifically from 708 ktonCO2-eq/year to 655 ktonCO2-eq/year.
- Passive techniques such as thorough insulation and passive solar gain, climate and lighting controls, and renewable energy techniques are integrated into the design of the administrative buildings. Under BREAAM, the rating 'very good' has been achieved (3rd highest score on a scale of 1 to 5). Taking into account the energy-efficient techniques used, the (indirect) CO2 emissions of the administrative building amount to approximately 300 tonnes of CO2/year. As the external electricity demand will be covered by green electricity, these emissions from the administrative building will therefore be eliminated.
- Although Project One already has significantly lower CO2 emissions than existing steam crackers in Europe, it is not yet zero. The INEOS group is committed to achieving the EU climate and energy targets for 2050 and reducing net CO2 emissions to zero. Project One has been designed with net zero CO2 emissions in mind and aims to become the first CO2-neutral cracker in Europe, playing a role in Antwerp's sustainable industrial future. Once the technology is feasible, Project One has three possible routes for reducing CO2 emissions:
    - Electrification of furnaces using green electricity.
    - Use of green and/or blue hydrogen as fuel.
    - Carbon Capture and Storage (CCS).

  Once the Project One installations are up and running, IOB will be well positioned to achieve zero CO2 emissions in the future. IOB's goal is to become Europe's first carbon-neutral cracking plant. It is currently expected that Project One will be able to achieve net zero emissions within 10 years of the installations being commissioned.

- **Operational phase - Climate adaptation**

  The consequences of climate change may have an impact on the project area itself:

- Flooding: The available flood risk maps (pluvial, fluvial and coastal) show that the flood risk is due to surface runoff and not to flooding from the Scheldt. It should be noted, however, that the flood map for flooding from the sea does not currently take into account the effect on the Scheldt. The design of the rainwater management system took into account a changed precipitation pattern under the influence of climate change, thereby making the project area more resistant to increased flood risks.
- Water supplies: Project One consumes a considerable amount of municipal water. The use of demineralised water reduces municipal water consumption by approximately half. The water company uses brackish dock water as a raw water source for the production of demineralised water, thereby reducing the pressure on the municipal water supply. The municipal water company also has a plan to guarantee the drinking water supply to industrial and residential customers in future periods of drought, even in a changed climate.
- Climate resilience is integrated into the design of Project One's industrial installations.
- Heat stress: The project area can currently be considered entirely green space. The removal of vegetation has eliminated this cooling and buffering effect. Given that the use of the space has changed (industrial installations), this will have no effect on the living environment. Moreover, the cooling effect of the Scheldt and the Canal Dock is greater than that of the project area. This cooling effect will be retained.

The following table shows the impact scores before and after the implementation of additional mitigating measures proposed by the experts. The project-integrated measures are not listed in the table, but they have been included in the impact assessment to obtain the impact score. The project-integrated measures are listed in § 18.2.

Table 18-1: Overview table of effects per discipline

Impact (after project-integrated mitigation measures)	Explanation	Score	Additional Measure / Monitoring	Score
Noise				
Construction phase: Construction site activities and vehicles in the project area during the day	Lillo	0	Source-related measures, mitigation measures of noise transmission and organisational measures.	0
	Berendrecht	0		0
	Galgenschoor North	0		0
	Galgenschoor south	-1/-2		-1/-2
	Opstal Valley	0		0
Construction phase: Construction site activities and vehicles in project area at night	Lillo	0		0
	Berendrecht	0		0
	Galgenschoor north	0		0
	Galgenschoor South	0		0
	Opstal Valley	0		0
Construction phase: Road traffic noise		0/-1	-	0/-1
Construction phase: Ship noise (sailing)		0	-	0
Operational phase: Installations + ships at the quay	Lillo	0	During the further progress of the project, it will be verify whether all more detailed and specific supplier data is in line with the assumptions in this EIA	0
	Berendrecht	0		0
	Galgenschoor	0		0
	Opstalvallei	0		0
	Canal dock and slipways 1 / 2	0/-1		0/-1

Effect (after project-integrated mitigation measures)	Explanation	Score	Additional measure / Monitoring	Score
Operational phase: At start-up/shutdown of the ECR (installations + ECR ground flare)	Occursbutsporadicallybefore	0/-1	As the project progresses, it is important to check whether all more detailed and specific supplier data are in line with the assumptions in this MER. Where possible, a low-noise type of flare should be selected.	0/-1
Operational phase: In the event of emergencies (ground flares and situation 1 open, high flare)	Emergency	/		/
Operational phase: Road traffic noise		0	-	0
Operational phase: Ship noise (sailing)		0	-	0
Air				
Construction phase: Shipyard activities, vehicles in the project area and ship traffic	Canal dock	-	-	-
	Up to 0.5 to 1 km northeast of the site Opstal Valley (limited part) and Galgenschoor (limited part)	-		-1
	All residential areas and other nature reserves	0		0
Construction phase: Road traffic		0	-	0
Operational phase: NO_2 (annual average)	Canal dock	-2	The project already applies BAT, resulting in emission levels are lower than those prescribed by BAT. It has been demonstrated that no additional measures are required with relevant additional reduction are feasible.	-2
	Up to approximately 2 km northeast of the site Opstal Valley (partly)	-1		-1
	All residential areas and other nature areas	0		0

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Effect (after project-integrated mitigation measures)	Explanation	Score	Additional measure / Monitoring	Score
Operational phase: SO_2	Canal dock	0/-1	-	0/-1
	All residential areas and nature reserves	0		0
Operational phase: CO		0	-	0
Operational phase: Fine particulate matter		0	-	0
Operational phase: Volatile organic compounds: benzene	Canal dock	-1	-	-
	All residential areas and others nature areas	0		0
Operational phase: traffic emissions		0	-	0
Soil				
Construction phase: Erosion		0		0
Construction phase: Change in soil stability		0/-1		0/-1
Construction phase: Earthworks and temporary storage of soil		0/-1		0/-1
Construction phase: Structural changes and profile changes		0		0
Construction phase: Change in soil quality due to leaks		0/-1		0/-1
Operational phase: Change in soil quality due to leaks (installations, tanks, transhipments)		0/-1		0/-1

Effect (after project-integrated mitigation measures)	Explanation	Score	Additional Measure / Monitoring	Score
Water				
Vegetation removal and construction of paved surfaces		-1		-
Construction phase - Drainage: Soil settlement, impact on existing groundwater extraction, salinisation and groundwater contamination around the project area		-1	Preventive measures already in place (infiltration and/or sheet piling) with monitoring (drainage report)	-1
Construction phase - Drainage: Change in surface water quality		0		0
Construction phase (including vegetation removal): Change in groundwater quality due to leaks		0		0/-1
Operational phase: worst-case impact of effluent discharge		0	Extensive purification is already planned.	0
Operational phase: impact on underwater sediment		0		0
Operational phase: effect on water quantity		0		0
Operational phase: effect on groundwater quantity due to paving (installations, tanks, transhipments)		-1		-1
Mobility				
Construction phase: Road safety		-1	Attention to traffic safety at site access and site circulation. Separation of freight traffic/passenger traffic and motorised traffic/vulnerable road users.	-1
Construction phase: Completion of motorised traffic road network	Liefkenshoek TunnelThijsman Tunnel A12 towards the Netherlands	-1	-	-
	All other roads	0		0

Effect (after project-integrated mitigating measures)	Explanation	Score	Additional measure / Monitoring	Score
Construction phase: Motorised traffic intersections	Vopak x Scheldelaan intersection	-	Well-considered design of the Vopak x Scheldelaan intersection during the construction phase with a view to optimising the traffic flow.	-1
	R2 x Scheldelaan intersection	-1/-3	Adjusted working hours	-1/-2
	All other intersections	0	-	0
Construction phase: Passenger car parking		0	-	0
Construction phase: Lorry parking		0	-	0
Operational phase: Road safety	Cycling safety	-1	Focus on road safety in further detailed design of access Project One. Separation of freight traffic / passenger traffic and motorised traffic/vulnerable road users.	-1
	Vesta intersection	-1		-1
Operational phase: Motorised traffic road network settlement		0		0
Operational phase: Settlement of intersections for motorised traffic	Intersection Project One (Vesta) x Scheldelaan	-1	-	-1
	Intersection R2 x Scheldelaan	-1		-1
	All other intersections	0		0
Operational phase: Passenger car parking	Ideal occupancy + overflow parking	0		0
Operational phase: Lorry parking		0		0

Effect (after project-integrated mitigation measures)	Explanation	Score	Additional measure/monitoring	Score
Biodiversity				
Construction phase: Soil disturbance		0		0
Construction phase: Noise disturbance during the day	Gallows	-1		-1
	Potpolder Lillo	0		0
	Project area	0		0
Construction phase: Noise disturbance at night		0		0
Construction phase: Loss of biotope and ecotope		-3	The effect in the project area is negligible. mitigate. Compensation took place outside the scope of the project and study area.	-3
Construction phase: Fragmentation and barrier effect		-1	Ecological management of the pipeline corridors has already been provided for	-1
Construction phase: Acidifying and fertilising deposition		0		0
Construction phase: Effect on groundwater management		0		0
Construction phase: Ecotoxicological effects on water and air emissions		0		0
Construction phase: Light pollution		0		0
Operational phase: Noise disturbance	Gallows	0		0
	Potpolder Lillo	0		0
	Project area	0		0
Operational phase: Acidifying and eutrophying deposition		0		0

Effect (after project-integrated mitigation measures)	Explanation	Score	Additional measure / Monitoring	Score
Operational phase: Ecotoxicological effects of water and air emissions		0		0
Operational phase: Light pollution		-1		-1
Landscape				
Vegetation removal/deforestation: Loss of heritage value		0	-	0
Vegetation removal/deforestation: Structural changes		-2	Local effects are an inherent consequence of deforestation in However, forest compensation does take place in other locations.	-2
Vegetation removal/Deforestation: Relationship changes		-2		-2
Vegetation removal/deforestation: Change in landscape appearance and perception		-1/-2		-1/-2
Construction phase: Loss of heritage value		0/-1	The phased archaeological research carried out (with postponed route) indicates a new site worthy of preservation site from prehistory. A follow-up investigation with evaluation test pits, due to the release of the site. It is recommended that additional targeted mechanical drilling be carried out in order to extensive scientific sampling and study (this is explained in the Programme of Measures for the deferred route).	0/-1
Construction phase: Structural changes		-1	-	-1
Construction phase: Relationship changes		-	-	-
Construction phase: Change in landscape appearance and perception		-1	-	-1
Operational phase: Loss of heritage value		0	-	0

Operational phase: Structural changes	-	-	-1

Effect (after project-integrated mitigating measures)	Explanation	Score	Additional measure / Monitoring	Score
Operational phase: Relationship changes		-1	-	-
Operational phase: Change in landscape appearance and perception	Varies depending on location	0/-1	These effects are an inherent consequence of the presence of conspicuous installations. These cannot be mitigated.	0/-1
People				
Construction phase: NO_2 (peak period of 1.5 years in the construction phase)	EIA-GAW	-1	The project already applies BAT, resulting in emission levels are lower than those prescribed by BAT. It has been demonstrated that no additional measures with relevant additional reduction are feasible.	-1
Construction phase: Noise	during the day	0	See above under 'Noise'	0
	At night	0		0
Construction phase: Light pollution		0	Principles of good lighting	0
Operational phase: NO_2	MER-GAW	-	See above under 'Air'	-
Operational phase: benzene		-1	See above under 'Air'	-1
Operational phase: butadiene		-1	See above under 'Air'	-1
Operational phase: PM_{10}	EIA-GAW	0	See above under 'Air'	0
Operational phase: $PM_{2.5}$	EIA-GAW	-1/-2	See above under 'Air'	-1/-2
Operational phase: Noise – continuous noise sources		0	See above under 'Noise'	0
Operational phase: Noise – continuous noise sources + flares		-1	See above under 'Noise'	-
Operational phase: light pollution		0	Principles of good lighting	0

Operational phase: Legionella	0	-	0

18.2 Mitigating measures

18.2.1 Noise

18.2.1.1 Construction phase

Project-integrated measures

In order to minimise noise emissions from activities during the construction phase of the project, Project One undertakes to implement the following measures:

- Screw foundation machines are used for the foundation work for the installations and buildings of Project One. First, a shaft is drilled, which is then filled with concrete mortar. When installing the sheet piling, a pressure technique is used, whereby the sheet piling is pushed into the ground using a crane and a hydraulic pressure machine. Both of these methods are low-noise and low-vibration alternatives to methods that use a percussion or vibration mechanism to drive preformed foundation piles and sheet piling into the ground.
- Project One requires contractors to use construction machinery whose emissions (exhaust gases) at least meet the Stage IV requirements (see Chapter 7 Air), which means that the machinery used generally dates from after 2014.
  When selecting construction site machinery, particular attention is paid to the noise emissions of the machines and, where possible, preference is given to low-noise equipment. In any case, the noise power level of the construction machinery may not exceed the assumptions considered in this EIA. The client has also considered the use of battery-powered construction machinery, which can have lower noise emissions than diesel-powered construction machinery. However, this technology is still in the pilot phase for rolling stock with the required power and, taking into account the scale of the construction phase of Project One, is therefore not applicable.
- Project One provides measures to limit traffic movements during the construction phase of the project by reducing and shifting transport (see Chapter 10 Mobility for details). Among other things, there are plans to work with modules transported by ship (pre-assembled installations that reduce the manpower required on site and the associated transport), bulk transport by ship (supply and removal of soil), shifting as much road freight transport as possible outside rush hour for site personnel, etc. These measures also have a reducing effect on noise emissions from road traffic.

Additional measures

Taking into account the above measures from Project One, limited negative effects and – very localised – negative effects are still possible. Although this is not a permanent situation, additional mitigating measures should be taken as far as possible to reduce the noise impact of the construction activities. The overview below provides a number of recommendations, distinguishing between source-related measures, measures relating to noise transmission and organisational measures. The list is not exhaustive.

- **Source-related measures**
  Project One undertakes to pay particular attention to the noise emitted by the relevant sources/machines on site in order to minimise noise emissions from activities during the construction phase. The following (additional) source-related measures are recommended in order to achieve the intended objective.
  - Preparation of a monthly inventory of the relevant sources/machines on site, stating the sound power level, by the coordinator of the various site contractors to check whether all sources can comply with the assumptions made in this EIA, with the aim of respecting the total sound power level per site stage.
  - Assessment of construction machinery against the requirements of European Directive CEE/2000/14, transposed into the Royal Decree of 6 March 2002 on the sound power level of equipment for outdoor use, by the coordinator of the various construction contractors. Some of the construction machinery has specific limit values imposed by this directive (the assumptions in this EIA take this into account), while others are required to state the guaranteed sound power level.

- Providing regular maintenance of the machines in accordance with the manufacturer's instructions.

- **Measures relating to noise transmission**
  - Arrange the site layout in such a way that non-mobile machinery (e.g. power generators, air compressors, drainage pumps, etc.) to be used on the western half of the project area is located as far away as possible from the nearby Galgenschoor nature reserve. The placement of this non-mobile machinery directly adjacent to the western boundary of the project area should therefore be avoided.
  - Use of temporary or permanent local screening of construction site activities and machinery in the direction of noise-sensitive areas (residential and nature areas). This can take the form of acoustic movable screens, earth embankments, etc. The client investigated the installation of a barrier in the form of an earth embankment or container-shaped wall at the southern boundary of the project area to limit noise transmission from the entire construction site towards the Galgenschoor nature reserve. According to the information obtained, the available space at this construction site does not allow for the installation of a collective barrier along the entire western boundary of the site, so this option was not considered further.

- **Organisational measures**
  - Limit working hours outside daytime hours, particularly for activities that may cause significant noise impact in the vicinity of the project area.
  - Prior to the execution of specific noise-generating activities that are expected to have a potential noise impact near residential areas, clearly inform local residents about the duration and type of work.

18.2.1.2 Operational phase – Continuous noise sources

Project-integrated measures

Within the framework of this EIA, noise emissions from future sources were estimated on the basis of available supplier data or, in the absence thereof, on the basis of noise data from similar sources. Based on the average sound power level per unit of surface area (Lw/m²) of the future installation zones, it can be said that Project One has made the necessary efforts to minimise noise emissions. To this end, Project One's design provides for the use of low-noise installations, supplemented by extensive noise reduction measures.

Additional measures

As the project progresses, it is important to check whether all supplier data is in line with the assumptions in this EIA and whether the maximum assumed noise emissions can therefore be met.

The impact assessment shows that during the operational phase of the project (during representative operating conditions and during a start-up or planned shutdown of the ECR), there may be a limited negative impact to the east of the project area in canal dock B2 (industrial area).

Given that Project One will comply with the applicable limit value at all points during the operational phase,

- complies with the applicable limit value at all points,
- The zone to the east of the project area, where there is a limited negative impact, is located entirely in the canal dock/inlet docks 1 and 2, where there may be no or only very short-term receptors.
- has a negligible or no effect on the most noise-sensitive areas (residential areas and nature reserves) and on the nearby industrial estates,
- already provides for the necessary investments to use low-noise installations, supplemented by noise-reducing measures where necessary,

no additional specific mitigating measures are necessary.

18.2.1.3 Operational phase – Flares

Project-integrated measures

Project One provides a single ground flare with a capacity for the ECR to prevent flaring via the ECR tower flare during a planned start-up or shutdown of the ECR. In addition, Project One provides a double tank ground flare (1 in use, 1 as backup) connected to the storage tanks (cryogenic tank and bullets), which can divert excess pressure from the tanks in the event of undesirable incidents. This limits the use of the ECR tower flare to unplanned process interruptions only, where gas flows are released that exceed the capacity of the installed ECR ground flare. This can happen after the start-up of the safety shutdown system, which can be activated after a major process failure, mechanical failure of rotating equipment or a failure of a vital service due to power or steam failures. In order to maintain stable operation of the production process and prevent the risk of unplanned downtime, Project One provides for the following investments:

- Use of reliable pumps with additional instruments to support stable operation and prevent improper activation of the shutdown system;
- Use of mechanical locks on installations (e.g. valves) that shut off when a temperature or pressure threshold is reached to prevent overpressure and release of a pressure relief valve for flaring;
- Use of a dual external power supply via two independent 380kV high-voltage cables (Elia) to ensure the electrical supply;
- Construction of an internal power supply for the ECR, which can prevent the ECR from stopping unexpectedly in the event of a power failure on the external electricity grid;
- Construction of two steam boilers that perform a dual function: on the one hand, they provide a continuous supply of steam to the process at all times to ensure normal operation (if one boiler fails, the other boiler takes over the entire steam demand) and, on the other hand, they consume the process exhaust gases in order to reduce the flaring of excess gas flows.
- Applying design standards for installation processes to ensure high technical availability and using automated systems that can limit the amount of waste gas sent to flares by automatically switching off equipment that can cause flaring.

Additional measures

As the project progresses, it is important to check whether all assumed noise levels for the flares are in line with the assumptions in this EIA and whether the maximum assumed noise emissions can therefore be met.

When making the final choice of tower flare, preference should be given to the quietest type made available by the suppliers.

18.2.2 Air

18.2.2.1 Construction phase

Project-integrated measures

- The use of Stage IV or better vehicles/machines for all medium-duty and heavy-duty vehicles/machines (from 56 to 560 kW).
  - Approximately three quarters of the vehicles/machines used fall into this category.
  - For lighter types (below 56 kW), there is little or no difference depending on the 'Stage' of the machines. These are only subject to stricter emission requirements from Stage V onwards (types from 2019-2020).
  - The use of less strictly regulated diesel generators of the heaviest type (> 560 kW) is excluded.
- The application of codes of good practice during excavation work, when handling (loading, unloading, etc.) any dust-sensitive (construction) materials and when storing them, for example by spraying materials and/or roads in dry weather and cleaning the roads periodically.
- Where possible, transport is planned using ships rather than lorries. This is the case for most land transport and for the delivery of the largest process installations (modules) and equipment.

18.2.2.2 Operational phase

Project-integrated measures

- Limiting NOx emissions:
  - Use of low-NOx burners in all combustion plants.
  - SCR-DeNOx on 8 chimneys (6 ECR chimneys, 2 steam boilers) to reduce NOx emissions (implementation of scenario B).
  - The combination of these techniques achieves lower emission levels than each BAT technique individually (72% reduction in NOx emissions for Project One as a whole). The following table shows the guaranteed emission limits.

Table 18-2: NOx and $_{NH3}$ emission limits

Emission limits for 6 cracking furnaces and 2 steam boilers	NOx	NH3
Concentrations during normal operating conditions		
Hourly average per chimney	60 mg/Nm³	8 mg/Nm³
Daily average per chimney	40 mg/Nm³	6 mg/Nm³
Annual load		
Moving three-year average for the eight chimneys combined*	148.8 tonnes/year	17.9 tonnes/year

* These annual loads are calculated based on an expected emission concentration, averaged across the various chimneys and over the lifetime of the catalyst, of 25 mg/Nm³ NOx and 3 mg/Nm³ $_{NH3}$ under normal operating conditions. The effects were calculated using these loads.

- The design of the installations (cracking furnaces and boilers) and their gas purification systems takes into account the possible application of carbon capture in the future. To this end, space has been provided in the installations for additional pipes and space on the site for additional installations.
- The decoking emissions from the ECR are limited by dust removal using cyclones.
- The installations in which the physico-chemical (primary) and biological wastewater treatment (secondary treatment) take place will be closed and equipped with an extraction system:
  - For the primary treatment stages, where larger quantities of hydrocarbons are expected, the extracted gases will be incinerated in a thermal oxidiser, in accordance with BAT.
  - For the secondary biological treatment steps, including sludge treatment, the extracted air will be sent through an odour removal installation, in accordance with BAT.
- To limit storage and loading emissions from the tanks for the C5+ fraction and pyrolysis oil, an activated carbon filter or membrane filter (or equivalent technology) is provided, in accordance with BAT.
- The ground and tower flares mainly serve a safety function. The ECR ground flare is used during planned start-up and shutdown procedures. The ECR tower flare and the ground flares of the gas storage facility are only used when gases need to be evacuated for safety reasons. The use of the flares is limited to these situations.
- To prevent and limit fugitive emissions, measures are taken in the areas of design, construction, commissioning, maintenance and monitoring. This means that technically sealed installation components are used in all parts of the installation where gaseous or volatile liquid product flows occur. During construction, specialised, trained personnel are deployed to install flanges, valves, etc. correctly. Before the installations are commissioned, leak tests are carried out and any leaks are repaired before the installations are put into operation. In terms of monitoring, a combination of measurements at installation components (sniffing method) and the use of advanced infrared cameras (OGI = Optical Gas Imaging) is provided in collaboration with the specialised contractor. This approach applies all aspects of BAT.
- The supply and removal of raw materials and end products is largely carried out by ship and pipeline.

Additional measures

The effects of emissions of N compounds (NOx and NH_3) are being evaluated as a point of attention in the disciplines of Air (NO_2), Human Health (NO_2) and Biodiversity (N deposition).

These effects already take into account maximum emissions per chimney which, as a result of the use of low-NOx burners in combination with SCR-DeNOx, comfortably comply with the emission levels associated with BAT (BAT-GENs). The combination of these techniques achieves a lower emission level than for each BAT technique individually.

The emission concentrations are as follows:

- Maximum emission concentration with SCR: concentrations expected at the end of the catalyst bed's service life (this needs to be replaced every 5 years).
- Expected emissions: average emissions over the lifetime of the catalytic converter: takes into account the slow deactivation of the SCR-DeNOx catalytic converter.

Table 18-3: Expected NOx and NH_3 emission concentrations

	Scenario A BAT without SCR Maximum emissions	Scenario B BAT with SCR	
		Maximum emissions (daily average)	Expected emissions (average over 3 years)
NOx (mg/Nm³)			
ECR Cracking furnaces (6) *	100	40	25
Steam boilers (2) *	80	40	25
NH_3 (mg/Nm³)			
ECR Cracking furnaces (6)	0	6	3
Steam boilers (2)	0	6	3

* Combustion plants with flue gases at 3% O_2

The table below shows that the use of SCR-DeNOx gas purification results in a significant reduction in NOx emissions (a 72% reduction for Project One as a whole). Project One has already decided to apply this purification method to the eight chimneys concerned. This will result in limited NH3 emissions.

Table 18-4: Expected emission load for Project One NOx and NH_3

	Without SCR	With SCR
NOx	591 tonnes/year	167 tonnes/year
NH_3	0 tonnes/year	18 tonnes/year

The maximum emission limits mentioned above are set for each chimney separately and must always be complied with. In addition, the expected values mentioned above should be considered as target values, which must be complied with for Project One as a whole and in the longer term. It is assumed that Project One's emissions will be below 167 tonnes of NOx and 18 tonnes of NH_3 per year, which corresponds to:

- a guideline value of 25 mg/Nm³ NOx for all chimneys with SCR-DeNOx;
- a guideline value of 3 mg/Nm³ NH_3 for all chimneys with SCR DeNOx.

As all chimneys with the most relevant NOx and NH3 emissions will be equipped with continuous measuring equipment, actual emissions can be monitored and quantified accurately. This guarantees that:

- the efficiency of the SCR catalyst is continuously monitored so that the emission limits are respected;
- the overall emissions from Project One are continuously quantified, demonstrating that they correspond to or are lower than the expected emissions mentioned above;
- The emissions from each chimney are well known, allowing the effect of the emissions to be verified using dispersion modelling based on actual emissions, where necessary.

The higher-estimated emissions have already been mitigated by additional mitigation measures, resulting in emission levels that are significantly lower than the emission levels associated with BAT (BAT-GENs). The possibilities for further reducing emissions were investigated but are limited:

- NOx emissions are reduced as much as possible by expanding the SCR catalyst beds and/or replacing them more regularly. However, the target concentration (guideline value of 25 mg/Nm³ with SCR) is close to the technical limits of the SCR, so there are no guarantees that even lower emissions will be achieved. In addition, it appears that the additional investment and operating costs (increased pressure drop across the SCR catalytic converter; replacement of the catalytic converter, production shutdown, etc.) for more far-reaching measures are high in relation to the unit reduction cost of 8.6 used.
  EUR/kg NOx removed. For a more detailed explanation, please refer to Appendix 6.4.
- The NH3 emissions from SCR-DeNOx are inherent to the operation of this technology and are kept as low as possible through continuous monitoring of the installation's operation. The BAT (BAT 7 for the LVOC and LCP sectors, see Annex 8) states that NH3 emissions can be limited by optimising the design and/or operation of the SCR system (e.g. optimised reagent/NOx ratio, homogeneous distribution of the reagent and optimal size of the reagent droplets). This is applied in the design of Project One. NH3 emissions cannot be further reduced by modifying the SCR-DeNOx. The expected emission concentrations of NH3 (lower than 6 mg/Nm³) can therefore already be considered low for the planned installations. According to BAT, there are no techniques available for further reduction of this concentration using a downstream technique. A commonly used downstream technique for NH3 removal is gas scrubbing. VITO mentions (https://emis.vito.be/nl/bbt/bbt-tools/techniekfiches/zure-wasser) mentions a few reference examples and a typical precondition for the concentration of ammonia to be removed of 200 to 1,000 (and sometimes 20,000) mg/Nm³ in the technical data sheet for scrubbers that remove NH3. The NH3 concentration after the SCR (< 6 mg/Nm³) is significantly lower, which means that a gas scrubber would not achieve efficient removal and is therefore not BAT in this case.

18.2.3 Soil

18.2.3.1 Construction phase

Project-integrated measures

A number of project-integrated measures are being taken to prevent or limit accidental contamination during the construction phase:

- Strict adherence to the recommendations formulated in the completed and ongoing soil investigations and strict adherence to the provisions in the technical report in order to prevent the spread of contaminated soil;
- In the event of emergencies: take immediate action in consultation with the soil remediation expert to minimise/eliminate the impact on soil quality;
- Draw up and follow work procedures that must be checked periodically for efficiency;
- Hose down materials at one or more central locations that are equipped with liquid-tight paving;
- Avoid using barrels and jerry cans as much as possible; if they are used, they must be equipped with good spouts and flexible filling hoses;
- Where possible, use environmentally friendly lubricating oils and greases (e.g. biodegradable oil).

Additional measures

Based on the impact assessments, additional mitigation measures are not considered necessary.

18.2.3.2 Operational phase

Based on the impact assessments, mitigating measures and recommendations for the operational phase are not considered necessary.

18.2.4 Water

18.2.4.1 Construction phase

Project-integrated measures

- Installation of sheet piling or equivalent technology.
- Purification of the contaminated pumped drainage water in accordance with the specified discharge standards before discharge.
- Carrying out the planned monitoring and control of water purification and drainage at the drainage zones. The monitoring plan is provided in the hydrogeological study, including the drainage note, with the environmental permit application.
- Monitor the effective impact during drainage works by monitoring the reduction in groundwater levels and monitoring subsidence, groundwater contamination and salinisation. The monitoring will be discussed in the hydrogeological study, including the drainage report, which will be attached to the permit application.

Additional measures

Based on the impact assessments, no additional mitigating measures are considered necessary.

18.2.4.2 Operational phase – surface water

Project-integrated measures

Within Project One, the following preventive measures, among others, are already being taken to limit the impact on the receiving water bodies:

- the use of demineralised water in the cooling circuits instead of just municipal water, which significantly reduces water consumption and wastewater discharge;
- the reuse of rainwater as cooling water and for sanitary applications;
- the separation and pre-treatment of specific wastewater streams at source and the appropriate treatment of different types of wastewater;
- potentially contaminated rainwater is collected separately in the first flush and second flush basins, so that it can then be used as cooling water if the quality is satisfactory;
- strictly monitor the application of good housekeeping practices:
  - keeping production facilities and surrounding areas clean
  - Wastewater streams are separated at source and directed to the appropriate drainage system for proper disposal and treatment.
- the use of ClO_2 to replace NaOCl, thereby avoiding the contaminant AOX in the effluent;
- the use of modified additives (anti-corrosion, anti-fouling agents) in the cooling water systems;
- installing pre-treatment, primary, secondary and tertiary treatment, with secondary treatment being a biological treatment process;
- providing sufficient buffer capacity in the water treatment system;
- Wastewater vapours that do not meet the specifications for processing in the wastewater treatment plant are collected in the off-spec tank.
- equipped with a monitoring system for the wastewater treatment plant from both the local and central control rooms:
  - on the incoming wastewater streams (online: pH, temperature, flow rate, TOC, suspended solids, oxygen consumption);

- on the effluent from the wastewater streams (online: pH, temperature, TOC, suspended solids, flow rate; on a daily basis: total N);
- with clear agreements on internal threshold values (e.g. flow rate, temperature, pH, TOC, turbidity as an indicator for suspended solids) for each of the incoming wastewater streams to the wastewater treatment plant;
- web-based dashboard (highly visual platform), accessible to all relevant "partners" for communication of online information on the various incoming wastewater streams, the efficiency of the WWTP and the concentrations of the outgoing effluent; designed to support a responsive, proactive attitude;

- Furthermore, a system of 'scenario response' cards with specific instructions will be developed for WZI managers. A high-performance system of 'lessons learned' management (covering both the identification of opportunities for improvement and implementation and follow-up) should support this approach. A similar approach should be provided at the source of the wastewater streams, in order to also be able to provide feedback at the 'source side' (process approach);
- improvement of the performance of the separators and reduction of the water load by:
  - maintaining a continuous and balanced hydraulic flow through the installation, e.g. by providing a sufficiently large collection tank, combined with the necessary process control to ensure sufficient buffer capacity at all times;
  - take measures (by means of additional dosing) to adjust the nutrient concentration where necessary in order to maintain optimal conditions in the biological treatment plants;
- providing monitoring and control measures to prevent the cooling water from becoming contaminated in the process heat exchangers. Appropriate measures include:
  - high-quality cooling pipes/sheet materials to prevent corrosion;
  - quality assurance and inspection of heat exchangers during construction;
  - adequate preventive maintenance, and;
  - online monitoring (of TOC) for the presence of contaminants in the cooling water; with immediate action if these are detected;
- minimising VOC emissions to the vapours released at the successive treatment stages in the wastewater system by:
  - covering as much as possible of the physico-chemical parts of the wastewater treatment plant, whereby the volatile components are collected for processing in an afterburner;
  - sending the vapours from the biological water treatment stages to a biogas scrubber to remove the odorous compounds and any remaining VOCs. This is discussed in Chapter 7 Air;
- Installation of online process monitoring equipment throughout the factory to record product flows and the risk of significant contamination in a timely manner and report this to the authorities (in the event of an incident). These online systems will be equipped with alarms to warn operators if certain operational parameters rise above a specified range.

Additional measures

Based on the impact assessments, additional measures are not considered necessary.

18.2.4.3 Operational phase – groundwater

Project-integrated measures

- Leak detection systems are provided on the tanks;
- the areas where the risk of spillage is greatest will be bundled or covered; a liquid-tight surface will be provided. Spilled liquids within these areas will be collected and removed by third parties;
- tanks containing environmentally hazardous liquids will be provided with liquid-tight floors and walls. Systems will be provided to check the seals;
- Tanks are designed to prevent hydrocarbons from entering the groundwater. In addition to design, operational management and performance, the maintenance, inspection and repair of tanks will be crucial to meeting this requirement.
- the containment will have sufficient capacity to collect any leaks of flammable/hazardous liquids and, where applicable, firefighting and cooling water, a layer of foam, rainwater and wind waves. The capacity for collecting firefighting water, cooling water and foam will be determined in accordance with a code of good practice;

- Loading and unloading areas for hazardous products will be equipped with liquid-tight paving and drainage to a collection pit or to the sewer system for oily waste water (to WZI).

Additional measures

Based on the impact assessments, additional measures are not considered necessary.

18.2.5 Mobility

18.2.5.1 Construction phase

During the construction phase, the following mitigating measures are considered necessary or desirable:

- Monitoring of parallel construction sites and current traffic situations for better management of construction site traffic. For example, at certain times it may be more advantageous to use complex 11 in order to relieve complex 12 and the R2 intersections. To this end, consultations will be held with the relevant authorities prior to and during the construction phase, including biweekly impact management meetings and weekly urban coordination meetings.
- Clear signage for site traffic. Possibly dynamic signage depending on traffic control.
  - Signage on public roads
  - IOB is consulting with the competent authorities about the possibility of dynamic signage for traffic control purposes.
- Further initiatives to encourage collective transport, for example by contractually obliging contractors to transport workers to the site by bus/water bus/minibus.
- Implementation of sustainable transport on the construction site (shared bicycles, electric vehicles, etc.).
- Monitoring of modes and use of parking spaces, with the possibility of adjusting available spaces in favour of more sustainable modes (e.g. reserved parking spaces for carpooling).
- Phased provision of parking spaces in the northern construction zone, depending on the needs of the project.
- Periodic and transparent communication about the works.
- Working with adjusted shifts in order to avoid rush hour periods.
- Separation of motorised traffic and active road users on company sites, for example by providing a parallel cycle path between Scheldelaan and the internal access road, so that cyclists do not come into conflict with motorised traffic.
- Securing intersections along Scheldelaan;
  - Securing the Vopak intersection by means of traffic lights. A design for this has already been discussed with AWV, with a view to having a cooperation agreement in place regarding implementation and financing prior to the permit application.
  - Correct implementation of markings and signage for improved legibility.
- Optimisation of intersections Scheldelaan x R2. For example, providing additional waiting lanes at the Scheldelaan x R2-East intersection.

18.2.5.2 Operational phase

During the operational phase, the following mitigating measures are considered necessary or desirable:

- Further initiatives to encourage cycling, public transport, carpooling, etc., with a view to achieving a more sustainable modal split for commuting. By way of comparison, reference is made to the modal split that applies to commuting in Flanders. 60% use the car as drivers, while according to conservative estimates, this will still be 64% under Project One. In order to achieve the 60% target, various initiatives are being further studied:
  1. Implementation of a mobility budget
  2. Roll-out of carpooling platform
  3. Organisation of awareness campaigns
  4. Encouraging the use of the Ibus
- Monitoring of modes and use of parking spaces, with the option of adjusting available spaces in favour of more sustainable modes.

- Securing the Vesta entrance (with a different intersection configuration) to improve clarity and road safety.
- Separation of motorised traffic and active road users on company sites.
- Correct implementation of markings and signage for improved clarity.
- Optimisation of intersections Scheldelaan x R2. For example, providing additional waiting lanes at the Scheldelaan x R2-East intersection.

18.2.5.3 Cumulative effects and development scenarios

Elia and Waterlink utility works

In order to mitigate the cumulative effects of the Elia and Waterlink utility works, the following measures are considered desirable:

- Limit construction traffic from the Antwerp and Flanders regions. This will be communicated during contract negotiations, in order to provide as much group accommodation as possible to the north or west of the site.
- Allow site traffic to also arrive from the north (A12 – exit 11 Zandvliet – northern part of Scheldelaan).
- Focus on passenger transport by water, for example with the Waterbus or private initiatives.

Oosterweel development scenario

To limit the expected disruption during the works on the Antwerp Ring Road and Oosterweel, Lantis is working on a comprehensive disruption reduction plan. This plan is mainly based on offering alternatives to private car traffic, for example by further expanding bicycle networks, increasing the number of park-and-ride facilities in the wider Antwerp area, and optimising and expanding public transport services. In this way, Lantis hopes to remove around 1,500 PAE from the main road network during the construction phase, so that the available capacity is sufficient during that period.

However, the current Less Nuisance Plan is not yet finalised, so it is not yet 100% certain what will and will not be implemented.

Desirable/necessary measures:

- Focus on collective transport for all employees during construction. This includes carpooling, use of Waterbus/I-bus/Bicycle bus, etc.
- Connect to the P&R facilities being built by Lantis as part of the Oosterweel project. These will be located in interesting locations in the wider vicinity of Project One. IOB can deploy additional shuttle buses from these parking areas to further limit individual passenger traffic to the site.
- Restrict construction traffic via the Antwerp region and the Antwerp main roads (R0, A12, R2).
- Avoid the Tijsman Tunnel during the construction phase by routing construction traffic via complex 11-Zandvliet and Scheldelaan.
- Focus on passenger transport by water, for example using the Waterbus or other initiatives.

18.2.6 Biodiversity

Given that the project will have a significant negative impact in terms of habitat and ecotope loss, fragmentation and barrier effects within the discipline of biodiversity, various mitigating, compensatory and restoration measures will be applied.

The compensatory measures only relate to forest compensation. Compensatory measures under Article 36ter of the Nature Decree, which are linked to the impact on European protected habitats and species, are not addressed here.

Throughout the project, all mitigating measures have already been integrated into the project and will therefore be implemented by the initiator in any case. The application of these project-integrated measures will mitigate the significant negative effects. Only in the case of ecotope and biotope loss does a significant impact remain, mainly at the local level, due to the fact that a contiguous area of ecological value will disappear permanently. Below is a summary of the various measures that contribute significantly to mitigating certain aspects, such as the impact on species.

In Project One, BBT is applied in the furnace technology and boilers, as well as SCR NOx reduction on the chimneys.

18.2.6.1 Construction phase

Prevention of protected species during the works

During vegetation removal, checks were carried out to ensure that there were no nesting birds present, and measures were taken to prevent birds from settling on the site.

In the case of temporary soil storage, care will be taken to ensure that it is unsuitable as a breeding habitat for cavity-nesting species such as the sand martin. In other words, vertical walls will be avoided.

Project One will set up a single nesting site so that sand martins can breed on the site. This nesting site will be placed in a location that is not essential for further levelling work. This will provide a temporary breeding site for sand martins. Where possible, consideration will also be given to whether this breeding site can be maintained in the long term.

Avoiding vertical walls is a necessary mitigation measure that has already been incorporated into the project.

Legally required forest compensation

The project resulted in the loss of approximately 39.31 hectares of forest, of which 14.245 hectares were older than 22 years. As mentioned above, taking into account a compensation factor of 2, this requires forest compensation of 28.49 hectares.

The deforestation has already been fully carried out (2022) and was licensed, including forest compensation.

➔This is a legally required compensatory measure.

Measures against colonisation by Japanese knotweed

Japanese knotweed is not currently present in either project area. To prevent Japanese knotweed from being introduced when soil is brought in, strict instructions will be included in the specifications for contractors that no soil originating from land with Japanese knotweed may be brought in at any time.

➔This is a necessary mitigating measure, which has already been incorporated into the project.

Measures for Annex I (category 2) bird species of the Species Decree

Several birds listed in Appendix I, category 2, of the Species Decree have been observed within the project area. The habitat of these species is not protected under the Species Decree. The works were carried out outside the breeding season and therefore no prohibited actions were taken. To mitigate the impact on these species, a number of restoration measures are proposed.

With regard to birds, it should be noted that the works were started before the breeding season and continued without interruption. Consequently, there was no deliberate disturbance, and breeding birds are no longer present. No exemption from the Species Decree is therefore requested for birds.

For most of these species, new habitat will be created at the location where 3 hectares of mixed (thorn) scrub was planted and at the forest compensation areas. A number of species can remain partially in place after completion of the project (e.g. black redstart, oystercatcher).

Restoration measures within the framework of the Species Decree

In order to mitigate the impact of vegetation removal on the Annex I category 1 species of the Species Decree, a series of restoration measures were implemented. An exemption was requested and obtained for this purpose under the Flemish Government Decree of 15 May 2009 on species protection and species management.

These measures were imposed as mitigating measures in the project EIA:

- Bee orchid and greater butterfly orchid: translocation within the Antwerp Port Area;
- Blue-winged grasshopper: no restoration measures required. This species can continue to develop on the 36 hectares of poor grassland that will be developed in the harbour;
- True centaury: ecological management of existing and new ecological infrastructure;
- Reindeer moss (Cladonia): development opportunities provided on the current sites through ecological management of open areas between the installations;
- Natterjack toad: creation of suitable breeding water and adjacent land habitat in the ecological infrastructure of the Port of Antwerp and on the company's own site in the administrative zone along Scheldelaan (deepened wadis).

Restoration measures in the context of the ban on vegetation modification

Restoration measures were taken to compensate for the loss of sea buckthorn scrub and reed vegetation. The reed vegetation is being restored on site. To compensate for the loss of 1.07 hectares of pure, free-standing sea buckthorn scrub, nature restoration measures are being taken, in particular the planting of 3 hectares of thorny scrub in the port of Antwerp.

Sea buckthorn scrub

Three hectares of native and mixed thorny scrub will be planted, consisting of hawthorn, wild privet, dog rose, wild rose, dune rose, creeping willow and blackthorn. The native (thorny) scrub provides much more biodiversity than the current vegetation or the planting of sea buckthorn alone. The area where the planting will take place is the cadastral parcel known as Antwerp, division 20, section A, number 1D2. This zone is part of the Flemish Ecological Network, which is why a VEN exemption was requested and obtained for this activity.

➔This is a legally necessary measure.

Reed vegetation

As part of nature restoration, efforts will be made to preserve the reed vegetation on the site as far as possible. If this proves impossible, an area will be set aside on the site for spontaneous reed growth or planting.

Restoration measures for the loss of pioneer vegetation with characteristics of poor grassland

Since the required 224 hectares of poor grassland that must be created as part of the Port of Antwerp Species Protection Programme is not yet available, a number of targeted measures will be taken within the port's existing ecological infrastructure or in new areas as an extension of the ecological infrastructure, as part of measures within the Port of Antwerp SBP.

This will create a total area of 36.25 hectares by converting existing, less valuable vegetation into ecologically valuable poor vegetation. An overview of the cadastral parcels, owners and commitment statement will also be added to the environmental permit. In mutual consultation between the port authority and the initiator, it was agreed that the port authority will additionally manage 7 hectares of grassland ecologically throughout the Port of Antwerp.

These 7 hectares concern an area along Scheldelaan, which contributes to a robust network of nutrient-poor grasslands and the communities that live there. In addition, ecological management is still carried out on the remaining plots on both the left and right banks.

The areas eligible for this are: Grote Kreek, Kuifeend railway zone, Zouten – Stocatradijk, Groot Buitenschoor, Scheldelaan, Sigmadijk.

Ecological management of pipeline corridor

In order to mitigate the effects of fragmentation and barrier action, the strip of land located in the southern part and owned by the Port of Antwerp will be managed ecologically so that it can retain and strengthen its function as an ecological connection.

Principles of good lighting

In view of light-shy bat species that fly and migrate along the Kanaaldok, care must be taken when installing lighting to ensure that the Kanaaldok is illuminated as little as possible.

The principles of good lighting must be applied during both the construction and operational phases:

- Respect the 20° rule;
- Completely avoid direct upward light flow by applying the principle of downward light flow;
- Limiting reflected upward light using the principle of minimum target area and the principle of minimum luminance with maximum uniformity.

Noise and emissions

The following measures have already been integrated into the project (to limit NO2 emissions and noise pollution):

- The use of Stage IV or better vehicles/machines for all medium-duty and heavy-duty vehicles/machines (from 56 to 560 kW), which corresponds to types from 2014 or later.
- Approximately three quarters of the vehicles/machines used fall into this category.
- For the lighter types (below 56 kW), there is little or no difference depending on the age of the machines. These are only subject to stricter emission requirements from Stage V onwards (types from 2019-2020).
- The use of less strictly regulated diesel generators of the heaviest type (> 560 kW) is excluded. Stage IV or better will be used for all types of machines, including diesel generators (< 560 kW).

Reference is also made here to other mitigating measures in the disciplines of Water, Air and Noise, which will also have a mitigating effect in nature areas/nature receptors.

18.2.7 Landscape

Given the size of the infrastructure, safety considerations and the limited space available for mitigating measures, it is not easy to provide for mitigating measures. Furthermore, the context of the port landscape means that mitigating measures are less necessary in this case. For these reasons, no mitigating measures are proposed from the perspective of Landscape, Architectural Heritage and Archaeology.

For the mitigating measures in the field of archaeology, reference is made to the additional studies described in the archaeology memorandum and to the accompanying Programme of Measures that was drawn up.

18.2.8 People

18.2.8.1 Construction phase

Project-integrated measures

- Use of Stage IV or better vehicles/machines for all medium and heavy vehicles/machines (from 56 to 560 kW), which corresponds to types from 2014 or later.
  - Approximately three quarters of the vehicles/machines used fall into this category.
  - For the lighter types (below 56 kW), there is little or no difference depending on the 'Stage' of the machines. These are only subject to stricter emission requirements from Stage V onwards (types from 2019-2020).
  - The use of less strictly regulated heavy-duty diesel generators (> 560 kW) is excluded. Stage IV machines or better will be used for all types of machines, including diesel generators (< 560 kW).
- Where possible, transport will be planned using ships instead of lorries. This is the case for most land transport and for the supply of the largest plant components (modules) and equipment.
- For recommendations regarding light pollution, please refer to § 18.2.8.2.

Additional measures

Based on the impact assessments, additional measures are not considered necessary.

18.2.8.2 Operational phase

Project-integrated measures

Emissions reduction measures for NO_2 were integrated into the project. These are described in Chapter 7 Air. SCR De-NOx gas purification is provided on eight chimneys to reduce NOx emissions. As a result of the use of SCR De-NOx gas purification (technology that goes far beyond BAT), emissions will be much lower than the emission levels associated with BAT. The contribution of Project One alone is therefore limited, but since 80% of the GAW in Berendrecht is already exceeded as a result of other sources (industry, traffic, etc.), mitigating measures are desirable. The possibilities for further reducing emissions were investigated in Chapter 7 Air. It was investigated (see Appendix 6.4) whether NOx emissions could be further reduced by expanding the SCR catalyst beds and/or replacing them more regularly. However, the target concentration (guideline value 25 mg/Nm³ with SCR) is close to the technical limits of the SCR, so there are no guarantees that even lower emissions will be achieved. In addition, it appears that the additional investment and operating costs (increased pressure drop across the SCR catalyst; replacement of the catalyst, production shutdown, etc.) for more far-reaching measures are very high compared to the unit reduction cost of 8.6 EUR/kg NOx removed.

The negative assessment for NO_2 is determined, among other things, by the fact that even without implementation of the project, the health advisory value of 20 µg/m³ will be exceeded. If the health advisory value is exceeded, health effects may occur, but this will not always be the case. This also depends on the specific characteristics of the population concerned and other environmental factors (including environmental factors).

Under current conditions, the negligible risk level for benzene and butadiene has already been exceeded. The risk of exposure to ambient concentrations is not negligible in either the current or planned situation, but may be acceptable subject to social considerations. Mitigating measures are desirable in view of the assessment. The aim should be to achieve the lowest possible emissions in accordance with the ALARA or ALARP principle. Measures to limit emissions of volatile organic compounds have already been integrated into the project: to prevent and limit fugitive emissions, action is being taken in the areas of design, construction, commissioning, maintenance and monitoring. This means that technically sealed installation components are used in all parts of the installation where gaseous or volatile liquid product flows occur.

During construction, specialised, trained personnel are deployed to install flanges, valves, etc. correctly. Before the installations are handed over, leak tests are carried out and any leaks are repaired before the installations are put into service. In terms of monitoring, in collaboration with the specialised contractor, a combination of measurements at installation components (sniffing method) and the use of advanced infrared cameras (OGI = Optical Gas Imaging) is provided. With this approach, all aspects of BAT are applied.

Mitigation measures are also desirable for $PM_{2.5}$, given that the health advisory value is already being exceeded in the current situation. The dust emissions mainly originate from the decoking processes, as only gaseous fuel is used. Measures are being integrated into the project to limit these emissions (see § 18.2.2 in Chapter Air). For example, the decoking emissions from the ECR are limited by dust removal using cyclones.

The operation of the ECR tower flare may cause noise pollution, particularly in Lillo. As a (project-integrated) measure, ECR ground flares are also planned to capture residual gas flows during planned start-up and shutdown. As a result, the tower flare will only need to be used in exceptional circumstances and only in emergency situations.

In addition, IOB will actively communicate with local residents about planned activities (e.g. major maintenance activities, etc.) that could cause nuisance (time, duration, nature of the nuisance and reason) and, where appropriate, after incidents, about the cause, any consequences and the measures taken. To this end, IOB will join existing initiatives (Antwerp Port Advisory Council). IOB will also set up an informative website for local residents with a form for submitting questions and up-to-date information.

For both the construction and operational phases, it is recommended that lighting of tall structures be limited where possible and that the principles of good lighting be applied:

- Respect the 20° rule;
- Completely avoid direct upward light flow by applying the principle of downward light flow;
- Limit reflected upward light via the principle of minimum target area and the principle of minimum luminance with maximum uniformity.

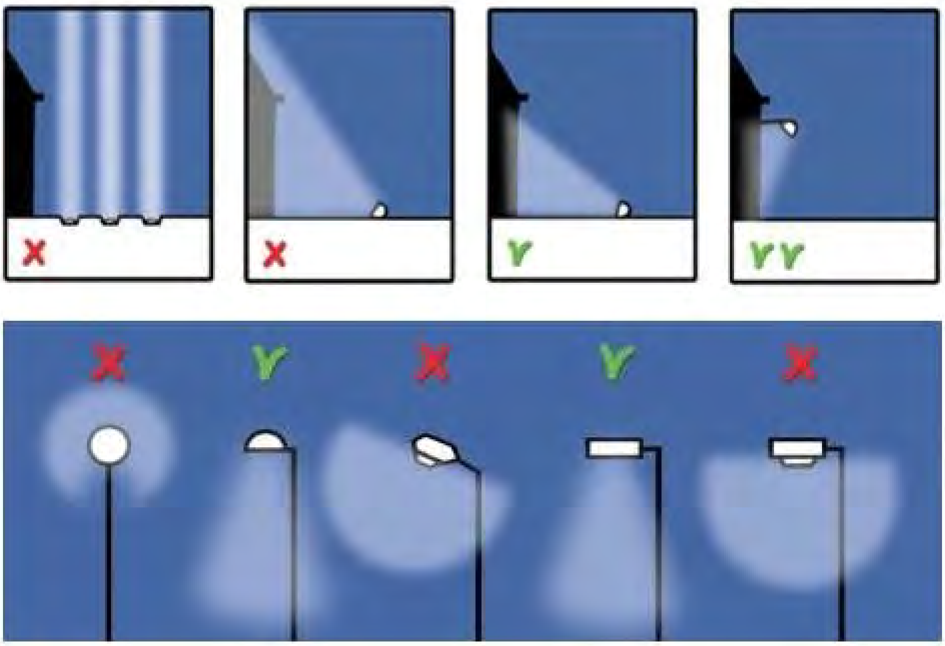

Figure 18-1: Tips for reducing light pollution

Additional measures

Based on the impact assessments, additional measures are not considered necessary.

18.2.9 Climate

18.2.9.1 Construction phase

Project-integrated mitigation measures

- The supply and removal of soil will mainly be carried out by inland waterway transport. This will limit CO2 emissions from the supply and removal of soil.

18.2.9.2 Operational phase

Project-integrated mitigation measures

Project-integrated mitigation measures for the operational phase of Project One are:

- The ECR is designed for selective and efficient ethylene production. Project One uses state-of-the-art technology for ethane cracking. Best available techniques (BAT) and energy integrations are consistently applied to achieve high energy and production efficiencies. Key process-integrated energy-saving and emission-reducing measures are applied in the design of Project One.
- Two power purchase agreements (PPAs) were concluded with energy suppliers Engie and RWE for the supply of green electricity (offshore wind energy) for a period of 10 years. This means that when Project One starts in 2026, external electricity demand will be covered by green electricity.
- Project One currently has three possible future prospects for further reducing the CO2 emissions of the ECR in the future:

  5. post-combustion CO2 capture technology or;
  6. a pre-combustion CO2 reduction technology with 100% green and/or blue hydrogen in the fuel gas supplied to the ECR or;
  7. a pre-combustion CO2 reduction technology with partial electrification of the ECR's cracking furnaces, with the rest of the furnaces operating on 100% hydrogen in the fuel gas.

  Project One has the necessary technological flexibility on the ethane cracking furnaces (ECR) and steam boilers for the first two scenarios. Sufficient space has been reserved in the project area for these scenarios, and the design already takes into account future retrofitting of the site and installations. Electrification of cracking furnaces, the third scenario, is currently still in the research and development phase and there is currently no established or cost-competitive technology. Electrification of the cracking furnaces can be evaluated once the technology is sufficiently developed. The three possible future scenarios will be the subject of further research as part of INEOS' roadmap to achieve net zero CO2 emissions. Project One is currently convinced that it is feasible to achieve net zero CO2 emissions within 10 years of the cracker's start-up, using one or more of the techniques described in this EIA.
- The administrative building is designed to be energy efficient. Passive techniques such as thorough insulation and passive solar gain, climate and lighting controls, and renewable energy techniques are integrated into the design. Under BREAAM, it achieves the third highest score on a scale of 1 to 5 (rating 'very good'). Given that the external electricity demand will be covered by green electricity, emissions from the administrative building will be eliminated.
- Ethane will be transported using efficient VLEC ships.
- Ethylene is transported via pipelines.
- In order to reduce the pressure on the city's water supply, it was decided to use an external supply of demineralised water. The water company involved uses brackish dock water as a raw water source, which reduces the pressure on the city's water supply. The use of demineralised water to replace city water means that Project One's city water consumption is reduced by approximately half.

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