North Sea Port

NSP PIPELINE FEASIBILTY STUDY

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[Included as separate document]

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1 NSP PIPELINE FEASIBILTY STUDY

1.1 BACKGROUND

1.1.1. Ammonia has been identified as an alternative energy source that can be used to power hard-to-abate sectors including chemicals, refining and other heavy industry. A number of these industries are concentrated in Western Germany. Dutch & Belgian ports are expected to serve as some of the main import terminals used to supply Western Germany with ammonia produced outside Europe. North Sea Port (NSP) and its stakeholders are therefore looking to better understand options of transporting ammonia from NSP to end users in Germany. In 2024, WSP was appointed by NSP to undertake a study on the feasibility constructing an ammonia pipeline that would connect Vlissingen Port with the planned Delta Rhine Corridor (DRC) at Moerdijk, with the ultimate objective of transporting ammonia to industrial users in Germany.

1.1.2. In the December 2024, the Dutch government announced the scope of the first phase of the DRC was being reduced to cover only hydrogen and carbon dioxide pipelines, which means alternative means of transporting ammonia from NSP to Germany are required. WSP has therefore been appointed by NSP to investigate alternative routes of transporting ammonia to Germany via Belgium.

1.1.3. The objective of the current study is to:

- Determine the technical feasibility of constructing pipelines from planned NSP ammonia terminal locations in Vlissingen and Terneuzen through Flanders, Belgium to Germany, connecting to existing or planned pipeline infrastructure around Antwerp;
- Undertake a comparative safety assessment of transporting ammonia using different transport modes; and
- Identify the ‘turning points’ at which transportation of ammonia using a newly constructed pipeline is more cost-effective than alternative transport modes (rail and barge transport).

1.1.4. This study has been produced by WSP, with support from external safety specialists AVIV.

1.2 OUR APPROACH

1.2.1. While the EU and European governments have ambitious targets for the uptake of ammonia, future demand and the size of market in the coming decades remains uncertain. The focus of this study is not the feasibility or practicality of using ammonia as an alternative energy source in the future. Instead, the purpose of this study is to assess and quantify the cost and safety implications of transporting ammonia between NSP and sources of demand in Germany using three different modes of transport – rail, barge, and ammonia pipelines.

1.2.2. To undertake this study, WSP and AVIV have drawn upon internal technical and industry expertise, undertaken a review of academic literature and industry reports, and consulted a number of industry stakeholders. Data and information sources are referenced throughout the document and stakeholders consulted as part of the study are shown in Table 1-1.

Table 1-1 - Stakeholders Consulted

Stakeholder Group	Stakeholder(s)
NSP Terminal Operators	• NSP Market Parties
NSP Stakeholders	• Smart Delta Resources • Province of Zeeland • NSP Rail & Barge Transportation Experts
Pipeline Operators	• Pipelink • Fluxys
Public bodies	• KGG (formerly EZK) and IenW, NL • FOD Economie, BE • Infrabel, BE • Departement Omgeving, Vlaanderen, BE

1.3 REPORT STRUCTURE

1.3.1. This report is structured as follows:

- Chapter 2 sets out the ammonia volume demand scenarios used within the assessment, as well as some of the practical and safety considerations for each transport mode;
- Chapter 3 sets out the approach used to quantify the ammonia transportation costs; and
- Chapter 4 summaries the economic feasibility assessment of the proposed ammonia pipeline.

1.3.2. Additional information on legislation, stakeholders, assumptions and detailed results is set out within the appendices to this report.

2 AMMONIA VOLUMES AND TRANSPORTATION

2.1 BACKGROUND

2.1.1. The objective of the European Green Deal is to reduce net greenhouse gas emissions by at least 55% compared to 1990 levels by 2030 (“Fit for 55”). The ultimate objective is achieving net zero by 2050. In order to reduce emissions, in many sectors much of the focus is on electrification and the use of renewable energy. However, for some energy-intensive industries alternative energy sources will be required. Potential alternative energy sources include hydrogen and ammonia, either directly or as a carrier for hydrogen.

2.1.2. Currently, the majority of ammonia consumed in Europe is produced locally, primarily from natural gas using grey hydrogen. However, as Europe transitions towards decarbonisation, there is a growing need for low-carbon and green ammonia, which will require significant imports from regions with abundant renewable energy. With its concentration of energy-intensive and hard-to-abate industries—including chemicals, refining, and steel production—Western Germany is an area of particularly high ammonia demand. Dutch and Belgian ports are practical and cost-effective locations from which to transport ammonia to Western Germany, due to their existing ecosystems, infrastructure, and proximity to German industrial clusters. In the future, these ports are expected to play a crucial role as import hubs for low-carbon and green ammonia, supporting the decarbonisation of Western Germany’s industrial sector.

2.1.3. An industry study[1] presented to the Dutch House of Representatives in 2023 states that in order to achieve European Green Deal and Fit for 55 targets ammonia, significant exports to Germany from the Netherlands are required, potentially reaching 20 million tonnes by 2030 to 2035. The vast majority of this ammonia would be imported to Europe through Dutch ports. While these ambitious targets may not be fully realised, the industrial demand for hydrogen and ammonia in Germany, and the volumes that will need to be transported from Dutch ports, are expected to increase significantly.

2.1.4. In order to meet the demand for hydrogen and ammonia in Germany, a number of industry stakeholders (BASF, Gasunie, OGE and Shell) signed an agreement to coordinate the development of the Delta Rhine Corridor (DRC). However, given the recent announcement from the Dutch government that initial focus of the DRC will be hydrogen and carbon dioxide, alternative means of ammonia transport will be required from Dutch ports to the German industrial hinterland.

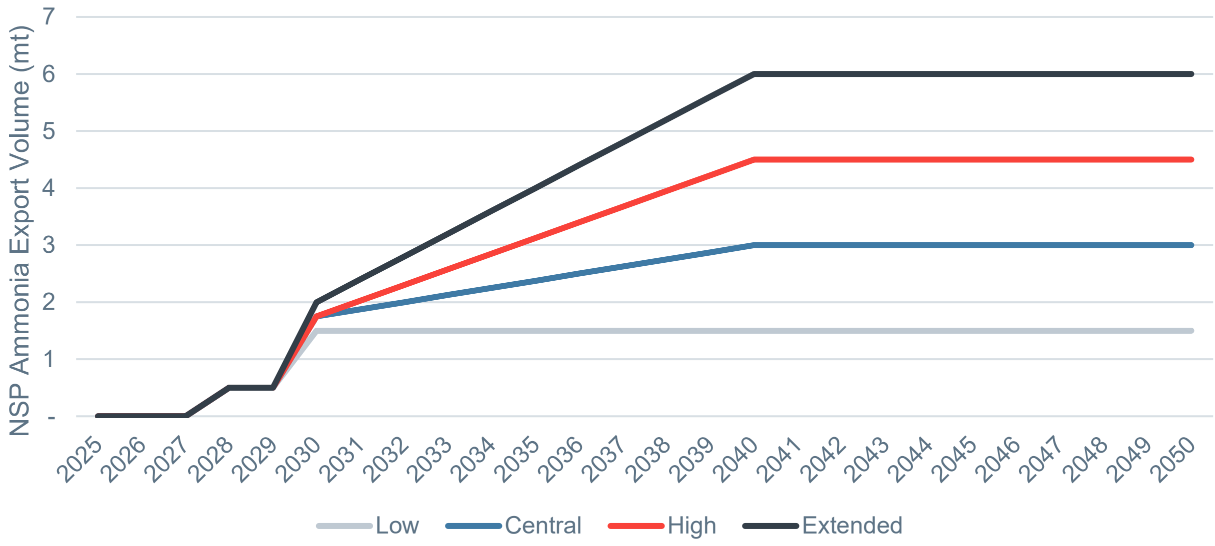
2.2 NSP AMMONIA VOLUMES

2.2.1. The Port of Rotterdam is expected to account for the majority of ammonia imports to the Netherlands; however, operators are also planning to construct ammonia storage capacity at NSP that will allow the import and onward transportation of ammonia.

2.2.2. The volumes of ammonia exported from NSP to Germany that are used in this study to calculate the transportation costs are projected across four scenarios shown in **Figure 2-1**, across all the scenarios, volumes increase gradually and reach a final steady-state level from 2040 onwards.

[1] Omgevingsveiligheid van toekomstige stromen waterstofrijke energiedragers (2023)

Figure 2-1 - NSP ammonia export volume scenarios (2025-2050)



Source: NSP & NSP stakeholders, WSP analysis

2.2.3. The four scenarios have been provided by NSP and are based on NSP terminal operators' planned ammonia storage capacity at NSP, an assumed level of throughput based on storage capacity volumes and the proportion of total ammonia throughput that is transported to Germany. All scenarios assume two thirds of ammonia volume is transported from Vlissingen and one third is transported from Terneuzen (except the low scenario which assumes a 50-50 split).

2.2.4. Based on consultation with NSP stakeholders, we have assumed that all ammonia exported from NSP is transported to Gelsenkirchen, unlike WSP's 2024 which assumed 25% is transported to Karlsruhe and reflected the location of operations of key DRC stakeholders. All discussion of transportation equipment and infrastructure requirements in the remainder of this chapter are based on the maximum 2040 volume level in the central scenario of 3.0 million tonnes.

2.3 EXTERNAL SAFETY ASSESSMENT

EXTERNAL SAFETY ASSESSMENT SUMMARY

In the Netherlands, external safety for ammonia transport is tightly regulated under the Environment and Planning Act. The key concern is location-specific risk, which must not exceed a 1 in a million annual probability of fatality for vulnerable buildings—if this threshold is breached, permits cannot be granted. Risk contours are calculated using the SAFETI-NL tool, and societal risk is also assessed, though it does not carry legal weight. The use of the crater model, now strongly recommended by the Dutch authorities, has widened risk contours compared to previous assessments. This model simulates crater formation and vertical gas release following a pipeline rupture, making safety assessments more conservative.

For high and extended volume scenarios, two smaller-diameter pipelines are proposed in this study instead of one large pipeline. This approach is chosen to comply with safety requirements and minimise the impact in case one pipeline fails. It is also noted that additional pipes of the same diameter and carrying the same volume do not imply larger risk contours, and therefore have no implications from a safety perspective when assessed using the crater model. While societal risk helps inform route selection, only location-specific risk directly affects pipeline permitting.

In Belgium, external safety legislation is less centralised and varies by transport mode. For pipelines, a risk analysis is required for permit approval, but toxic substances like ammonia are not yet formally included in the technical code. As a result, ammonia pipeline assessments follow standards for flammable and oxidising substances, with risk thresholds set at 10^{-5}/yr within 10 metres of the pipeline (or 4 metres for low-pressure lines) and 10^{-6}/yr in residential areas beyond that. No residential objects are permitted within the 10^{-6} contour, aligning with Dutch standards.

From 2025, new civil code provisions introduce non-contractual liability, meaning pipeline operators and subcontractors can be held directly responsible for safety failures, even without formal contracts. Barge transport through Belgium has not been considered in this study due to infrastructure limitations.

2.3.1. Transporting ammonia has safety implications, though the relevant legislation and guidance differs within the Netherlands and Belgium (Germany has not been considered as part of this study).

THE NETHERLANDS

Within the Netherlands, there are three ways to calculate the external safety risks:

- Focus area (not in scope);
- Societal risk; and
- Location specific risk.

2.3.2. Where applicable, calculations have been made for each transport mode routing, based on applicable legislation and prescribed methodologies – these are described in more detail in Appendices C, D and E.

2.3.3. The transport of the additional ammonia (based on the volume scenarios above) is assessed against a projected ‘baseline’ amount of ammonia and other hazardous goods, consistent with the Reconnaissance Transport of Hazardous Substances[2] report.

Focus Areas

2.3.4. The focus areas for Basisnet routes (the waterways and railways) are specifically made for spatial planning to see what kind of effects (fire, explosive or toxic) are possible and which effects should be taken into account up to what distance. For rail and barge these are fixed distances. These distances are always the same, regardless of the type of dangerous substance or the number of transports.

2.3.5. For pipelines the focus areas need to be calculated and are effect based. The probability of an incident occurring is not considered. The amount of dangerous goods that can be released in case of an incident determines the result, which means the distance of focus areas do not change with a different throughput or route.

[2] Verkenning vervoer gevaarlijke stoffen

2.3.6. The focus area is therefore not a good tool to compare different modalities, routes or throughputs and is therefore not used for calculations to compare the risks of the different routes within this assessment.

Societal Risk

2.3.7. In previous legislation societal risk was used to determine the risk of a societal disruption. No limit value has been established for the societal risk. This risk must be justified in relation to the environment and possible societal disruption. The societal risk is calculated per route kilometre and can be used to compare different routes, different modalities and different throughputs. Although the societal risk level has no necessity or consequence for routes (in terms of legislation or permitting), it can be used to make a well-founded quantitative based decision for which modality and route is preferred from a risk point of view.

2.3.8. For each transport mode and route a societal risk calculation has been made at one location on the route. The locations are within big cities with dense populations and are the points of highest societal risk along each route.

2.3.9. Societal risk calculations therefore may to lead to the requirement for additional justification or measures to be taken for new infrastructure or transport routings, but do not have direct implications for permitting decisions.

Location specific risk

2.3.10. The location specific risk is to ensure that individual persons are not subjected to a high risk of death from an accident involving dangerous goods, and applied along the whole transport route. Location specific risk contours become larger when more goods are transported. For rail and water transport the location specific risk contours are not part of the permitting process as permitting only applies when constructing new rail or waterway infrastructure.

2.3.11. However, the location specific risk contours are part of the permitting process for pipelines, because it would be new infrastructure. The location specific risk cannot be higher than 1 in a million per year for vulnerable objects such as houses or office buildings. If the risk is higher than this, the permit cannot be issued.

2.3.12. For each transport mode route, the location specific risk contours have been calculated. To properly compare the different routes and modalities the number of objects within the location specific risk contour for $10^{-6/}$yr have been quantified and compared.

2.3.13. Only location specific risk has implications for the permitting of new infrastructure, so it is only relevant to transportation by pipeline. Rail and barge transport use existing infrastructure.

Pipeline Crater Model

2.3.14. For external safety assessments of pipelines, for each of the risk categories described above, RIVM recommends (but does not require) the use of a crater model in the safety calculations using the risk tool SAFETI-NL.

2.3.15. The outflow of a pressurised liquefied gas from underground pipelines in the event of rupture is accompanied by the formation of a crater and a vertical outflow of the pressurised liquefied gas. Using SAFETI-NL without a crater model does not take into account entrainment of air as a result of the crater and the extent to which air is mixed in the crater when pressurised liquefied gases are released is not known.

2.3.16. RIVM states that the crater model allows for a better assessment and mapping of pipeline safety risks, as it takes account of the entrainment of air the (reduced) discharge velocity resulting from a crater formed by a rupture of an underground pipeline. As a result, the use of the crater model leads to considerably larger risk contours when assessing the transportation of hazardous substances in pipelines.

2.3.17. As is set out in more detail in a previous study, the results external safety assessment for the pipelines are highly dependent on whether a crater model is used.

BELGIUM

2.3.18. Unlike the Netherlands, in Belgium there is no consistent legislation governing the external safety of the transportation of hazardous substances and specific legislation varies by transportation mode. As part of this study, we have not considered barge transport through Belgium (for reasons described below) and there are no legal or safety assessment requirements relating to the transportation of hazardous goods (including ammonia) by rail through Belgium as long as operations, infrastructure and equipment are Regulations concerning the International Carriage of Dangerous Goods by Rail (RID) compliant.

2.3.19. For pipelines, the requirements use a similar approach as the location specific risk within the Netherlands and seek to ensure that individual persons are not subjected to a high risk of death from an accident involving dangerous goods applied within defined contours around the pipeline.

2.3.20. The relevant legislation states a risk analysis for the relevant hazardous substance must be undertaken in order for a permit to be provided. However, toxic hazardous goods (including ammonia) are not yet included in the code, which means risk analysis of ammonia pipelines is based on the requirements for flammable and oxidizing goods.

2.3.21. Therefore, based on these requirements, for ammonia pipelines the risk of death may not exceed 10^{-5}/yr within 10 metres of the pipeline (4 metres for pipelines with pressure under 16 bar) and may not exceed 10^{-6}/yr within residential areas beyond this distance. Within the 10^{-6}/yr contour, no residential objects are permitted, equivalent to the vulnerable objects under the Dutch legislation.

2.4 TRANSPORTATION MODES

TRANSPORTATION MODES SUMMARY

Rail

Rail transport of ammonia from North Sea Port (NSP) to Germany is technically feasible via existing infrastructure in both the Netherlands and Belgium, but faces significant operational, safety, and political constraints. Two routes—via Vlissingen and Terneuzen—have been assessed in consultation with Infrabel, with the Terneuzen route preferred due to its shorter distance, lower societal risk, and absence of vulnerable buildings within risk contours.

In this study, the analysis is based on 25 wagons per block train (aligned with the May 2025 hydrogen carriers study) Based on this, to move 3 mtpa would require 7–8 daily block trains, or 2,500–2,900 trains per year, and a dedicated fleet of approximately 1,250 RID Class 2 wagons.

Infrastructure constraints are significant. Vlissingen's Sloehaven yard has limited shunting and departure capacity, and Terneuzen's Dow track infrastructure can only accommodate 1–2 additional daily trains. Wider network bottlenecks in both countries—especially around Ghent and

Terneuzen—remain unresolved since a 2018 study, and no major upgrades have occurred since. Terminal loading capacity is also a limiting factor, with current operations supporting 300 trains annually from Terneuzen and 900 from Vlissingen, enabling a combined throughput of 1.5 mtpa.

While no new permitting is required, current and projected volumes exceed Basisnet thresholds. The Dutch government has stated that increasing ammonia rail volumes is undesirable and less preferable than barge or pipeline transport. Therefore, while both routes are technically feasible, only Terneuzen appears politically and spatially more acceptable for future expansion.

Inland Shipping

Inland shipping is the most politically acceptable and safest mode for ammonia transport within the Netherlands, though routes through Belgium have been excluded in this study due to infrastructure limitations. The selected route uses Class 6 waterways suitable for large Type G tanker barges, which meet ADN safety standards and typically carry up to 2,000 tonnes of ammonia per trip. To transport 3 mtpa, approximately 1,500 barge trips per year are required, supported by a dedicated fleet of 29 vessels operating weekly round trips.

While ammonia is currently transported using pressurised tankers, there may be a future shift towards refrigerated tankers, which offer safety benefits and are expected to incur only marginal additional costs due to ammonia's relatively high liquefaction point of –33°C. However, competition for vessels and trained crews—particularly from other commodities and ports like Rotterdam—means crew shortages may pose a challenge to scaling up inland shipping capacity.

Safety assessments show no vulnerable buildings within risk contours, and societal risk remains well below guideline levels, indicating that inland shipping is unlikely to face safety-related permitting restrictions. Providing there are sufficient vessels available in the future, it does not appear waterway capacity will act as a constraint, though congestion around inland ports—with wait times of 20–30 hours—and seasonal water level fluctuations on the Rhine are likely to continue to act as constraints in specific areas and at specific times.

Despite these operational challenges, inland shipping remains a preferred mode over rail, though less scalable than pipeline transport for long-term volumes.

Ammonia Pipeline

Pipeline transport is the most scalable and cost-effective solution for high-volume ammonia movement, particularly above 1.5 million tonnes per annum (mtpa), but faces safety, permitting, and infrastructure challenges in both the Netherlands and Belgium. In the Netherlands, new pipelines must follow designated SvB corridors under the Main Energy Structure Programme (PEH), with eligibility based on national importance. This study assumes a MUK (Multi Utiliteiten Kruising) tunnel for ammonia under the Schelde delta to connect Vlissingen and Terneuzen, allowing a single ammonia pipeline inland to serve both ports.

Several routing options were assessed, with the Sluiskil route from Terneuzen through the Netherlands identified as the only option that meets safety requirements under the low-volume scenario.

Pipeline development will take several years and faces permitting complexity, stakeholder coordination, and potential construction bottlenecks. Additionally, pipeline transport is only viable for end users located along the corridor, meaning rail and barge transport will remain essential in the medium term to establish supply chains and serve dispersed demand. Despite these permitting and infrastructure challenges, pipeline transport remains the most scalable and preferred mode for long-term ammonia volumes, though it requires significant upfront investment and regulatory certainty.

2.4.1. For each of the three transport modes, the remainder of this chapter discusses the transport equipment and infrastructure required to transport 3.0 million tonnes of ammonia and discusses some of the potential constraints at a high level. A more detailed assessment and quantification of transport constraints would require further investigation and/or consultation with NSP terminal operators.

RAIL

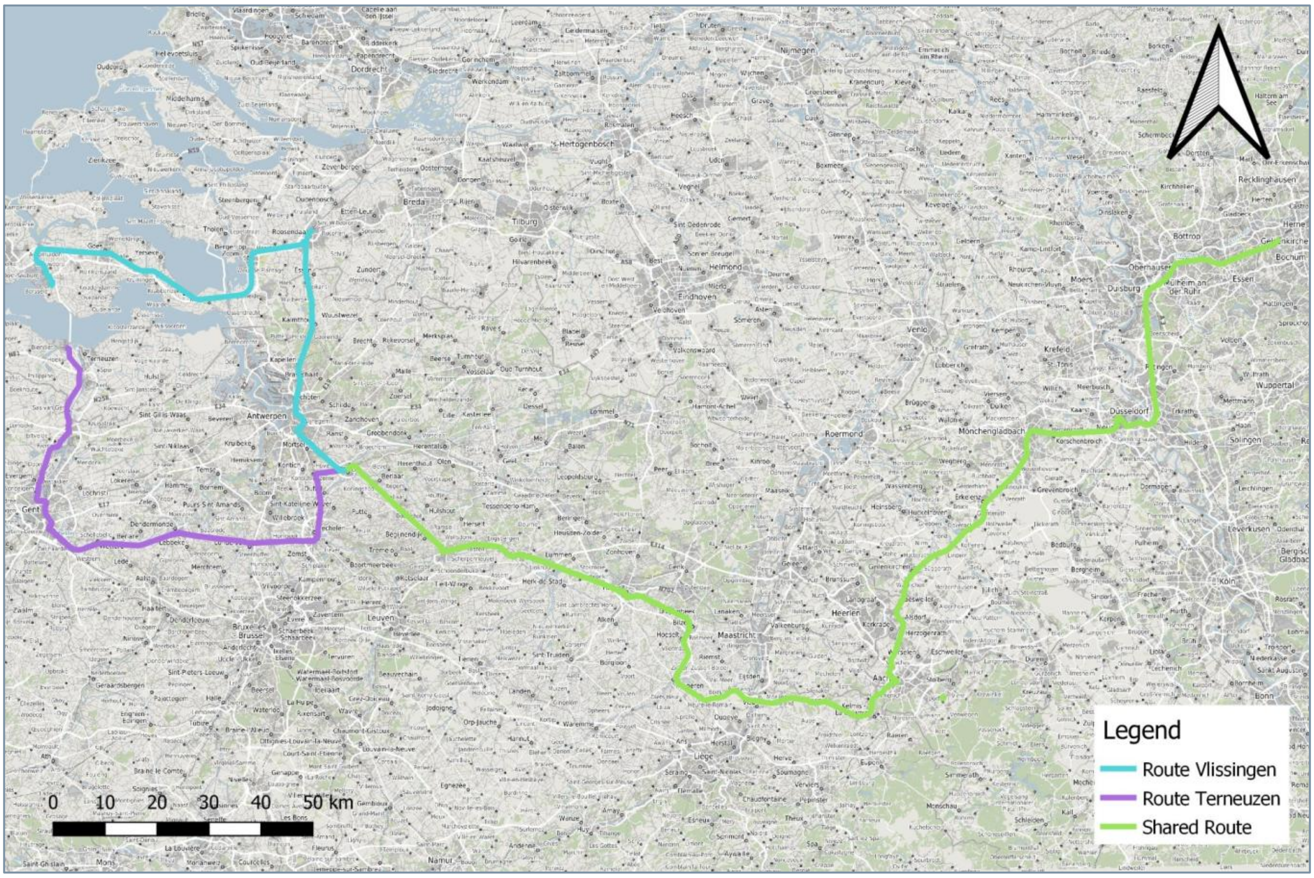
Routing

2.4.2. To get freight from NSP to Gelsenkirchen through Belgium by rail, two routes have been considered; one route from Vlissingen and one Terneuzen, which use the same route east of Antwerp. The routes have been chosen based on consultation with Infrabel on the most appropriate routing through Belgium.

2.4.3. Infrabel also confirmed a standard route for freight trains from Gent-Zeehaven towards Germany, which runs slightly south of the Antwerp–Germany route. This route includes key waypoints such as Gent-Dampoort, Mechelen, Leuven, Tienen, Waremme, Visé, and continues via Montzen towards Germany.

2.4.4. Along each route one city is chosen to calculate the societal risk for comparison of the three routes. The choice for a particular city is based on the highest expected societal risk.

Figure 2-2 - Rail transport routes



Source: AVIV, WSP analysis

Equipment

2.4.5. Using freight trains, liquid bulk is transported using either specialised tank wagons (i.e. liquid bulk wagons with their own axels) or standardised intermodal ISO tank containers loaded on flat wagons, and according to Regulation concerning the International Carriage of Dangerous Good by Rail (RID)[3], ammonia must be transported in RID Class 2 tank wagons or T50 ISO tank containers.

2.4.6. Tank wagons and tank containers generally have a total capacity of 70 and 30 tonnes of ammonia respectively and according to the PtX Hub[4] are generally filled to between 57% and 85% of total capacity to avoid problems with thermal expansion. The mid-point filling capacity of 71% gives a tank wagon capacity of 50 tonnes ammonia and a tank container capacity of 22 tonnes – these are the capacities we have assumed within this study.

2.4.7. While there are multiple specifications of tank wagons and flat wagons, for the purposes of this study we have assumed a standard wagon length of 16.5 metres for both tank and flat wagons, based on Union of Railways (UIC) ordinary two-axle wagons. Based on ProRail[5] requirements, the maximum permitted freight train length in the Netherlands is 740m, though is 650m when crossing the border in Germany at Venlo. Within Belgium 640m is the maximum standard length, with special permission required for 740m trains (which are only permitted in non-peak hours).

2.4.8. Based on consultation of NSP market parties and the track infrastructure at the port, the maximum train length for trains loading at NSP is closer to 400m (though this will vary by terminal). For this study we have assumed an average train length of 440m (assuming a 20m locomotive wagon), equivalent to 25 wagons (consistent with the assumptions within the May 2025 study[6] for the Province of Zeeland on hydrogen carries), lower than the 650m assumed within the 2024 study.

2.4.9. Therefore, to theoretically transport 3.0 million tonnes of ammonia would require 60,000 annual tank wagon loads or 140,000 annual tank container loads leaving NSP per year, which translates to 15 daily trains fully loaded with tank containers or 7-8 daily dedicated block trains with tank wagons (4 to 5 from Vlissingen and the remainder from Terneuzen).

2.4.10. Assuming a round-trip time of one week implies a dedicated fleet of 1,250 RID Class 2 tank wagons would be required. The ERA[7] reports there are approximately 16,500 tank wagons registered in the Netherlands, and based on UIP[8] fleet figures, approximately a quarter of European tank wagons are RID Class 2 compliant (which would imply a fleet of c. 4,000 tank wagons registered in the Netherlands). Using tank containers, a round trip of a week implies a dedicated fleet of c 6,000 containers; the number of operational T50 containers is not readily available, though ITCO[9] reports there are over 115,000 tank containers registered in the Netherlands.

2.4.11. Market parties have indicated that block trains typically consist of 18–25 wagons. NSP's position is that rail will need to become more efficient in the future, and therefore we have retained the

[3] RID
[4] Ammonia Transport & Storage (2024)
[5] Network Statement 2025
[6] Omgevingsverkenning Waterstofdragers Zeeland
[7] ERA Railway Factsheets
[8] UIP Fleet Figures
[9] Global Tank Container Fleet Survey 2024

assumption of 25 wagons per block train for this study. If the number of wagons were reduced to 20, rail capacity would fall from 1.5 MTPA to 1.2 MTPA, which would increase reliance on barge transport in the mix and constrained allocation scenarios.

2.4.12. While there will be competition for these wagons from other rail freight corridors and commodities, the transportation of ammonia from the Netherlands to Germany can also draw upon the large tank and rolling stock fleets of neighbouring and destination countries (particularly Germany) and units to be built in the future to meet demand from transport operators to alleviate potential equipment shortages.

2.4.13. While ammonia can be transported by rail will using both tank containers and tank wagons, when consulted as part of this study, market parties stated that transportation of ammonia will only be viable using block trains if it is to compete with barge transport in terms of cost, volumes and reliability. As part of this study, we have therefore assumed all ammonia transported by rail uses block trains (in the 2024 study a mix of block trains and tank containers was assumed).

Infrastructure

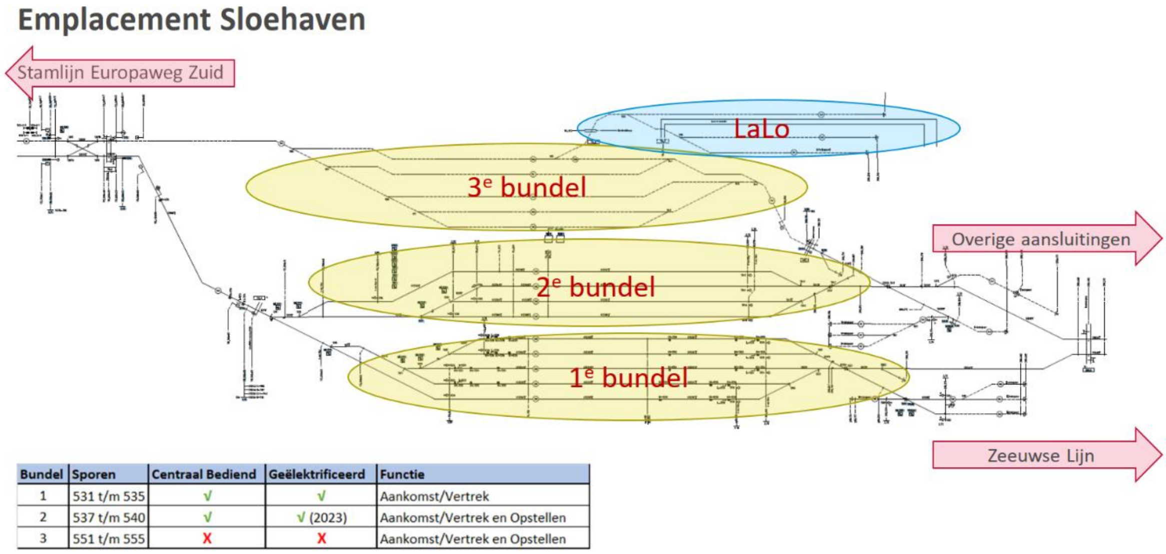
Vlissingen

2.4.14. As part of this study, NSP shared a study[10] undertaken by ProRail in 2023 on the capacity of the rail handling facilities at NSP's Sloehaven (Vlissingen) facilities. In 2022, there were c. 2,500 freight trains arriving and departing Sloehaven (equivalent to 2-3 daily departing trains), down from over 3,000 in 2018 (over 4 daily departing trains). The track infrastructure at Sloehaven is shown in the figure below and is as follows:

- Bundle 1 – 5 electrified tracks used for arriving and departing trains.
- Bundle 2 – 4 tracks electrified in 2023 and used for arriving and departing trains, having previously being used for shunting prior to electrification.
- Bundle 3 – 5 non-electrified tracks used for shunting, with 1 track needing to kept clear at all times for through access to the LaLo terminal.
- A planned Bundle 4 – 4 or 5 non-electrified tracks to be used for shunting.
- A planned 'Maltaweg' yard – 4 non-electrified tracks to be used for shunting.

[10] Capaciteitsanalyse emplacement Sloe Maltaweg (ProRail, November 2023)

Figure 2-3 - Sloehaven Rail Infrastructure



Bundel	Sporen	Centraal Bediend	Geëlektrificeerd	Functie
1	531 t/m 535	√	√	Aankomst/Vertrek
2	537 t/m 540	√	√ (2023)	Aankomst/Vertrek en Opstellen
3	551 t/m 555	X	X	Aankomst/Vertrek en Opstellen

Source: ProRail[11]

2.4.15. Based on ProRail's market expectations for 2040 (and using the high-end projections), there will be up to 26 daily arriving and departing trains in Sloehaven, which will require:

- Up to 11 arrival/departure tracks, which implies the current 9 arrival/departure tracks can accommodate 21 daily arriving and departing trains, or daily 10-11 departing trains.
- Up to 19 shunting tracks, assuming dwell times remain at 2022 levels and all of Bundle 2 is used for arriving and departing trains, which implies:
  - The current 4 shunting tracks in Bundle 3 can accommodate 5-6 daily arriving and departing trains, or daily 2-3 departing trains.
  - The planned 13 shunting tracks across Bundle 3, Bundle 4 and Maltweg can accommodate 17-18 daily arriving and departing trains, or daily 8-9 departing trains.

2.4.16. The implied shunting capacities above are likely lower bound estimates as capacity could likely be increased by better use of technology and/or increasing dwell times – the maximum number of daily trains implied by the current shunting capacity is also lower than 2018 levels (although this is while Bundle 2 was still being used for shunting).

2.4.17. More broadly, the arrival/departure and shunting track capacities at Sloehaven should be treated as high-level estimates but give an indication of the maximum number of daily freight trains that could be sent from Sloehaven. Based on both current and planned capacity, the rail infrastructure at Sloehaven is likely to act as a constraint on the volume of ammonia that can be transported as the number of daily trains that can be accommodated is lower than projected future level of rail transport activity (in terms of projected daily trains) even before the additional 4 to 5 ammonia trains are taken

[11] ibid

into account (as the extent ammonia transportation has been taken into account in ProRail's market projections is unclear).

2.4.18. On the wider network, based on ProRail's 2021 Integrated Mobility Analysis report[12] and the most recent capacity strategy report[13], the projected timetabled level of freight traffic operating on the Sloe-Roosendaal in 2040 will be between 20 and 24 daily freight trains (10-12 in each direction). The projected traffic was increased to up to 26 daily trains within the 2023 Sloehaven report cited above, which translates to over 9,000 annual trains, up from 2,500 in 2024.

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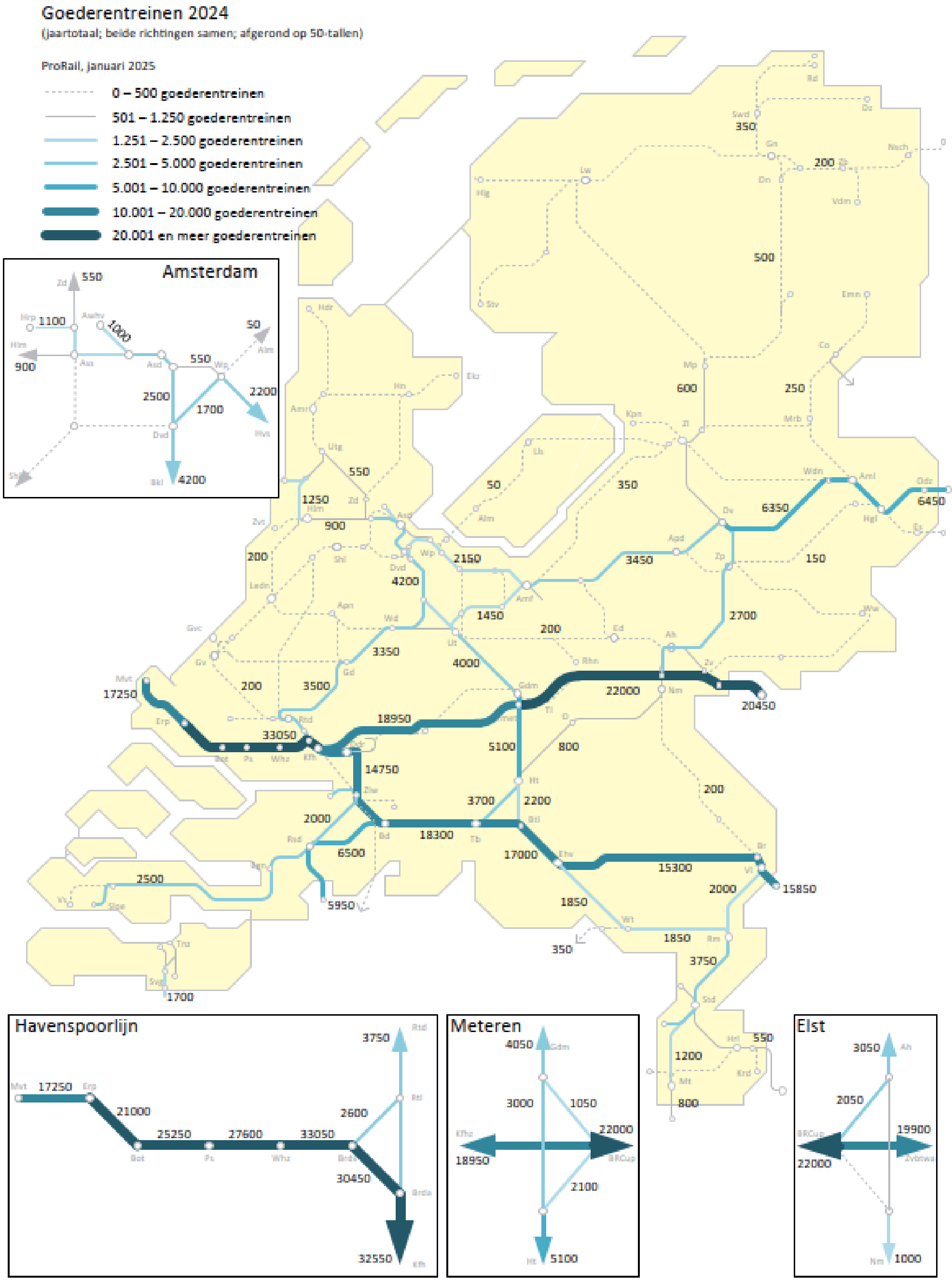
12 Integrated Mobility Analysis 2021
Capacity Strategy Netherlands 2026

Figure 2-4 - Netherlands Rail Freight Transport Volume (2024)



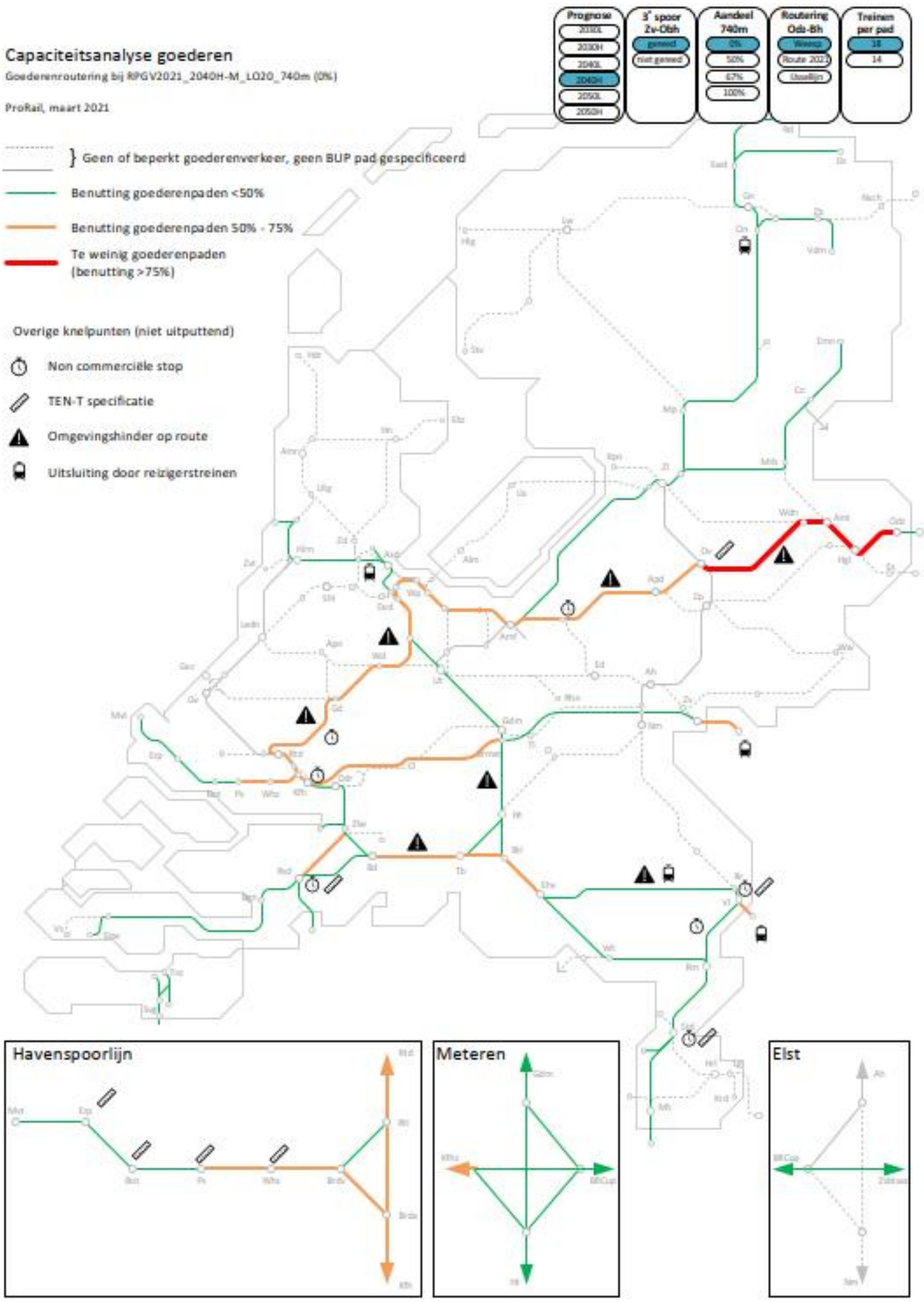
Source: ProRail[14]

2.4.19. Freight services are permitted to use 75% of available timetabled capacity and a freight path available for 24 hours a day provides capacity for a maximum of 18 freight trains per day in each direction (though this can be lower where freight paths converge or where there are other operating restrictions). Based on ProRail's projections for 2040, the Sloe-Roosendaal track is likely to have

[14] Ontwikkeling spoorgoederen in Nederland

capacity for the additional 4 to 5 daily trains required to transport ammonia, as it is projected to be less than 50% full with 24 daily trains in 2040, though there may be constraints on other parts of the Dutch network.

Figure 2-5 - Projected Netherlands Freight Path Utilisation (2040)



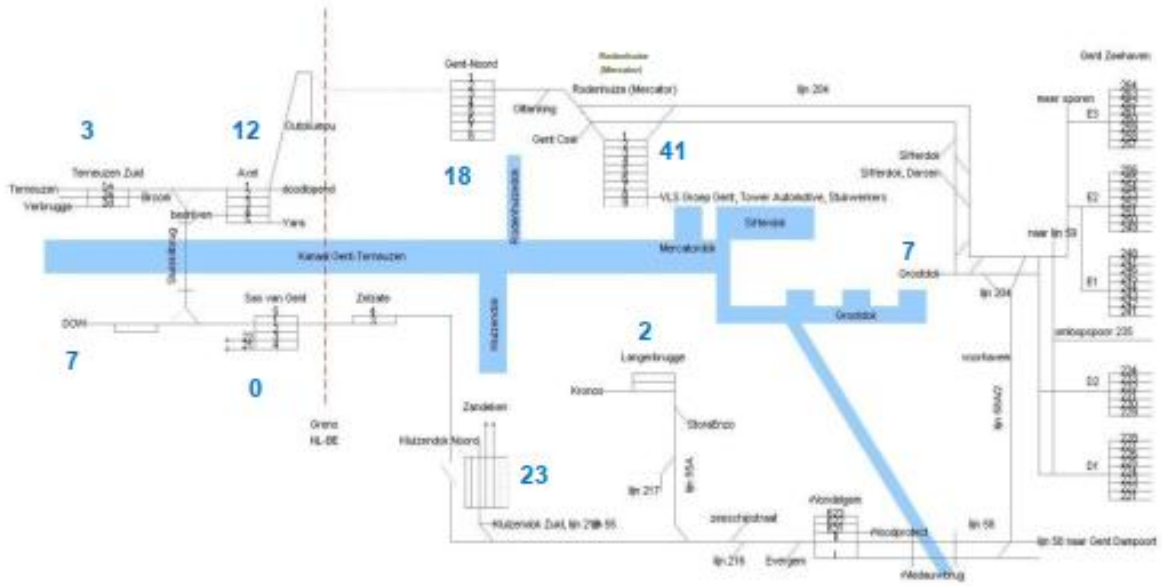
Source: ProRail[15]

2.4.20. The projected timetabled level of freight traffic operating on other parts of the routes defined in Figure 2-2 range from 25 to 120, though the majority of the routes are over 50 freight trains (25 in each direction).

Terneuzen

2.4.21. Based on Figure 2-4 above, 1,700 freight trains crossed the Netherlands-Belgium border in 2024 to access Terneuzen, equivalent to 2-3 daily departing trains. The track infrastructure (and the number of daily trains in 2018) around Terneuzen and Ghent ports are shown in the figure below, based on a study[16] undertaken in 2018 by Rail Ghent Terneuzen (a collaboration of North Sea Port, ProRail and Infrabel). Ammonia volumes within the scope of this study will be transported from the EVOS terminal at Terneuzen, located in the North-West of the port (and the bottom right of the figure below) and will use Dow track infrastructure to enter the network.

Figure 2-6 - Terneuzen Rail Infrastructure



Source: Rail Ghent Terneuzen[17]

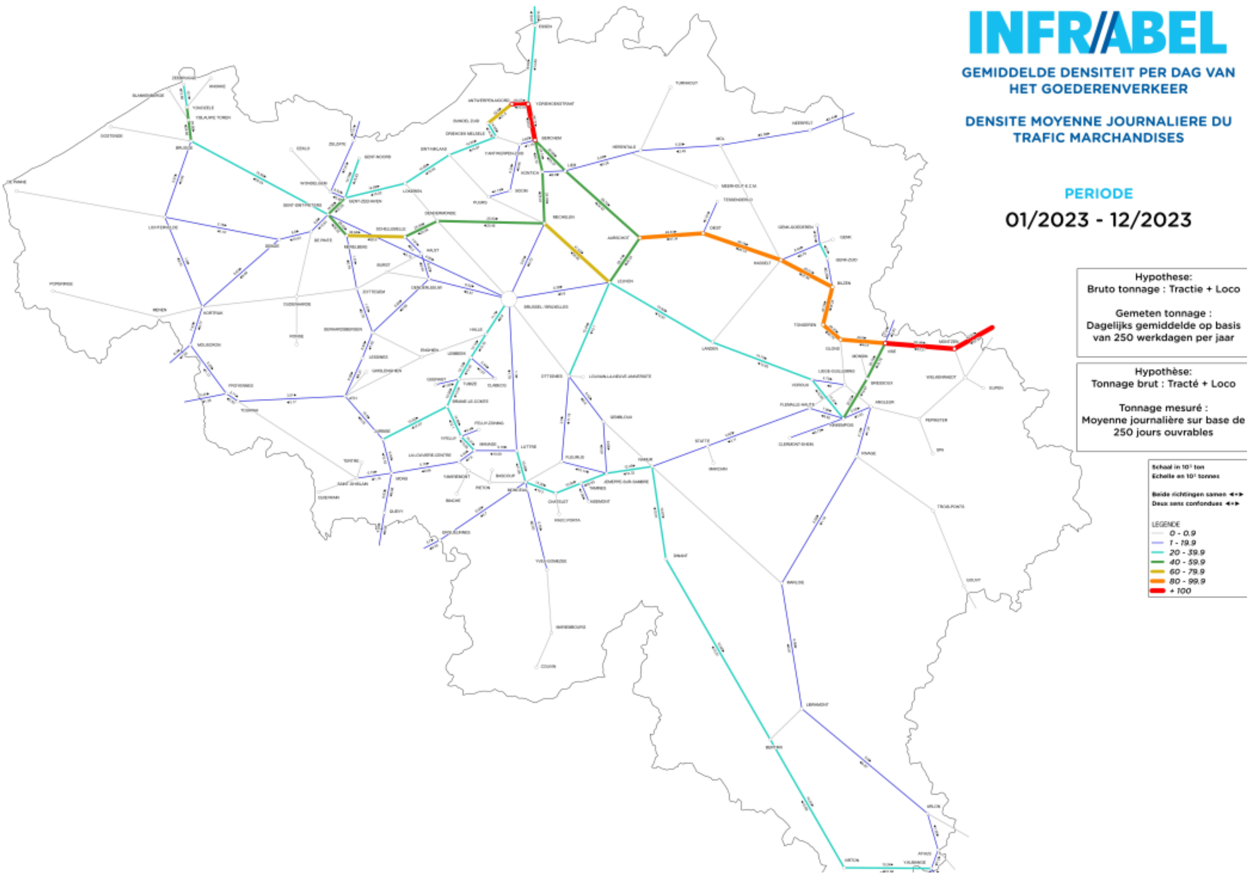
2.4.22. Based on the 2018 capacity study, infrastructure will be required for 106 weekly trains on the Dutch part of the network and 389 weekly trains on the Belgian side of the network in 2030 (low scenario). The study found the current infrastructure is insufficient to support this level of traffic due to a number of bottlenecks around Terneuzen and Ghent ports, and a number of upgrades will be required to accommodate the projected level of traffic demand. We understand that there are plans to address these bottlenecks, but no major infrastructure upgrades have taken place since the 2018 study.

15 Eindrapportage corridorstudie 740 meter
16 Vervoers- en Capacitieitsanalyse
17 ibid

2.4.23. When consulted as part of this study, Infrabel and other stakeholders stated that there is spare capacity on the Dow track infrastructure and it could likely handle some (1 to 2) additional daily trains, though not a significant quantity (the 2030 high scenario projects 10 daily train on this part of the track). However, how much additional traffic could be accommodated to and/from the EVOS terminal will also depend on the traffic and bottlenecks in the wider area. Infrabel stated trains traveling from Terneuzen also need to change locomotives (from diesel to electric) before they can travel through the Belgian rail network, which adds an additional bottleneck.

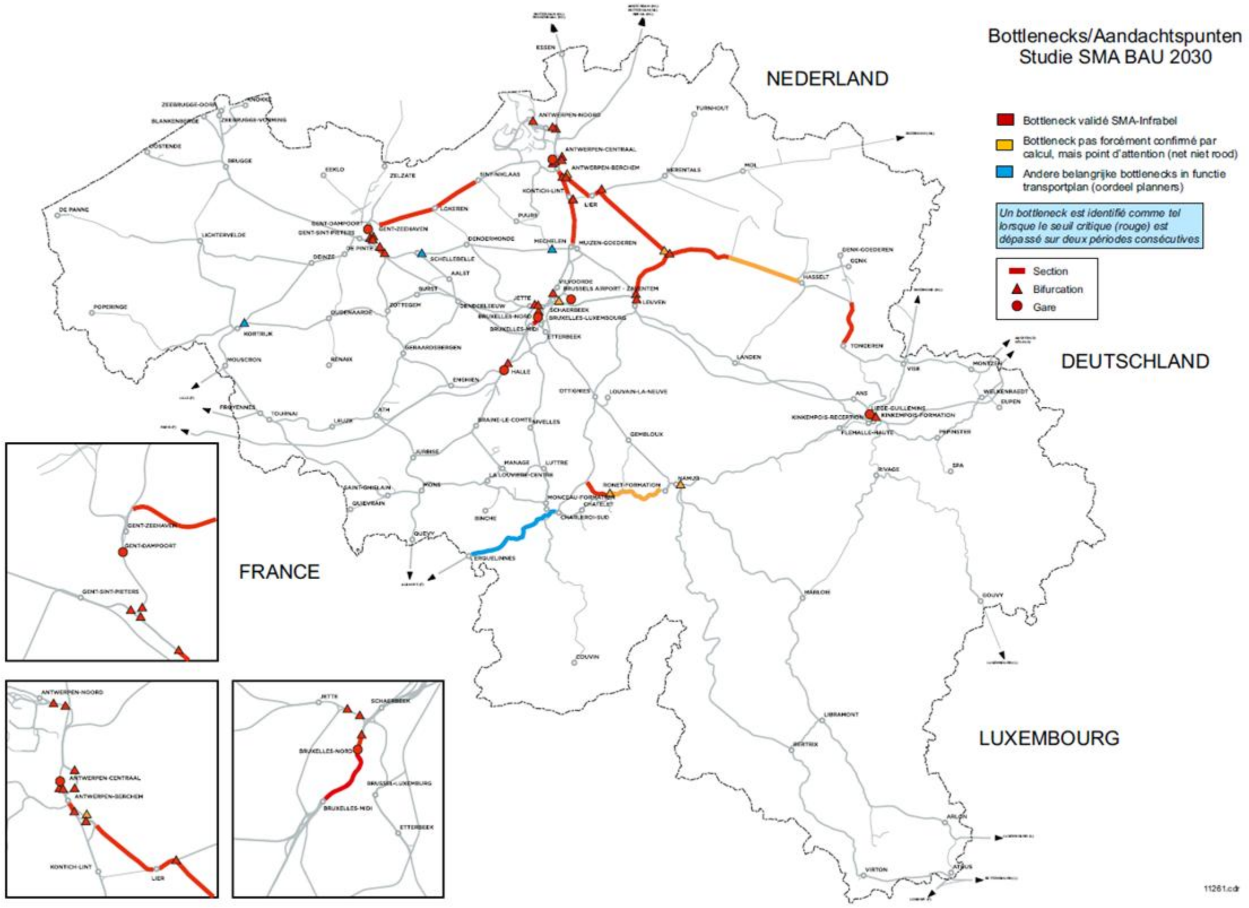
2.4.24. On the wider network, Infrabel stated track capacity on the wider network is also an issue and that there are a number of identified bottlenecks, though did not provide quantifications on the projected level of freight traffic or capacity. The volume of freight traffic on the Belgian network and the projected capacity bottlenecks in 2030, based on information provided by Infrabel, are shown in the figures below.

Figure 2-7 – Belgian Freight Rail Traffic (2023)



Source: Infrabel

Figure 2-8 – Belgian Freight Rail Bottlenecks (2030)



Source: Infrabel

Combined capacity

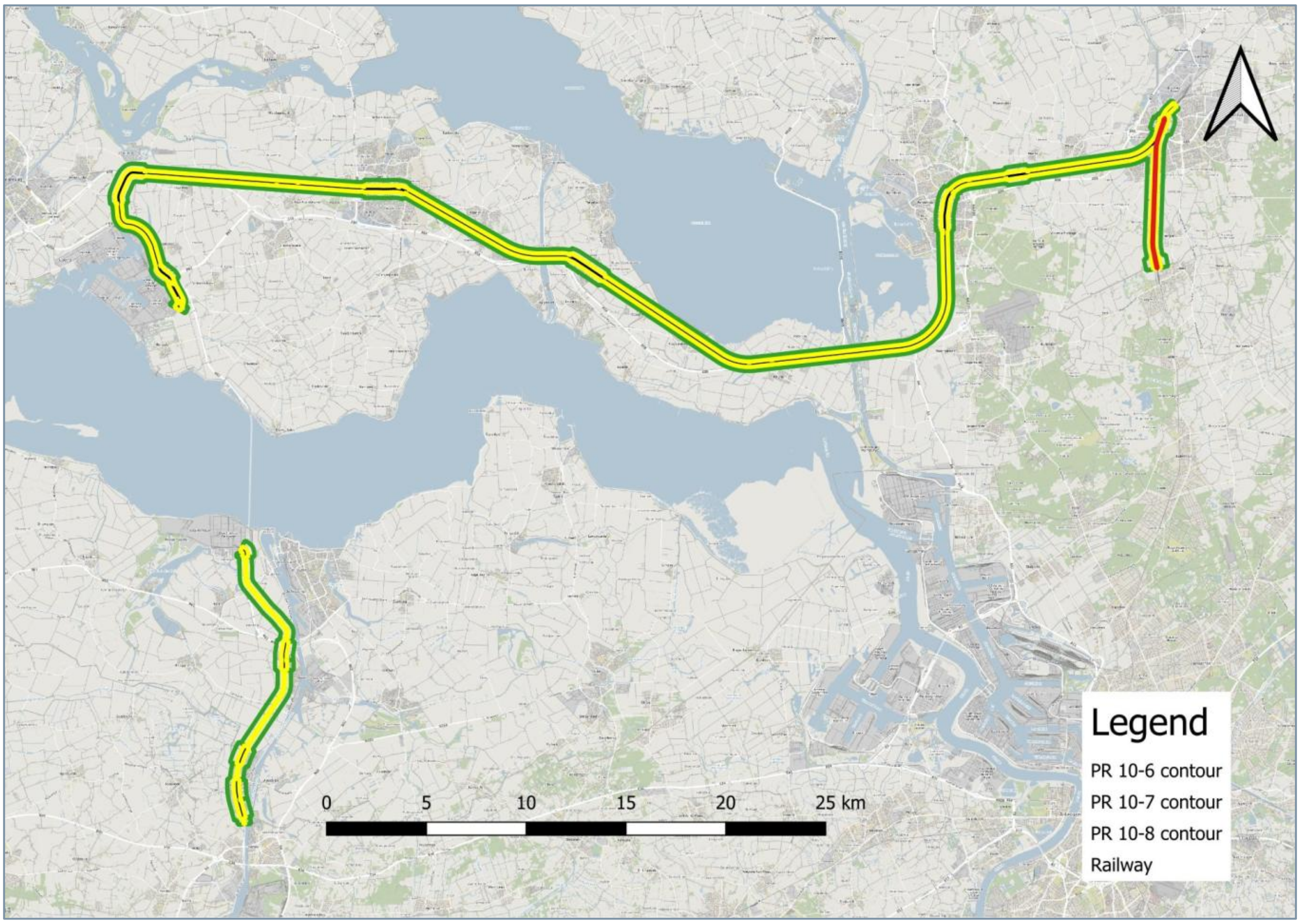
2.4.25. As has been discussed above, there are capacity constraints on both the Dutch and Belgian rail networks, and in and around North Sea Port at both Vlissingen and Terneuzen. Understanding and quantifying the implications of these constraints for ammonia transportation from North Sea Port is complex and would require a much more detailed rail capacity study to quantify in more detail, particularly as it is also unclear if the planned capacity improvements will materialise. While the precise extent of the capacity restrictions is unclear, it is unlikely that there is sufficient capacity available to transport 3 mpta of ammonia.

2.4.26. An additional constraint is the train loading capacity of North Sea Port terminals and, when consulted as part of this study, market parties stated this is likely to be the primary constraint on ammonia rail transportation capacity by rail. Based on current operations, loading slightly less than one block train a day (equivalent to 300 trains a year) is a reasonable assumption for terminal loading capacity (though more than this may be technically possible in the future). This translates to 375,000 tpa (tonnes per annum) from Terneuzen (with one terminal importing ammonia) and 1.125 million tpa (mtpa) from Vlissingen (with three terminals importing ammonia).

Safety Restrictions

2.4.27. The external safety assessment for rail transport has been undertaken based on the routings described above. The risk contours for routings under the central volume scenarios are shown in Figure 2-9 – the risk contours are shown for the part of the routes through the Netherlands as safety risk assessments are not applicable within Belgium (as discussed above). Two thirds of the central scenario ammonia volumes are transported from Vlissingen and the remainder from Terneuzen.

Figure 2-9 - Rail Risk Contours (2050)



Source: AVIV

2.4.28. The number of vulnerable objects within the defined location specific risk contours around each of the rail routes is shown in

2.4.29.

2.4.30.

2.4.31. Table 2-1 – the figures shown include the total number of vulnerable objects and the number relative to the projected baseline situation in brackets (i.e. with no additional ammonia transportation).

Table 2-1 - Rail Transport Vulnerable Objects (2050)

Volume Scenario	Vlissingen Route		Terneuzen Route	
	Vulnerable	Very Vulnerable	Vulnerable	Very Vulnerable
Baseline	7	-	-	-
Low	7	-	-	-
Central	7	2 (+2)	-	-
High	11 (+4)	2 (+2)	-	-
Extended	14 (+7)	2 (+2)	-	-

Source: AVIV analysis

2.4.32. While there are no vulnerable buildings on the Terneuzen route, there are multiple vulnerable buildings (seven houses) within the rail route risk contours on the Vlissingen route. Transportation of additional ammonia on the Vlissingen route increases the size of the risk contours and increases the number of vulnerable objects (to 11 and 14 houses in the high and extended scenarios respectively) within the contours, though the thresholds are already breached under the baseline scenario. Given the baseline scenario is above the threshold, there is no 'turning point' at which additional ammonia volumes breach the threshold. The very vulnerable buildings within the contours are a school and a care home.

2.4.33. As noted above, if the above assessment was in relation to new rail infrastructure, there would be permitting implications arising from these results. However, as the infrastructure already exists, no additional permitting is currently required to transport additional volumes on existing rail infrastructure. The current volumes of ammonia and other hazardous substances are also in breach of Basisnet legislation restrictions (described in more detail in Appendix D), though this also does not currently represent a practical constraint. As with the location-specific risk current (and projected) volumes of hazardous goods are already above the Basisnet threshold, therefore, there is no 'turning point' at which additional ammonia volumes breach the threshold.

2.4.34. While the results of this assessment imply transporting up to 6 mtpa of ammonia by rail is permitted by current legislation (subject to capacity constraints), the Dutch government has stated[18] that increasing the volume of ammonia transported by rail is undesirable (though not entirely avoidable),

1.1.1. [18] Kamerbrief over kabinetsvisie waterstofdragers is less preferable than transportation by barge or pipeline, and should be limited as much as possible.

2.4.35. Therefore, while no hard restrictions on transporting ammonia by rail in the Netherlands currently exist, transporting significant volumes by rail is unlikely to be acceptable to authorities. The Terneuzen route assessed may be more acceptable to authorities given it takes the shortest possible route to Belgium, and has lower volumes and fewer vulnerable objects relative to the Vlissingen route.

2.4.36. The societal risk assessment, which does not have any direct implications for permitting, is set out in Appendix E. As with the location-specific risk, for all rail routes the projected baseline level of transportation is above the guideline level.

INLAND SHIPPING

Routing

2.4.37. For inland shipping from the NSP to Germany, one route has been considered, which is the same route considered as part of the 2024 study. It uses waterways of the highest navigability (class 6), which means it is suitable for largest barges. The selected route is preferable to another potential route via Dordrecht, because it is shorter, and it avoids Dordrecht (which is preferable from a safety perspective).

2.4.38. No routes through Belgium have been considered, as the inland waterway infrastructure is not sufficient to handle the required number of large barges. While smaller barges can technically travel through Belgium, this option has not been included in this assessment. For clarity, ‘smaller barges’ refers to any vessel below Class VI standard (typically Class IV or V), which generally have capacities of 1,000–2,500 tonnes compared to Class VI barges that can carry 3,000–4,500 tonnes or more. Using these smaller classes would require significantly more trips to transport equivalent volumes, increasing operational complexity, risk and cost.

Figure 2-10 - Inland shipping transport route

Source: AVIV, WSP analysis

Equipment

2.4.39. On inland shipping routes, liquid bulk is generally transported using specialised barges and according to the European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways (ADN)[19], ammonia must be transported on Type G tanker barges. Type G tanker barges are specialised vessels that meet the technical and safety requirements for transporting ammonia, though can also be used to transport other substances including liquified petroleum gas (LPG). Based on a recent study for the Province of Zeeland[20] current volumes transported by Type G tanker barges to and from North Sea Port are currently low; of c. 41,000 annual inland shipping movements, 16,000 transport hazardous goods and 112 are category GT3 (which includes ammonia).

2.4.40. Depending on the size, these barges can carry between 500 and 2,500 tonnes of ammonia, with most operational vessels at the higher end of this range. For this study we have assumed ammonia vessels are capable of transporting 2,000 tonnes of ammonia. Transporting 3.0 million tonnes of ammonia from NSP a year would require 1,500 annual barge loads. Assuming a round-trip time of a week, this would require a dedicated fleet of 29 vessels all undertaking one round trip a week (equivalent to 4-5 daily barge loads).

2.4.41. Based on market report[21] and data provided by Central Commission for the Navigation of the Rhine (CCNR), there was a Europe-wide fleet of 73 ADN Type G tanker barges in 2021 and, based on the volumes of liquid bulk transported by inland shipping across Europe, the vast majority of these were based in the Antwerp-Rotterdam-Rhine-Ruhr Area (ARRRA) region. A 2024 study for the Port of Rotterdam[22] reports that there are around 80 gas tanker inland shipping vessels operating across the Netherlands, Germany and Belgium. These tanker ammonia barges will also require specially trained crews, which may be a challenge to recruit given the crew shortage in the inland tanker market.

2.4.42. In addition to the existing fleet, if there is sufficient demand from operators, additional vessels can be produced by original equipment manufacturers (OEMs). The same Port of Rotterdam study reports that, based on current build rates, an additional 50 ammonia tankers could be produced by 2030. This suggests that the ammonia barge fleet will be sufficient to meet NSP's transportation needs alone; however, there will be competition for these vessels from other ports (particularly Rotterdam) and from other commodities, such as LPG, for both the vessels and trained crews, which means there may be a shortage within the ARRRA region.

2.4.43. Vessels capable of transporting ammonia currently generally use pressurised tanks, though in the future there may be a shift to greater use of refrigerated tankers for ammonia and there are already a small number of these vessels already under development (including KGK Shipping's 'Pioneer' project). Refrigerated tankers are beneficial from a safety perspective and, based on the views of market parties, additional costs relative to pressurised tankers will be marginal given the liquefaction point of ammonia (-33°C) is relatively high compared to other gases such as hydrogen.

2.4.44. NSP also stated it is currently, in collaboration with Ecoport and terminal operators, developing a floating pipeline concept for ammonia, where converted push barges are transported in groups of six

[19] ADN
[20] Omgevingsverkenning Waterstofdragers Zeeland
[21] CCNR Economic Reports
[22] Executive Summary: Ammonia Transport Study (Royal Haskoning DHV, 2024)

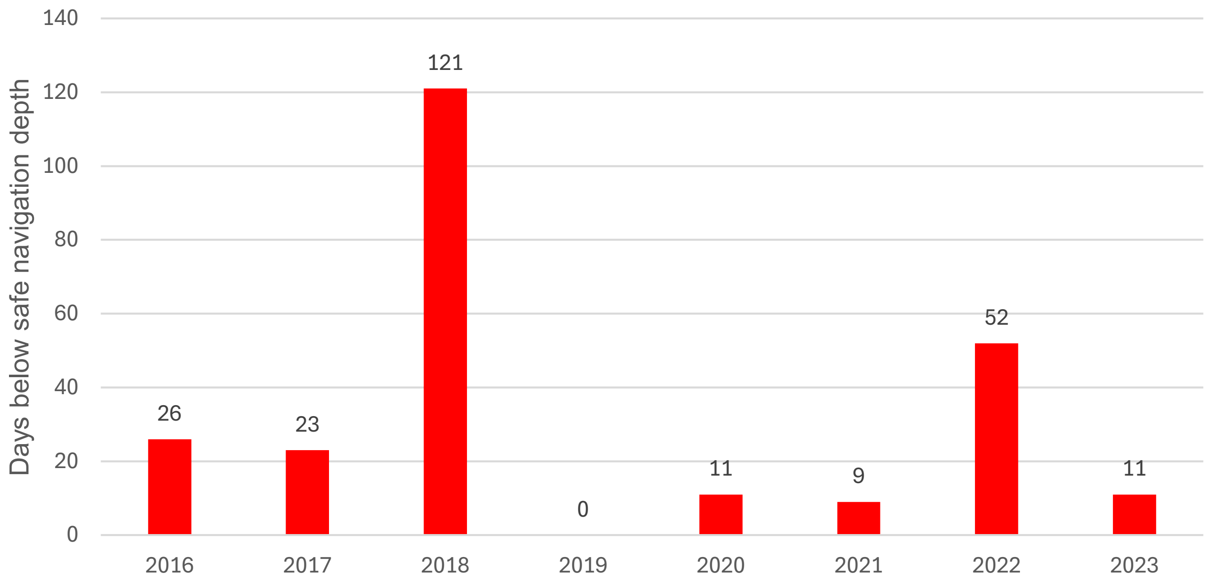
or seven by tugboats to the German hinterland, where the ammonia is unloaded and/or cracked. This concept is currently in the early stages of development, and we have not included it within any of the capacity or cost calculations as part of this study.

Infrastructure

2.4.45. Under normal operating conditions, there does not appear to be restrictions on the number of barges on the Rhine or Rhine Delta; CCNR reports[23] an average of 600 vessels cross the Dutch-German border each day. However, due to high or low water levels, temporary vessel restrictions or closures can be imposed on certain sections of the river, or vessel weight limits imposed, both of which can reduce barge transportation capacity.

Given the anticipated trajectory of climate change, it is likely that high and low water levels on the Rhine will continue to have an adverse impact on barge transportation capacity. **Figure 2-11** shows the number of days per year between 2016 and 2023 during which water levels at the Cologne gauge station fell below the navigation depth required for safe inland shipping, highlighting the uncertainty created by year-to-year variation and the capacity constraints imposed during significant portions of some years.

Figure 2-11 – Number of days below the equivalent water level in Cologne (2016 – 2023)



Source: CCNR 2024 Annual report[24]

2.4.46. In addition to water level capacity restrictions, there is also significant congestion at key inland locks and canal bottlenecks, where CCNR[25] reported wait times of 20 to 30 hours in recent years. These inland bottlenecks can create knock-on delays across the wider Rhine shipping corridor. In addition, the loading capacity and potential for congestion at NSP itself also need to be considered.

[23] Information on the waterway Rhine
[24] CCNR 2024 Annual Report
[25] Disruption in the Container Supply Chain (2020)

2.4.47. Canal locks within the Netherlands are also potential bottlenecks for hazardous substances, though in July 2025, the Dutch government also amended the Binnenvaartpolitiereglement (BPR), allowing mixed lock use for vessels carrying some hazardous goods, enabling certain categories of hazardous cargo to share lock chambers and berths with other vessels – though some restrictions for toxic substances (including ammonia) still remain in place.

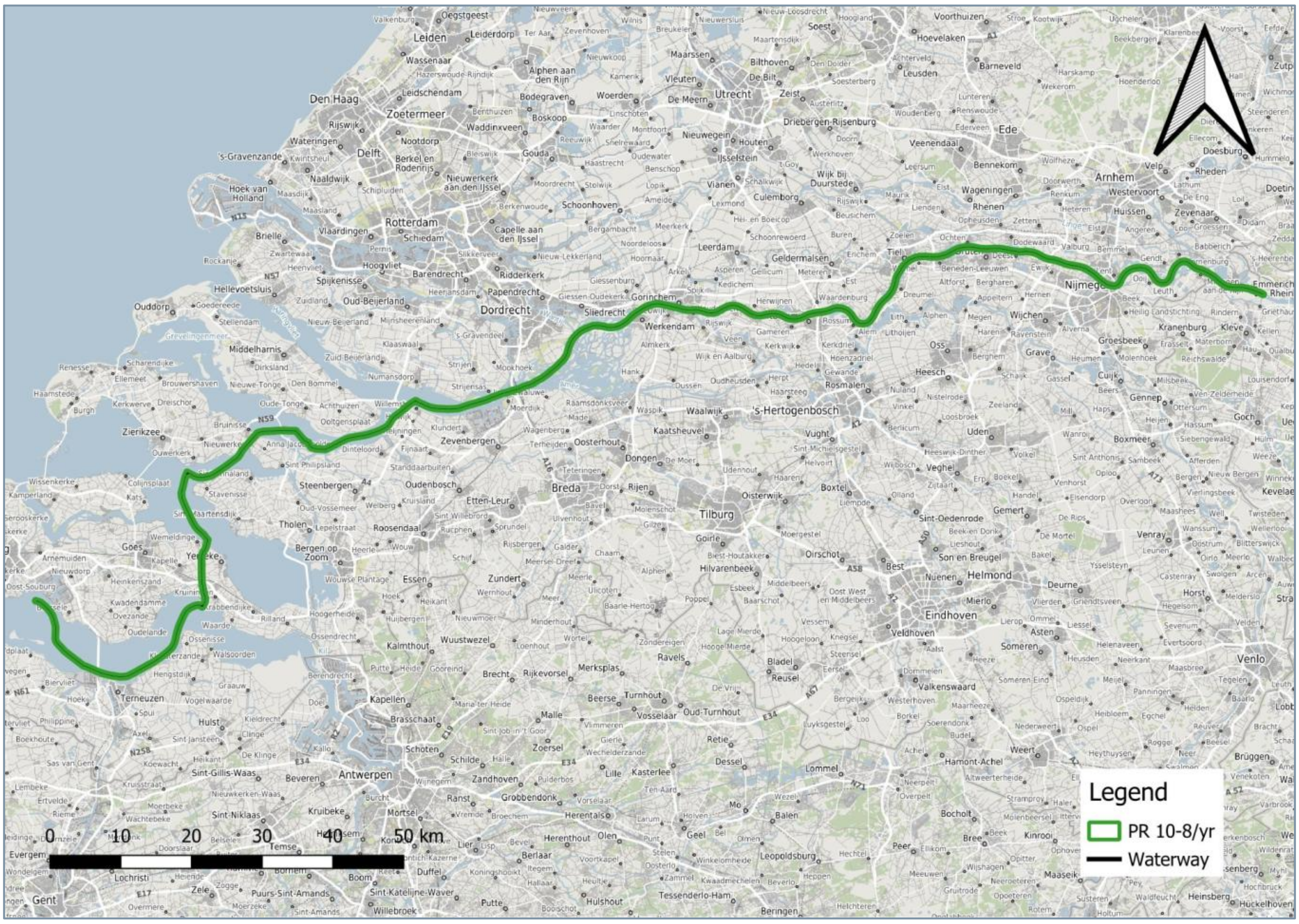
2.4.48. As with rail, an additional constraint on barge transportation will be operators' barge loading capacity at NSP; however, this information is considered commercially sensitive by some stakeholders and we have therefore not considered this in detail as part of the study.

Providing there are sufficient vessels available in the future, it does not appear waterway capacity will act as a constraint on transportation of ammonia by barge, though inland lock congestion and fluctuating Rhine water levels are likely to continue to act as constraints in specific areas and at specific times.

Safety Restrictions

2.4.49. The external safety assessment for inland shipping transport has been undertaken based on the route described above shown in the figure below.

Figure 2-12 - Inland shipping transport route within the Netherlands



Source: AVIV

2.4.50. Under the baseline scenario and each of the ammonia volume scenarios, there are no vulnerable buildings within the risk contours on the route. This means it is unlikely any safety capacity restrictions will be imposed on inland shipping based on the projected volumes that need be transported. The Dutch government has stated[26] that transportation of ammonia by inland shipping is preferable to rail but less preferable to pipeline transport.

2.4.51. The societal risk assessment results, which does not have any direct implications for permitting, is set out in Appendix E. Under the baseline and all ammonia volume scenarios, the risk is well below the guideline level.

AMMONIA PIPELINE

2.4.52. In the Netherlands the new ammonia pipeline needs to be constructed in the designated pipeline corridors. These corridors connect the Dutch industry clusters and facilitate legislation, stakeholders, construction etc. The legislation for these corridors is contained within the Spatial Planning Act (omgevingsinpassing). This act determines whether a pipeline, which goes beyond the borders of local municipalities, is eligible to be constructed within these corridors.

2.4.53. If a pipeline meets the requirements to be marked of national importance (Nationaal Belang), this pipeline will be allowed to be constructed within these corridors. These corridors are generally called the SvB-corridors, which comes from the old legislation of the Spatial Vision Pipelines (Structuurvisie Buisleidingen (SvB), 2012-2035). In recent years this legislation has been adopted into the Main Energy Structure Programme (Programma Energie-Hoofdstructuur (PEH)) for the spatial planning for energy and its transport within the Netherlands.

2.4.54. All pipelines are assumed to transport the full ammonia volumes projected under each of the volume scenario as, for the purposes of this study, it is assumed a Multi-Utiliteiten Kruising (MUK) pipeline tunnel including ammonia under the Schelde river delta will be constructed connecting Vlissingen and Terneuzen so only one ammonia pipeline from one of the locations will be needed. The costs of constructing this connection between the harbours of Vlissingen and Terneuzen are not part of this project.

Vlissingen – Antwerp pipeline routing

2.4.55. The pipeline routing between Vlissingen (Sloehaven) to the Port of Antwerp, shown in Figure 2-13, follows the SvB-corridors until close to the Belgium border and is mostly the same routing that was considered at a high level within the 2024 study.

2.4.56. In Noord-Brabant the pipeline is partly located within the SvB-corridor owned by LSNED. LSNED is part of the SvB-corridor running from the Port of Rotterdam to the Port of Antwerp via the Moerdijk industrial area. This corridor is owned and managed by LSNED. LSNED is a party handles a specific set of rules to ensure the safe construction and operation of pipelines, along with making sure that enough space is present for future pipelines.

2.4.57. Within the Port of Antwerp area, the route follows the A12. This route does cross the municipality of Zandvliet. Another possible route could go through the harbour area. However, this route was not chosen for this study because there is very limited space available for a new pipeline. It may still be necessary to find a route through the port area based on safety requirements. Based on current

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1.1.2. [26] Kamerbrief over kabinetsvisie waterstofdragers feasibility considerations, there are two possible routes. One follows the Scheldelaan through the industrial port area, where there are a lot of interactions with cables, pipelines, locks and other infrastructure, which adds complexity and additional risks to pipeline feasibility.

2.4.58. The alternative route within the Port of Antwerp follows the A12 highway until the take-over point with the pipeline corridor. The pipeline is mainly located in rural areas, resulting in a technically less complex route, though there are many interactions with private landowners.

Figure 2-13 - Vlissingen-Antwerp Pipeline Routing

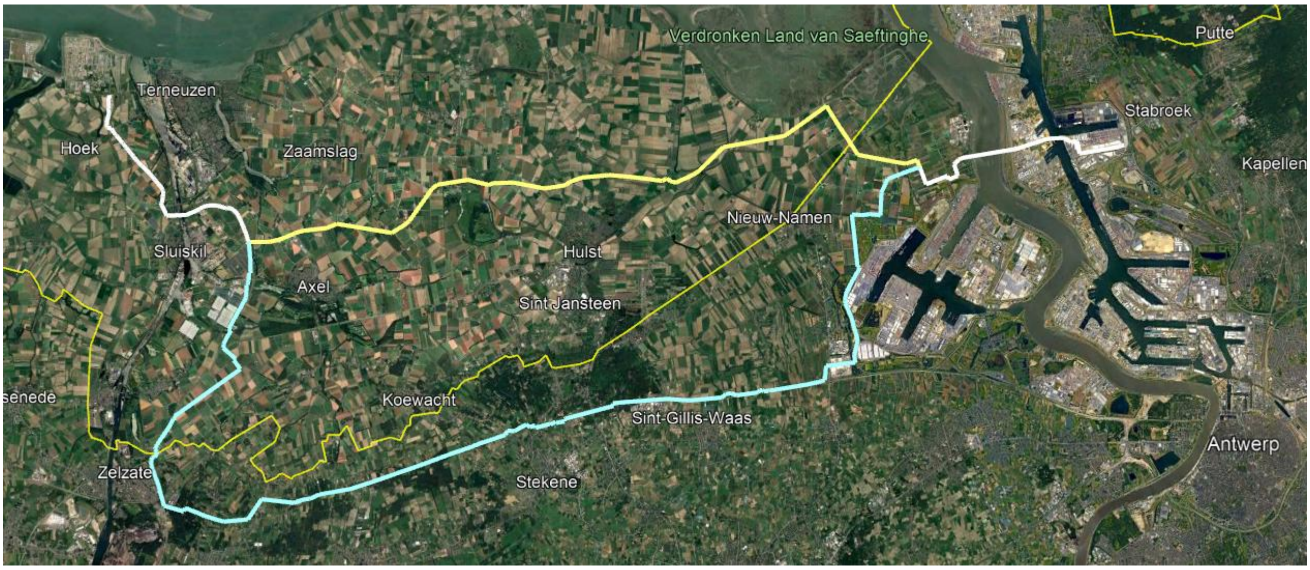
2.4.59. 

Source: Google Earth & WSP analysis

Terneuzen – Antwerp pipeline routings

2.4.60. From Terneuzen, there are two route options to reach the Port of Antwerp, both of which are shown in Figure 2-14. One option passes mainly through Belgium and connects to the Port of Gent, and the other takes a shorter route and passes mainly through the Netherlands.

Figure 2-14 - Terneuzen-Antwerp Pipeline Routings



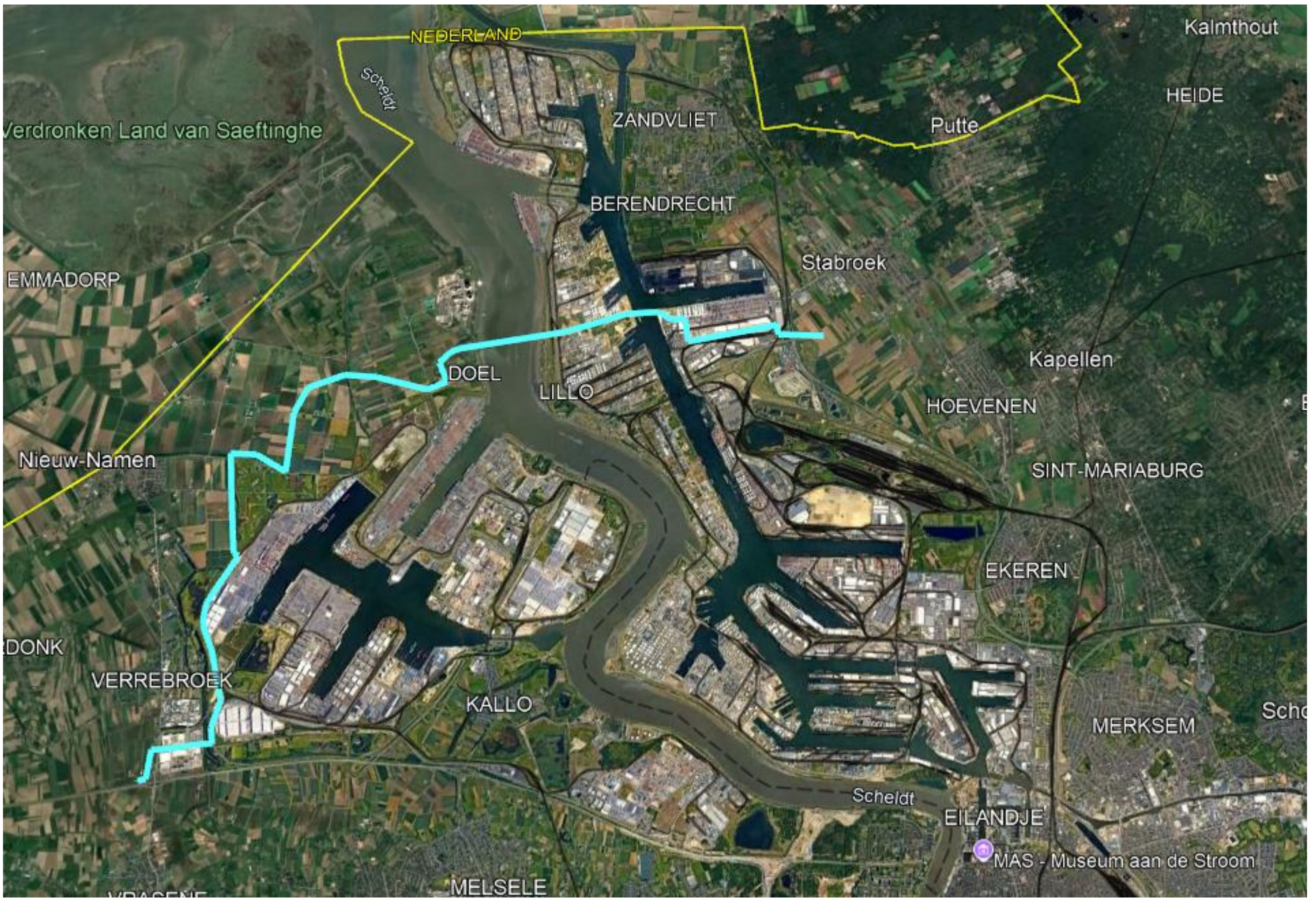
Source: Google Earth & WSP analysis

2.4.61. The blue pipeline route in the figure above follows the E34 highway in Belgium from Gent to Antwerp and is the same routing as a new gas pipeline is being constructed by Fluxys. When consulted as part of this study, Fluxys confirmed that this is the most logical route from Gent to Antwerp, although the available space at some locations is very narrow. This, in addition to interactions with private landowners, implies a risk for the feasibility of a new ammonia pipeline.

2.4.62. The alternative pipeline route passes through Zeeland. From Sluiskil it follows an existing pipeline corridor that contains a Gasunie pipeline, and we have assumed that the new pipeline is accepted in the existing pipeline corridor agreement with private landowners. The pipeline routing follows the corridor until “Verdronken land van Saeftinghe” where it deviates south towards the village of Doel.

2.4.63. Within the Port of Antwerp, three route options have been evaluated. After consultation with Pipelink two options were disregarded because of bottlenecks within the Port of Antwerp area.

Figure 2-15 - Terneuzen-Antwerp Pipeline Routing (within the Port of Antwerp)



Source: Google Earth & WSP analysis

2.4.64. The blue route option is the most feasible route, though there are complexities including interactions with port developments including the expansion of the Doel dock and the construction of an earth wall. The crossing of the Schelde river, by means of horizontal directional drilling (HDD) is located just south of the Nuclear powerplant of Doel, after which the pipeline route follows the existing infrastructure until the take-over point with the Antwerp-Ruhr pipeline corridor. The intention is to align this route as much as possible with existing NH_3 pipeline corridors within the port area to maximise synergies and minimise disruption. The pipeline route also crosses the industrial site of Sea Tank via a tolerated pipeline corridor, which means Sea Tank, as well the Port of Antwerp, are important stakeholders to consider.

Equipment & Infrastructure

2.4.65. The following construction methods are considered for each pipeline route:

- Open trench; and
- Drilling, which can either be micro-tunnelling or HDD.

2.4.66. Table 2-2 shows the number of sections and the total combined length for each of the construction methods.

Table 2-2 - Required pipeline construction methods

Type of crossing	Vlissingen – Antwerp		Terneuzen – Antwerp NL route		Terneuzen – Antwerp BE route	
	Sections	Length	Sections	Length	Sections	Length
Open trench	29	51.2	33	40.9	41	51.0
Drillings	28	9.4	32	7.9	40	9.8
Total length	60.6 km		48.8 km		60.8 km	

Source: WSP Analysis

2.4.67. The sizing of the pipelines is based on the assumption that each routing is required to carry total ammonia volumes under each scenario and that a MUK pipeline tunnel will connect Vlissingen and Terneuzen so only one pipeline will be needed.

2.4.68. Table 2-3 sets out the pipeline dimensions for each of the different volume scenarios; the indicated pipeline diameter, wall thickness and material are the minimum required values for each of these scenarios (a singular pump for the entire length of the pipeline trajectories is assumed).

2.4.69. For the High and Extended scenarios, there are two pipelines with a smaller diameter instead of one pipeline with a larger diameter in order to comply with safety requirements and minimize the effect in case one pipeline fails (described in more detail in safety section below).

Table 2-3 - Estimated pipeline dimensions

Scenario	Amount (mton/yr)	Flow rate (m^3/hr)	Velocity (m/s)	Diameter		Wall thickness		Material	Design Pressure (barg)
				Inch	mm	Sch	Mm		
Extended (two pipes)	6.0	1,000	2.03 2.03	12 12	323.8 323.8	60 60	14.27 14.27	L290 L290	100 100
High (two pipes)	4.5	750	2.03 1.44	12 10	323.8 273.0	60 60	14.27 12.70	L290 L290	100 100
Central	3.0	500	2.03	12	323.8	60	14.27	L290	100
Low	1.5	250	1.44	10	273.0	60	12.70	L290	100

Source: WSP Analysis

2.4.70. For ammonia pipelines, the specific safety measures and regulatory requirements are unclear at this point in time. Therefore, the pipeline specifications are based on assumptions of the future ammonia pipeline requirements and safety measures, including extra wall thickness (approximately +40% compared to the minimum required), the use of leak detection, and the use of an automatic valve at every 3 km or less. The pipeline, within open excavation, will be laid at a standard depth of 1.0 metre, although in this study a minimum depth of 2.0 metres has been applied for additional safety.

2.4.71. The design does not include additional safety measures that could be mandated in the future, such as thicker pipeline walls, a pipe in pipe casing construction or secondary parallel pipes. A 50% thicker pipeline wall would increase costs by around 10% (discussed further in Appendix B) and pipe in pipe casing would theoretically reduce the pipeline failure rate but make inspections and maintenance extremely difficult.

2.4.72. In order for the design of an ammonia pipeline to be approved, a number of practical and legislative requirements need to be met. These are discussed in Appendix A.

NSP-Antwerp Pipeline Safety Restrictions

2.4.73. The results of the external safety assessment for the NSP- Antwerp pipeline are dependent on whether a crater model is used. For external safety assessment modelling of a pipeline within the Netherlands, RIVM strongly recommends the use of a crater model using the risk tool SAFETI-NL and has strengthened this guidance since the 2024 study. We have therefore used the crater model within the Netherlands as part of this study.

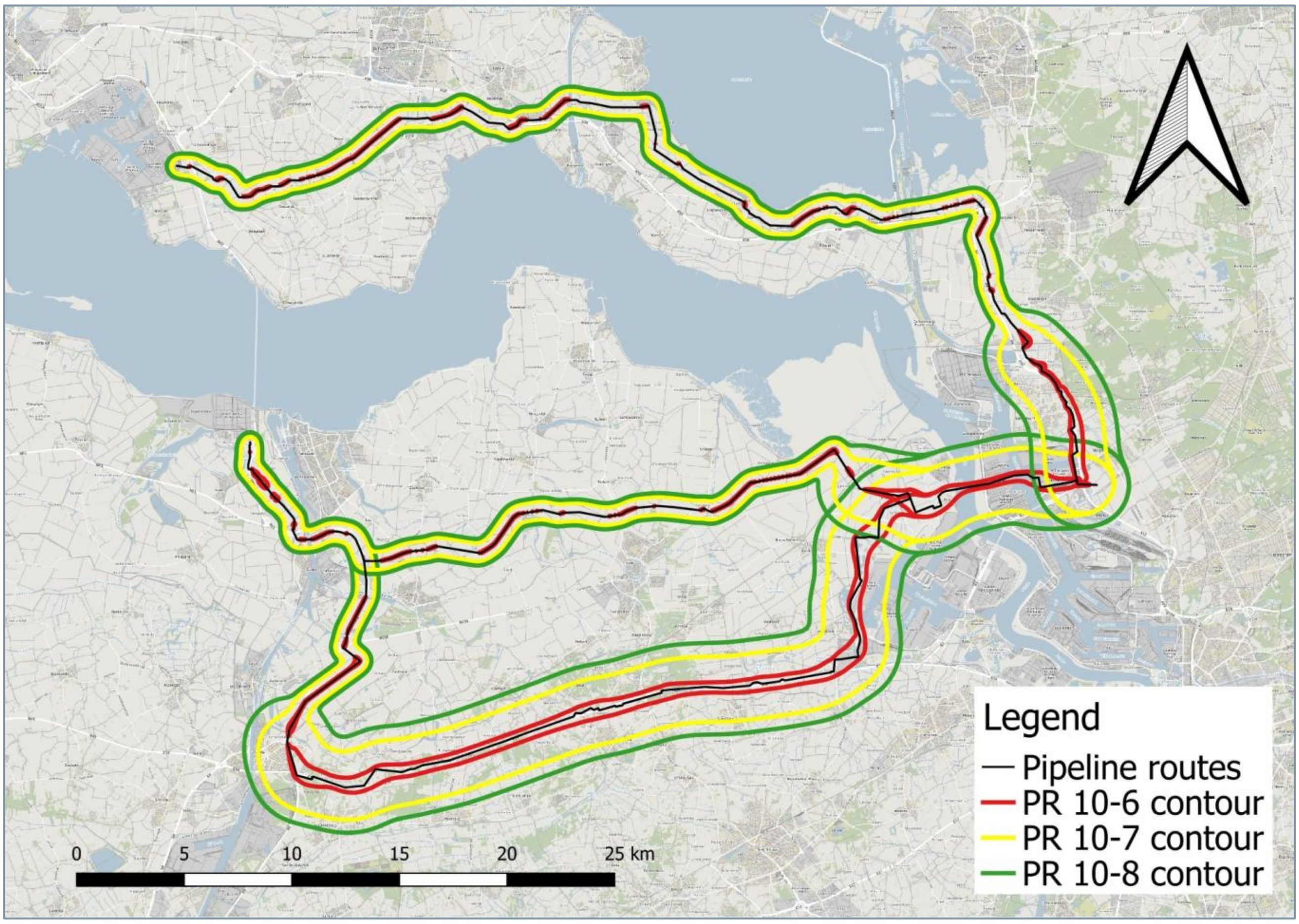
2.4.74. There are a number of vulnerable and residential objects on the selected routes shown in Figure 2-16 (there is no baseline scenario for the pipeline as the infrastructure does not currently exist), which are shown in Table 2-4. The 10^{-6}/yr contours are wider within Belgium because Belgian safety calculation guidance assumes a higher starting pipeline failure probability than the Netherlands, leading to stricter location-specific risk requirements. The following measures have been assumed (and costed) to minimise the failure probability and the size of the contours:

- Pipeline complies with state-of-the-art technology
- Active reminder
- Warning tape
- In-line inspection
- Extensive measures whereby unacceptable settlement or stress can reasonably be ruled out by means of an evaluation.
- Safety Integrity Level +1

2.4.75. There is only one routing where there are no vulnerable or residential objects within the 10^{-6}/yr contours – the Sluiskil Netherlands route from Terneuzen under the Low volume scenario using a 10-inch pipe.

2.4.76. Regular inspections and maintenance will be critical to ensure pipeline integrity and compliance with future safety requirements. This includes periodic in-line inspections, monitoring for settlement or stress, and adherence to evolving regulatory standards for ammonia pipelines.

Figure 2-16 - Pipeline location-specific risk assessment (2050)



Source: AVIV analysis

2.4.77. The pipeline safety assessments have all been undertaken for the required scenario volumes and only one pipeline route will be needed as it is assumed a MUK pipeline tunnel under the Westerschelde will connect Vlissingen and Terneuzen.

2.4.78. It should be noted that, based on the guidance within the safety calculation guidance, additional pipes of the same diameter and carrying the same volume of ammonia do not imply larger risk contours and have no implications from a safety perspective.

Table 2-4 - Pipeline safety assessment

Route	Very Vulnerable Objects	Vulnerable/ Residential Objects	
		NL	BE
Low Volume Scenario – single 10-inch pipe			
Vlissingen Route	-	-	70
Terneuzen Sluiskil Belgium	-	-	532
Terneuzen Sluiskil Netherlands	-	-	-

Route	Very Vulnerable Objects	Vulnerable/ Residential Objects	
		NL	BE
Central Volume Scenario – single 12-inch pipe			
Vlissingen Route	-	3	88
Terneuzen Sluiskil Belgium	-	4	2,324
Terneuzen Sluiskil Netherlands	-	1	6
High Volume Scenario – single 14-inch pipe			
Vlissingen Route	-	6	198
Terneuzen Sluiskil Belgium	-	5	3,915
Terneuzen Sluiskil Netherlands	-	1	9

Source: AVIV analysis

2.4.79. The societal risk assessment, which does not have any direct implications for permitting, is set out in Appendix E. Without using the crater model, the risk level is well below the guideline level, though is above the guideline level when the crater model is used.

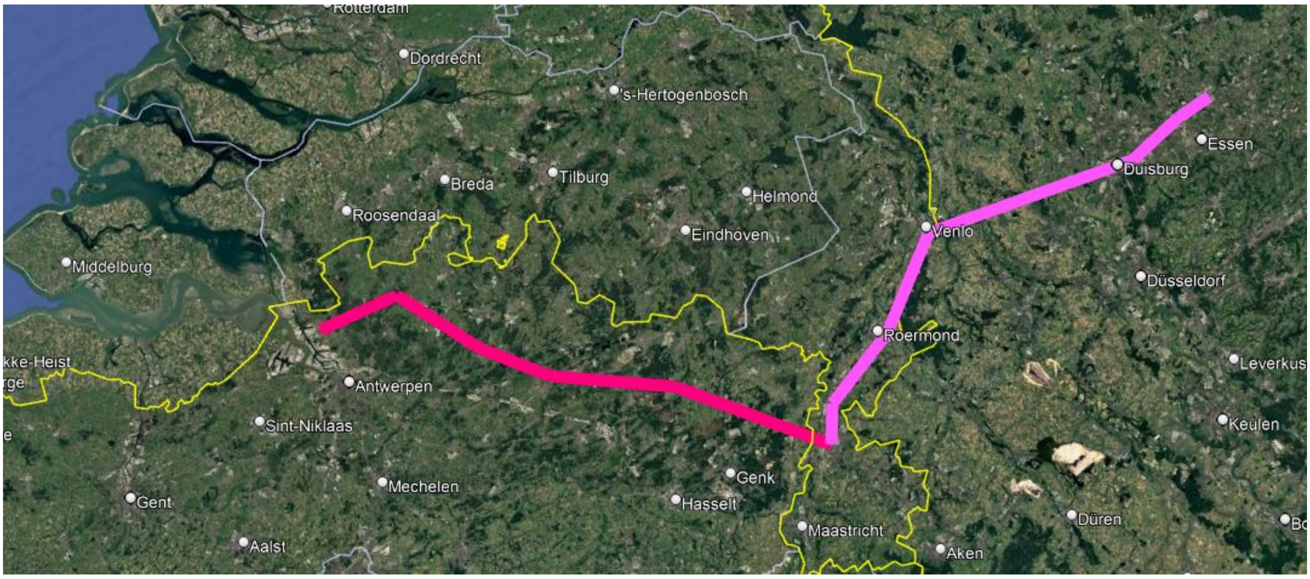
Antwerp - Germany Pipeline Routing

2.4.80. Belgian authorities have been conducting studies for a new pipeline corridor between Antwerp and Geleen. While there is currently no preferred route or advanced plans on pipeline construction, one study[27] considered a route via Wuustwezel, Lille, Geel, Hechtel-Eksel and Geleen, which is shown in Figure 2-17. As part of this study, we have assumed the routing from Antwerp to Geleen shown in Figure 2-17 and a routing from Geleen to Gelsenkirchen following the route of the Delta-Rhine Corridor. The likelihood of this Antwerp–Geleen pipeline being constructed is currently low; it has been included in this study only to estimate indicative distances (km) for potential future routing.

2.4.81. The substances planned for this pipeline corridor are not currently known, though if ammonia is to be transported from the Port of Antwerp to the Ruhr in the future, this pipeline corridor is a likely option given work undertaken to date. Based on the various route options discussed above, we have assumed that the start of the pipeline corridor is near the village of Stabroek at the junction between the A12 and R2 highways. This location is the take-over point between pipeline routes from North Sea Port to Antwerp assessed in detail within this study and the Antwerp-Ruhr pipeline corridor.

[27] Onderzoek naar de ruimtelijke mogelijkheden voor inplanting van een leidingstraat tussen de zeehaven van Antwerpen en het Ruhrgebied (Geleen)

Figure 2-17 – Antwerp-Ruhr pipeline corridor



Source: Google Earth and WSP analysis

2.4.82. The total length of the pipeline corridor between Antwerp and Gelsenkirchen, based on the assumed route shown in the figure above, is estimated to be between 280km and 300km, of which the Antwerp-Geleen section is approximately 110km. For the purposes of the study, we have also assumed the capacity of this ammonia pipeline is 12.5 mtpa (in comparison to 25 mtpa for the Delta Rhine Corridor in the 2024 study), reflecting the relative volumes of likely planned ammonia import capacity at the Port of Rotterdam and the Port of Antwerp.

2.4.83. We have not undertaken an external safety assessment of the Antwerp-Geleen pipeline as this infrastructure is assumed to be pre-existing for the purposes of this study.

3 TRANSPORT COST ASSESSMENT

TRANSPORTATION COST ASSESSMENT SUMMARY

Transport costs were assessed across three modes—rail, inland shipping, and pipeline—using €/tkm as the standard metric. The analysis draws on market data, stakeholder consultations, and previous studies, with costs modelled under multiple volume scenarios.

Rail Transport

Rail transport costs are based on block trains of tank wagons, with an assumed rate of €0.03/tkm, consistent with the 2024 study and KiM benchmarks. This rate reflects operational efficiencies but excludes ancillary charges such as loading and waiting. While rail appears cost-competitive at lower volumes, capacity constraints at NSP terminals and on the wider network limit scalability. Rail costs are sensitive to market conditions and vary by operator, with DB Cargo and Lineas dominating the Dutch and Belgian markets.

Inland Shipping

Inland shipping costs are estimated at €0.06/tkm, reflecting recent CCNR data and KiM studies. These rates are broadly consistent with stakeholder estimates for ammonia transport to destinations like Karlsruhe. However, costs are influenced by seasonal water level fluctuations and port congestion, which can affect reliability and scheduling. Inland shipping remains a viable and politically acceptable option, particularly for medium volumes, but is less cost-effective than pipeline transport at scale.

Pipeline Transport

Pipeline transport is the most cost-effective option for ammonia volumes above 1 mtpa, particularly over the long term. Costs vary by route and volume scenario, with the Sluiskil route from Terneuzen through the Netherlands identified as the lowest-cost option. For the central scenario (3 mtpa), the NSP–Antwerp pipeline has a lifecycle cost of €0.076/tkm, while the Antwerp–Germany pipeline is estimated at €0.052/tkm.

The cost assessment was conducted using the SSK 2018 cost estimation framework (CROW publication 137), applying deterministic business economics principles and drawing on cost data from comparable infrastructure projects. The methodology separates costs into Capital Expenditure (CAPEX) and Operational Expenditure (OPEX). CAPEX includes materials, construction, pump stations, consultancy, and corridor rights. OPEX covers maintenance, power consumption, and annual fees, with lifecycle costs calculated over a 25-year design life.

For the central volume scenario, CAPEX ranges from €128M to €159M, and annual OPEX reaches €6M to €7M once volumes hit 3 mtpa. A 40% risk reserve is included to account for contingencies and unknowns. Costs increase between the central and high scenarios due to the shift from a single pipeline to two smaller-diameter pipes, which is required to comply with safety regulations and reduce risk exposure. Importantly, the use of two pipes does not increase risk contours, as each carries the same volume and diameter, and is assessed independently under the crater model.

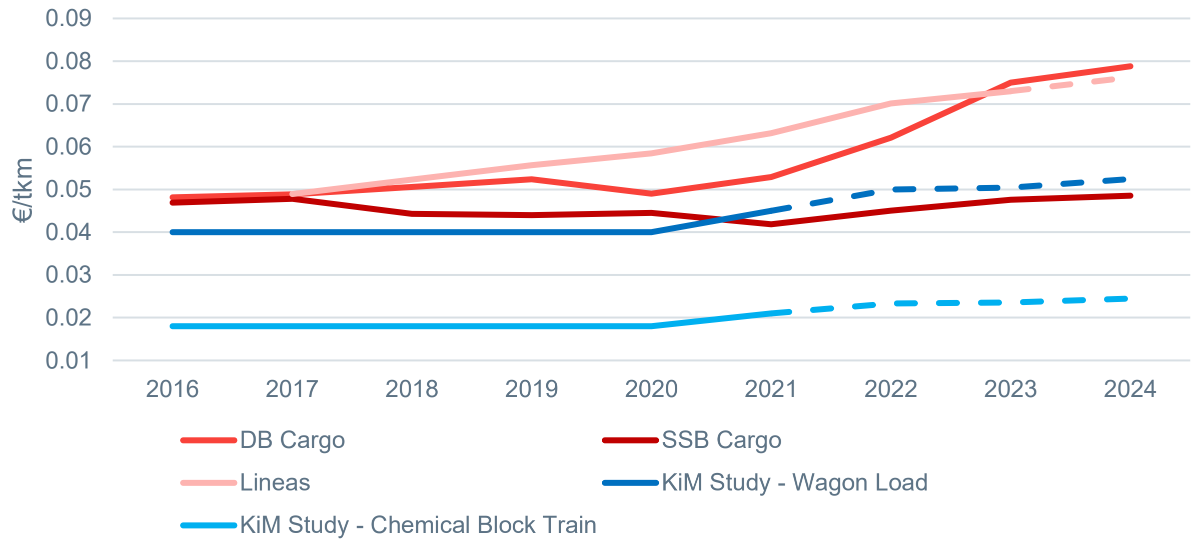
Despite higher upfront investment, pipeline transport offers the lowest cost per tonne-kilometre for large-scale ammonia volumes, with stable long-term operating costs and strong scalability.

Relevant EU and regional subsidy mechanisms have also been highlighted to support future ammonia transport infrastructure development.

3.1 RAIL TRANSPORTATION COSTS

3.1.1. Rail transportation costs shown in the figure below have been estimated on a tonne-kilometre (tkm) basis based on a combination of the freight transport cost study[28] undertaken by the Dutch Knowledge Institute for Mobility Policy (Kennisinstituut voor Mobiliteitsbeleid (KiM)) and a survey of freight rail operators' annual reports. The latest year of the KiM study is 2021, costs shown in subsequent years are 2021 costs inflated by Netherlands CPI.

Figure 3-1 - Rail transportation cost (€/tkm)



Source: KiM & operator annual reports

3.1.2. The KiM study rail considered a generic wagon load, analogous to transporting ammonia on a flat wagon using a tank container, and the cost of transporting chemical products using a block train (i.e. a dedicated train for a single customer and/or commodity), analogous to transporting ammonia using a block train of tank wagons. Within block trains, the cost of transporting chemicals and other liquid bulk goods are around 30% more expensive than transporting dry bulk goods.

3.1.3. The KiM study found the cost of transportation using a block train is cheaper than a single wagon across all commodity types, due to operational efficiencies and economies of scale. The KiM study covers only core transportation costs and does not include additional charges for loading, waiting or other ancillary charges, nor do they include the margin that would be charged to customers.

3.1.4. The estimated rates charged by rail freight operators are based on the average annual revenue per net tkm (i.e. excluding the weight of the rolling stock) for operators where this information is publicly available[29]. DB Cargo and Lineas represent c.50% of the Dutch[30] and Belgian[31] markets

[28] Kostenkengetallen voor het goederenvervoer
[29] Lineas estimated based on reported Belgian market share and operations
[30] Vervoersmonitor 2019
[31] Monitoring Rail Freight Transport 2023

respectively, while all three operators have some operations (c. 2.5-15% market share) across both Belgium and the Netherlands. Unlike operators' standard rates (which are generally not publicly available), the operators' average revenue per tkm represent revenue received from customers, across a mix of block trains and single wagon loads, that take into account additional ancillary charges and discounts for regular long-term customers.

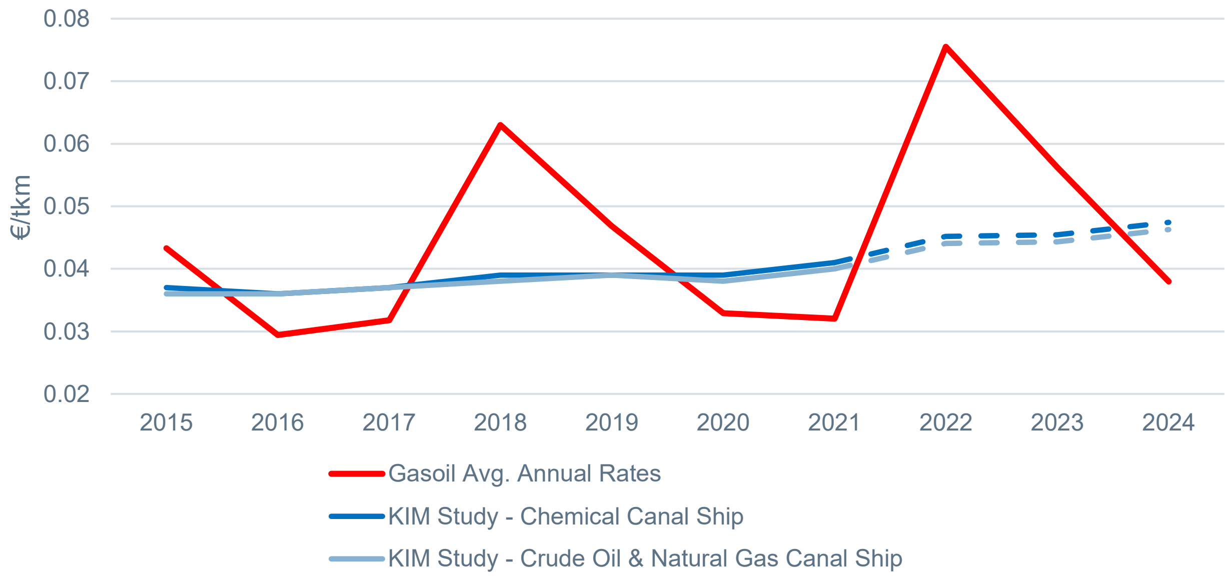
3.1.5. The €/tkm figures are also in line with a recent study[32] undertaken for the European Rail Freight Association, which estimated the average cost of rail freight across Belgium, Germany and the Netherlands was €0.043/tkm in 2019 (€0.054/tkm in 2024 prices).

3.1.6. Within our analysis, we have assumed the cost of transporting ammonia in block trains of tank wagons is €0.03/tkm (the same value used in the 2024 study), reflecting the extrapolated 2024 KiM value, which should be considered a lower bound, and additional cost and charges for loading, waiting and other ancillary costs. Tank container costs have not been estimated as all ammonia is assumed to be transported in block trains.

3.2 INLAND SHIPPING TRANSPORTATION COSTS

3.2.1. Inland shipping transportation costs shown in the Figure 3-1 have been estimated on a tkm basis based on a combination of the freight transport cost study undertaken KiM and gasoil liquid bulk inland shipping rates from the Netherlands the Germany provided by the Central Commission for the Navigation of the Rhine (CCNR). The latest year of the KiM study is 2021, costs shown in subsequent years are 2021 costs inflated by Netherlands CPI.

Figure 3-2 - Annual inland shipping transportation cost (€/tkm)



Source: KiM & Market Insight via CCNR

3.2.2. The KiM study-based estimate the cost of transporting ammonia based on the cost of transporting chemical products on medium-sized inland vessels that can operate on both canals and the river Rhine. No generic container-based costs have been used for inland shipping. As with rail freight, the

[32] The European Rail Freight Market Competitive Analysis and Recommendations

KiM study covers only core transportation costs and does not include additional charges for loading, waiting or other ancillary charges, nor do they include the margin that would be charged to customers.

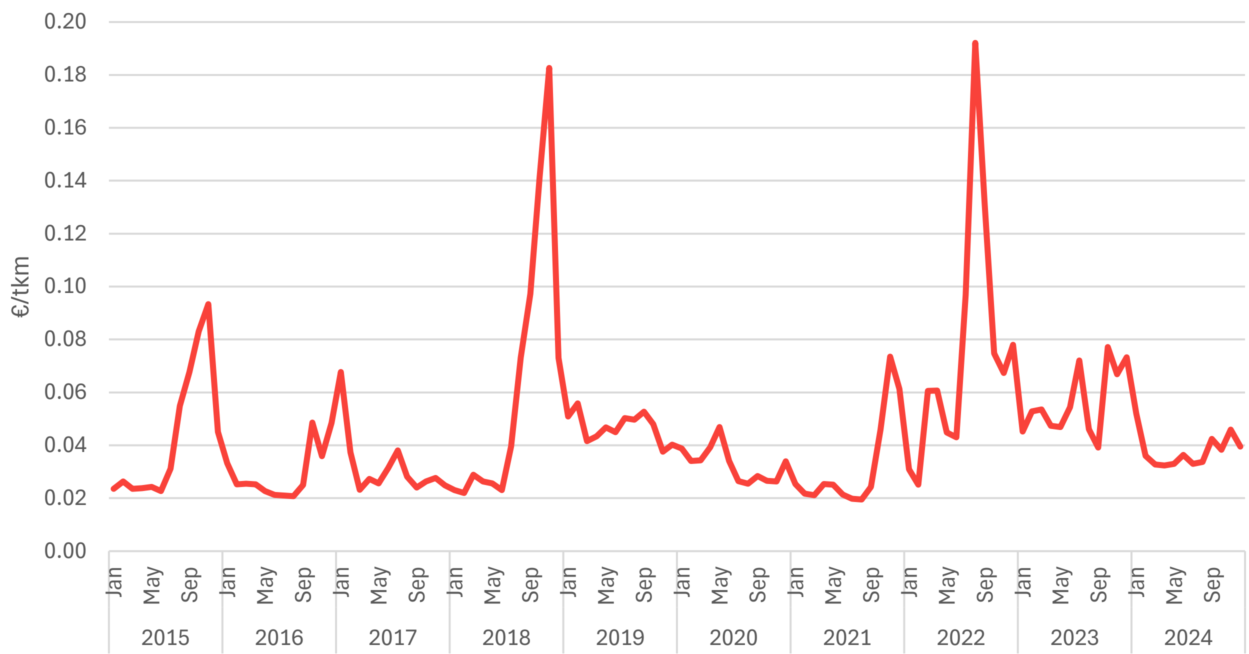
3.2.3. The estimated rates charged by inland shipping freight operators are based on average gasoil shipping rates between the Netherlands and multiple destinations in Germany from Market Insight provided by CCNR. As with rail, unlike operators' standard rates (which are generally not publicly available), the operators' average revenue per tkm represent revenue received from customers that take into account additional ancillary charges and discounts for regular long-term customers.

3.2.4. While gasoil and ammonia transportation rates are not directly comparable, when consulted as part of this study, CCNR stated that the markets for commodities such as ammonia (or commodities transported in similar vessels such as LNG or LPG) are not sufficiently large to generate readily available freight rates.

3.2.5. While some transporting LPG or ammonia in Type G tank barges will incur some additional costs (loading, pressurisation/refrigeration, smaller supply of vessels) many of the rate drivers will be the same as gasoil (journey distance, fuel costs, port congestion, fuel costs, water levels) – the KiM study cost of transporting chemicals is equivalent or marginally above the cost of transporting crude oil and natural gas.

3.2.6. The monthly average gasoil shipping rates between the Netherlands and Germany in recent years are shown in Figure 3-3. For most of the time period shown, rates were €0.04/tkm or lower; however, there have been significant short-term increases in rates caused by lower water levels and capacity constraints.

Figure 3-3 - Monthly gasoil inland shipping transportation cost (€/tkm)



Source: Market Insight via CCNR

3.2.7. Within our analysis we have assumed the cost of transporting ammonia in barges of €0.06/tkm (the same value used in the 2024 study) to reflect the rates in recent years, which have been impacted by supply constraints due to water levels. The liquid bulk rates provided by CCNR are likely to be lower than ammonia inland shipping rates; however, the rates are broadly consistent, on a €/tonne basis, with cost of transporting ammonia from the Netherlands to Karlsruhe based on consultation of stakeholders.

3.3 AMMONIA PIPELINE COSTS

NSP-Antwerp Pipeline

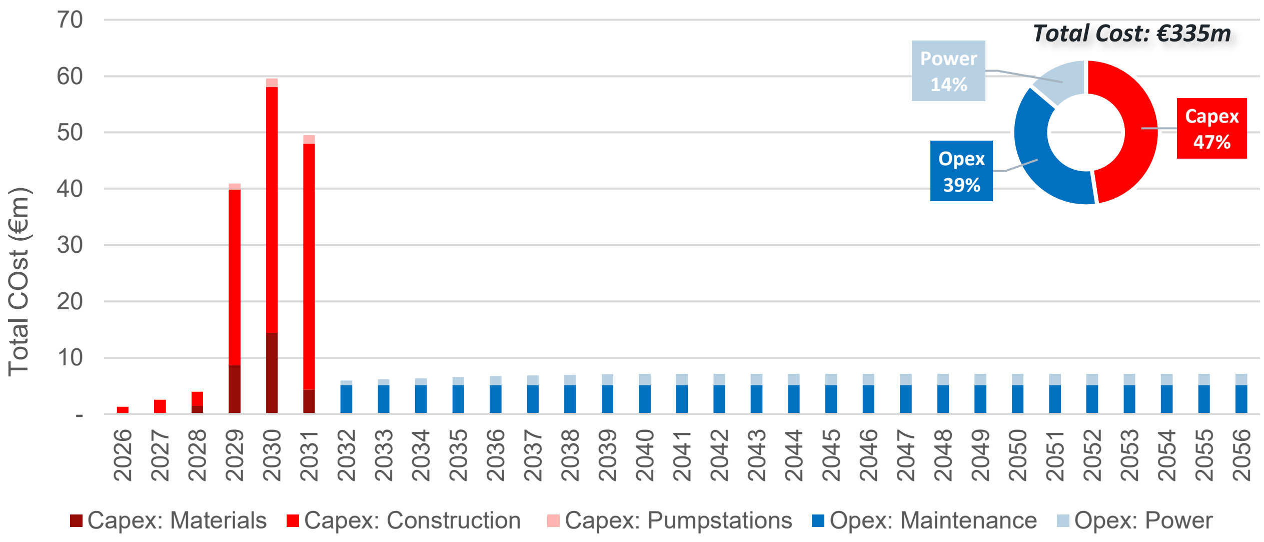
3.3.1. The cost estimate for the construction and lifecycle costs of the proposed ammonia pipeline has been derived based the following approach:

- Using a Standard System for Cost Estimation (SSK) spreadsheet, cost components can generally be categorised into Capital Expenditure (CAPEX) and Operational Expenditure (OPEX).
- CAPEX costs include the initial investment costs for construction of the infrastructure, such as consultancy and design fees, materials costs, labour and one-off property rights fees.
- OPEX costs comprise of primarily maintenance and management costs of the pipeline and pumpstations, and power use of the pumpstations themselves.
- Lifecycle costs (including maintenance, ongoing fees, power use etc.) have been derived assuming an infrastructure design life of 25 years, based on the general economic lifetime of gas pipelines between 20 till 50 years.
- Assuming a 6 year design and construction phase.
- Costs include a risk reserve of 40%, as is consistent with cost estimation as this stage.
- Cost have been estimated across the four volumes scenarios set out in Chapter 1.

3.3.2. Cost estimation assumptions and breakdowns are set out in more detail in Appendix B.

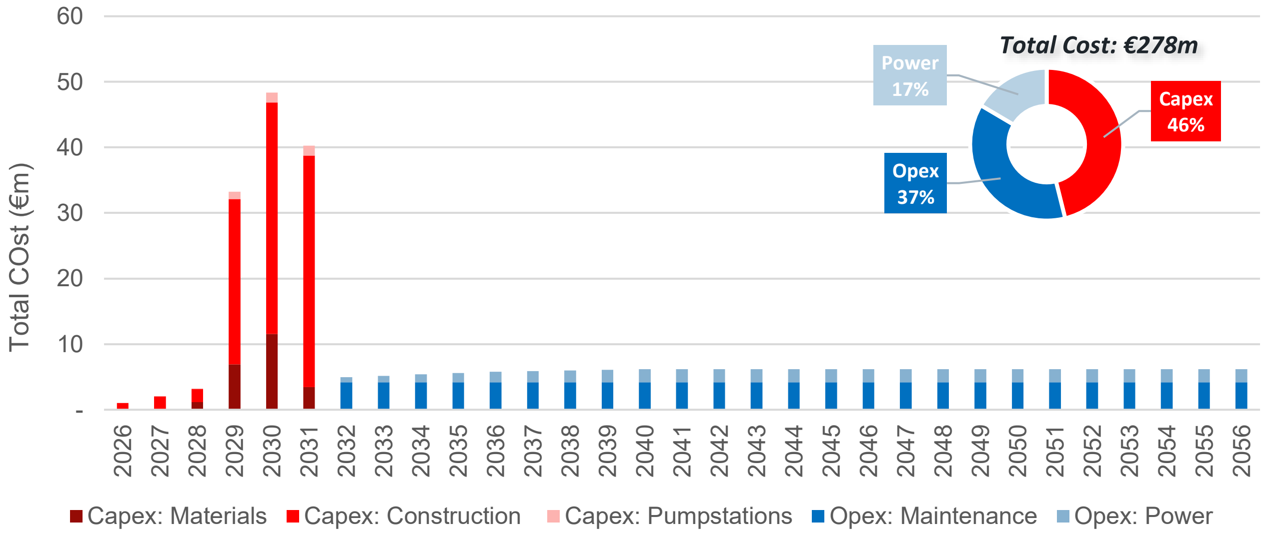
3.3.3. The profile of costs under the central volume scenario for each of the three pipeline routes are shown in the figures below. The upfront capital costs are estimated at between €118 million and €159 million and the annual operating costs will reach between €6 million and €7 million once ammonia volumes have reached 3 mtpa.

Figure 3-4 - Total Pipeline Costs – Belgian Sluiskil Route



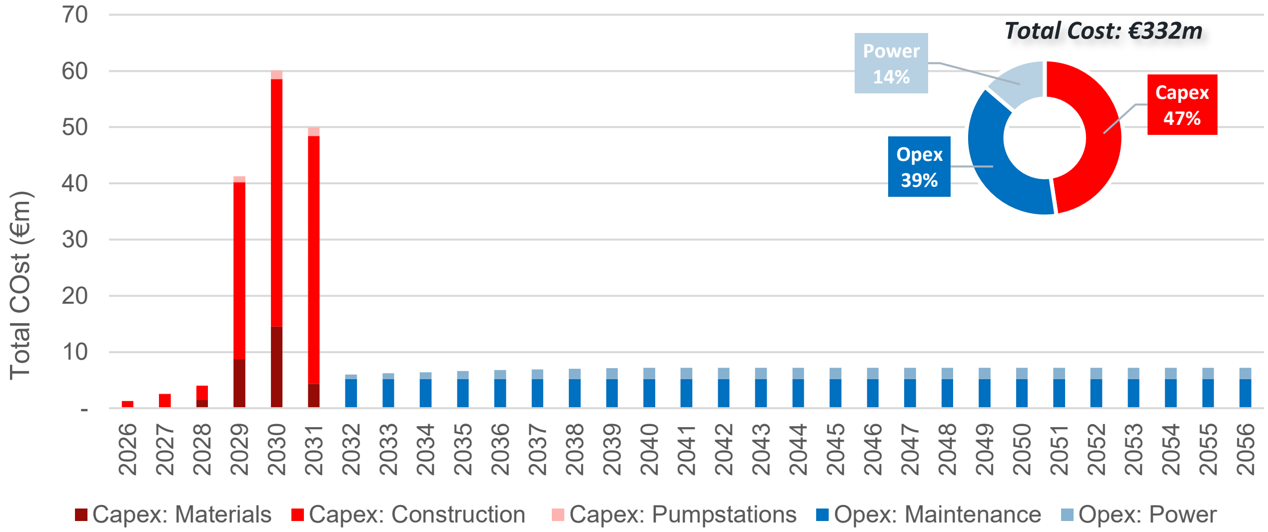
Source: WSP Analysis

Figure 3-5 - Total Pipeline Costs – Netherlands Sluiskil Route



Source: WSP Analysis

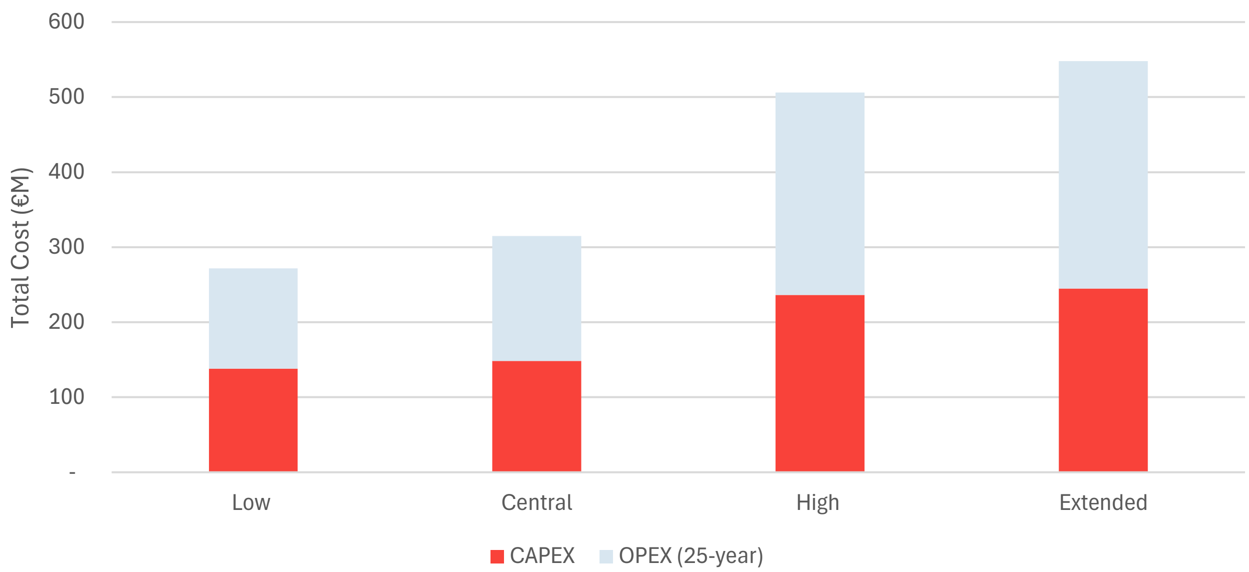
Figure 3-6 - Total Pipeline Costs – Vlissingen Route



Source: WSP Analysis

3.3.4. The average total Opex and Capex costs across the three routings are shown in Figure 3-7. Costs increase with increasing ammonia volumes, though step up from the Central to High scenario due to the move to two pipes.

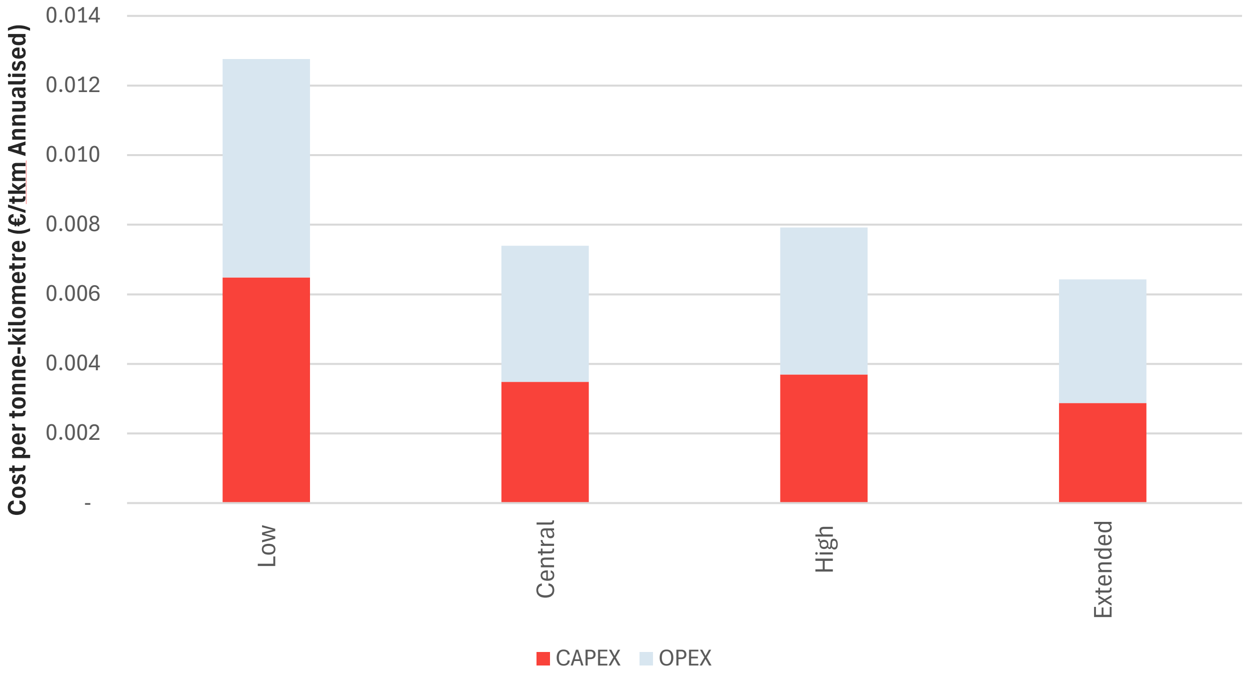
Figure 3-7 - Pipeline Routings Average Total Cost



Source: WSP Analysis

3.3.5. The average €/tkm cost across the three routings are shown in Figure 3-8. Across volume scenarios, there is a significant reduction in €/tkm cost between the low and central scenarios due high fixed costs and economies of scale associated with transporting larger volumes. From the central to high scenario, the increase in €/tkm costs is driven by the need for an additional pipe, with scale economies driving the reduction in the €/tkm cost between the high and extended scenario.

Figure 3-8 – Average Pipeline Cost per TKM



Source: WSP Analysis

Antwerp-Germany Pipeline

3.3.6. In addition to the costs of the pipeline from NSP to the Port of Antwerp, to transport ammonia from NSP to Germany will require usage charges to be paid for the pipeline from Antwerp to Germany. As discusses in Chapter 2, this pipeline is still in the early stages of development but for the purposes of this study we have assumed the pipeline will have a capacity of 12.5 mtpa and a distance of 300km. Extrapolating the €/tkm costs from scenarios (excluding the low scenario) within Figure 3-8 above implies a cost of €0.052/tkm for a 300km 12.5 mtpa pipeline, equivalent to around €4.9 billion.

3.3.7. The charging structure of the pipeline is also not currently known; however, we have estimated usage charges based on the approach generally used for regulated energy and transport infrastructure (and the proposed charging structure for the European Hydrogen Backbone, described in more detail within the 2024 study), whereby infrastructure operators are permitted to charge uses for costs and a permitted weighted average cost of capital (WACC). We have also assumed both entry and exit fees (i.e. all costs) are paid by users.

3.3.8. Within our 2024 study, we used a WACC of 4.0% applied to annualised capex cost (based on asset life) to estimate the access charge for the Delta Rhine Corridor based on initial plans[33] on how the European Hydrogen Backbone will be charged within the Netherlands. Based on the 2024 study and

[33] Hydrogen State of Play

a recent regulatory determination[34] for electricity and gas Distribution System Operators (DSOs) in Flanders, we have used a WACC of 4.2% for this study.

Table 3-1 - Estimated Antwerp-Germany Pipeline Charge

Cost/Charge	Unit	Capex & Opex	WACC	Total
Total Cost	€m	4,101	791	**4,893**
Annual Cost	€m	164	32	**196**
Annual Unit Charge	€/tonne	13.1	2.6	**15.7**

Source: WSP Analysis

3.3.9. The NSP–Antwerp section has a higher €/tkm because it is a shorter route with high fixed costs for new infrastructure and complex port-area construction, whereas the Antwerp–Germany segment benefits from greater length and higher assumed capacity, allowing economies of scale to reduce its unit cost.

[34] The WACC for the Flemish DSOs for the regulatory period starting in 2025

3.4 SUBSIDIES

3.4.1. The following table provides an overview of major public funding programmes and subsidy mechanisms relevant to ammonia and hydrogen transport infrastructure across the EU, the Netherlands, and Belgium. Each entry summarises the fund's scope, eligibility criteria, project coverage, and example funded projects, with a specific focus on their applicability to the NSP pipeline study. This comparative overview is intended to support project sponsors and stakeholders in identifying potential sources of financial support for infrastructure development, feasibility studies, and innovation pilots along the Sloehaven–Antwerp–Germany corridor.

Name	Location	Description	Funding Scope	Project Coverage	Example Funded Projects	Applicability to NSP study
EU Innovation Fund (Large-Scale Projects)	EU	This is one of the EU's largest funding programs for climate innovation, financed through revenues from the Emissions Trading System (ETS). It supports first-of-a-kind commercial demonstrations of low-carbon technologies. For ammonia transport, it is relevant when infrastructure (like pipelines) enable significant greenhouse gas (GHG) reductions—such as transporting ammonia into locations where it can be used for industrial use.	The fund is estimated to have a total budget of €40 billion.	The subsidy can cover up to 60% of eligible costs, paid in milestones.	**ENHANCE (Belgium):** European Network for Hydrogen and Ammonia Carbon-Neutral Energy – includes RFNBO ammonia transport and liquefaction of renewable hydrogen.	Applicable if ammonia transport infrastructure—via pipeline, barge, or rail—enables measurable GHG reductions. For example, transporting ammonia to industrial sites along the corridor for use in decarbonisation could qualify if it meets the Innovation Fund's criteria for climate impact and novelty.
Connecting Europe Facility (CEF)	EU	The Connecting Europe Facility (CEF) provides subsidies (grants) for trans-European infrastructure projects in energy, transport, and digital sectors for the 2021-2027 period. Projects must be designated as Projects of Common or Mutual Interest (PCIs/PMIs) under the Trans-European Networks (TEN) policy. The Energy stream (CEF-E) can support hydrogen pipelines, storage, and terminals. However, the projects must be on designated as one of the EU's Projects of Common or Mutual Interest (PCI). For the 2021-2027 funding period, a new category of eligible projects was introduced for cross-border	€1.25B total, with €258M allocated to hydrogen projects.	30–50% of project costs; includes both studies and construction.	**AmplifHy ammonia terminal (Antwerp):** Ammonia terminal supporting hydrogen distribution. **Brunsbüttel hydrogen terminal (Germany):** Hydrogen terminal for clean fuel imports. **Delta Rhine Corridor pipeline studies:** Feasibility studies for cross-border hydrogen pipelines.	Applicable if the infrastructure is designated as a Project of Common or Mutual Interest (PCI/PMI) under the Trans-European Networks (TEN-E or TEN-T). Cross-border transport infrastructure—such as pipelines or rail for ammonia—between the Netherlands and Belgium may qualify under the energy or transport stream,

		projects in the field of renewable energy. The Transport stream (CEF-T) funds alternative fuel infrastructure, which can include hydrogen refuelling stations for rail and ports. Ammonia infrastructure is eligible when it supports hydrogen distribution or bunkering.				especially if it supports hydrogen distribution.
Horizon Europe & Clean Hydrogen Partnership	EU	This is the EU's main R&D funding programme. It supports research and demonstration projects, including those involving ammonia as a hydrogen carrier. The Clean Hydrogen Partnership (a public-private initiative under Horizon) has supported various pilot initiatives exploring the use of ammonia in maritime applications. Funding opportunities are announced through official Clean Hydrogen Partnership calls, published on the EU Funding and Tenders Portal and the Clean Hydrogen Partnership website.	€2–15M available per project. €184.5M allocated for the 2025 call for proposals.	50-100% of project cost's depending on type (research vs innovation).	**MAGPIE ammonia bunkering pilot (Rotterdam):** Demonstrated ammonia bunkering at Port of Rotterdam. **H2Ports fuel cell barge (Valencia):** Hydrogen-powered barge pilot in Valencia. **HyFlow hydrogen train trials:** Pilot trials of hydrogen-powered trains.	Applicable for early-stage innovation and feasibility studies focused on ammonia transport between Sloehaven and Antwerp. Not suitable for full-scale infrastructure, but useful for validating transport concepts and safety protocols.
Important Projects of Common European Interest (IPCEI)	EU	IPCEI includes cross-border infrastructure, research and development, and first industrial deployment projects in areas aligned with the EU's Green and Digital Agendas, such as microelectronics, batteries, hydrogen, cloud computing, and health. These large-scale, strategically important projects require substantial upfront investment and aim to overcome market failures by fostering innovation and creating positive spillover effects for the entire European economy. The IPCEI covers the entire hydrogen value chain, from production and import to transport and end-use, supporting the transition to renewable energy. Projects involving green and blue ammonia and its use in the hydrogen value chain are included.	€6.9B in public funds across seven EU member states.	Up to 100% of the funding gap for eligible infrastructure.	**Puertollano Green Hydrogen Plant (Spain):** Produces green hydrogen for Fertiberia's ammonia and fertilizer plant using solar-powered electrolysis. **Ver-Amonia Initiative (Utrillas, Spain):** Developing a 25 MW electrolysis plant and Haber-Bosch system to produce 15,000 t/year of green ammonia for fertilizer use.	Applicable only if the IPCEI Commission determines that the project will benefit citizens across the EU and contribute to the creation of markets that work for people.
Recovery and Resilience Facility (RRF)	EU	Part of the EU's post-COVID recovery plan (NextGenerationEU), the RRF provides grants to member states for green and digital transitions. Several countries have used RRF funds to co-finance hydrogen infrastructure, including ammonia import terminals and	€650 billion total investment in reforms and projects, including €359 billion in grants	Varies by country, often co-finances infrastructure.	**Belgium's 150 km H_2 pipeline:** Hydrogen pipeline funded under Belgium's recovery plan. Portugal's hydrogen valley: Integrated hydrogen	Unlikely to be applicable. While the RRF has allocated funding to support green and digital transitions, including hydrogen infrastructure,

		pipelines. While not ammonia-specific, the RRF supports near-term infrastructure that facilitates ammonia-based hydrogen transport. To benefit from this support, EU governments have submitted national Recovery and Resilience Plans outlining the reforms and investments they will implement by the end of 2026, with clear milestones and targets.	and €291 billion in loans allocated across EU member states.		ecosystem in Portugal. **Poland's hydrogen import terminal:** Hydrogen import terminal co-financed by RRF.	current national Recovery and Resilience Plans (RRPs) for countries like the Netherlands and Belgium do not include provisions for the NSP study. To benefit from RRF support, these governments would need to apply for amendments to their existing RRPs. Additionally, the RRF mid-term evaluation took place in 2024, with the ex-post evaluation scheduled for 2028, making direct funding for the NSP study improbable within the current RRF framework.
InvestEU	EU	Provides guarantees and co-financing for sustainable infrastructure, innovation, and climate-related projects. InvestEU builds on EFSI and works with implementing partners like the EIB and national promotional banks. It supports hydrogen and clean fuel infrastructure, including ammonia-related assets when aligned with EU decarbonization goals. At least 30% of the InvestEU Programme, in line with the European Green Deal objectives, shall support financing for investments that contribute to the EU's climate objectives. Moreover, 60% of the investments supported under the "Sustainable Infrastructure Window" of the InvestEU Fund shall contribute to EU's climate and environmental objectives.	€26.2 billion in guarantees expected to mobilize over €372 billion in investments.	Guarantees can cover up to 50% of project risk; co-financing varies by sector and partner.	**BlueInvest marine infrastructure:** EU-backed marine sustainability infrastructure. **Nature-based hydrogen corridor advisory:** Advisory services for hydrogen corridors using nature-based solutions.	Potentially applicable if the NSP study aligns with EU climate and environmental objectives and is eligible under the Sustainable Infrastructure Window. However, applicability depends on whether the project meets InvestEU's criteria and is supported by implementing partners such as the EIB or national promotional banks.
European Regional Development Fund (ERDF)	EU (Regional – Belgium, Netherlands)	Provides co-financing for regional development, innovation, and clean transport and energy infrastructure. The European Regional Development Fund (ERDF) is managed at the regional level, allowing authorities in areas such as Flanders and Wallonia to tailor funding to local sustainability and industrial decarbonization priorities. It supports hydrogen and ammonia transport	€226 billion allocated for 2021–2027 across EU regions.	Typically 40–60% of eligible costs; higher rates possible in less developed regions.	**Antwerp-Ghent pipeline:** Pipeline connecting Belgian industrial zones. **HyOffWind electrolyser (Zeebrugge):** Electrolyser project for green hydrogen. **Flanders port hydrogen upgrades:** Infrastructure	Potentially applicable if the NSP study aligns with regional sustainability and industrial decarbonization priorities. ERDF is managed at the regional level, giving authorities in Flanders and Wallonia the flexibility to support

		infrastructure when aligned with regional and EU climate goals. In Flanders, ERDF calls have focused on strategic investments for a smart and sustainable future, while Wallonia has leveraged ERDF to co-finance clean energy projects. This regional autonomy makes ERDF particularly relevant for ammonia-related infrastructure in these areas.			upgrades for hydrogen handling.	ammonia-related infrastructure when it contributes to local development goals. However, applicability depends on whether the NSP study is included in regional funding calls and meets the criteria set by the managing authorities.
National Hydrogen Backbone Investment	Netherlands	Public financing for the Dutch national hydrogen pipeline network, led by Gasunie through its subsidiary Hynetwork. The backbone will repurpose ~85% of existing natural gas pipelines and add new segments, totalling ~1,200 km. It will connect five industrial clusters and link to Germany and Belgium. The first segment in Rotterdam is expected by 2026, with full rollout across clusters—including the Delta Rhine Corridor—by 2033. The network is designed as open-access infrastructure with regulated tariffs, enabling ammonia-derived hydrogen to benefit from reduced CAPEX and affordable transport fees.	€1.5–2B allocated by the Dutch government.	Full subsidy if aligned with Gasunie's national plan.	**Delta Corridor pipeline:** Pipeline corridor connecting Dutch industrial clusters. **Rotterdam pipeline repurposing:** Repurposing pipelines for hydrogen in Rotterdam. **Gasunie H_2 backbone:** National hydrogen pipeline network.	While ammonia-derived hydrogen could benefit from the backbone, the NSP study is not currently included in the Dutch national hydrogen network strategy. To be eligible, the project would need to be formally connected through future amendments to the strategy, which was last revised in December 2024 and submitted to the Ministry for Climate Policy and Green Growth.
SWIM - Stimuleringsregeling Waterstof in Mobiliteit or Hydrogen in Mobility Study	Netherlands	Competitive grant program supporting hydrogen mobility infrastructure. SWIM funds partnerships between hydrogen refuelling station operators and transport companies to deploy hydrogen-powered vehicles and build or upgrade refuelling stations. While primarily focused on road transport, some stations may be adapted to serve hydrogen-powered inland vessels or trains. If ammonia is used as a hydrogen carrier and cracked at the station, the program indirectly supports ammonia infrastructure.	€40M allocated for 2025.	Up to €7M per project.	**23 public H_2 stations**: Hydrogen refuelling stations across the Netherlands. **200+ hydrogen vehicles:** Fleet of hydrogen-powered vehicles. **Inland vessel refuelling pilot:** Refuelling pilot for hydrogen-powered vessels.	Indirectly applicable. The SWIM program does not directly fund ammonia infrastructure, but if ammonia is cracked to hydrogen for use in mobility applications, the resulting refuelling stations and vehicle deployments may form part of the enabling ecosystem.
Support for Ports and Shipping	Netherlands	Public and EU-backed grants supporting ammonia bunkering and import terminal infrastructure in Dutch ports, particularly Rotterdam. These projects are funded through targeted innovation programs such as DKTI,	Hundreds of millions via Climate Envelope and	Varies, for example €3M for floating	**Ammonia bunkering pilot (Rotterdam):** Pilot for bunkering ammonia at Dutch ports. **Floating ammonia plant:**	The infrastructure being investigated within this study will not be not eligible for direct funding under these programs. However,

		MOOI, and the Climate Envelope, and may also receive co-financing from EU instruments like CEF and Horizon Europe. The funding is project-specific and awarded through competitive calls, making it a direct subsidy mechanism for eligible infrastructure. These initiatives aim to enable safe handling and fuelling of ammonia for maritime use, making them directly relevant to barge and terminal infrastructure.	innovation programs.	ammonia plant.	Floating facility for ammonia storage and fuelling. **DKTI-funded port terminal:** Port terminal funded under Dutch innovation program.	it may enable future infrastructure—such as bunkering terminals or barge networks—that could attract investment through targeted innovation grants and EU co-financing.
Hydrogen Production Subsidies	Netherlands	These are public subsidies for green hydrogen production through schemes like OWE (Offshore Wind Electrolysis) and H2Production, aimed at scaling up domestic hydrogen supply. These programs do not directly fund transport infrastructure but play a critical enabling role by ensuring hydrogen availability, which increases utilization of ammonia import and distribution networks. Projects are selected through competitive calls and must align with national decarbonization goals.	€750M (OWE), €838M (H2Production).	Up to €838M per project.	**H2 Hollandia:** Green hydrogen production project. **Eemshydrogen:** Hydrogen production facility in Eemshaven. **NorthH2 electrolyzer cluster:** Large-scale electrolyzer cluster for green hydrogen.	The infrastructure within the scope of this study itself is not eligible for direct funding under these production subsidies. However, it may enable downstream infrastructure—such as ammonia import terminals or distribution pipelines—that benefit from increased hydrogen availability and utilization driven by these programs.
H2 Import Call Subsidy	Belgium	Targeted federal grant program supporting early-stage hydrogen import infrastructure at Belgian ports. The €10 million call co-finances feasibility studies and pilot projects for ammonia reception, storage, and cracking. Though modest in size, the program provides direct subsidies to help de-risk initial investments in hydrogen and ammonia terminal infrastructure.	€10M total.	Up to €2–5M per project.	**Antwerp-Bruges terminal:** Ammonia import terminal in Belgium. **Zeebrugge cracking unit:** Facility for cracking ammonia into hydrogen. **Feasibility study for ammonia reception:** Study for ammonia import infrastructure.	The infrastructure within the scope of this study will not be eligible for direct funding under this program. However, it may enable future infrastructure—such as ammonia terminals or cracking units—that could attract investment through similar federal calls.
Regional Support (Flanders/Wallonia)	Belgium	Innovation grants and infrastructure support from the Flemish and Walloon regional governments, including programs like VLAIO and regional co-financing for IPCEI projects. These initiatives fund hydrogen and ammonia infrastructure such as port pipelines, electrolyzers, and pilot projects. Regional support complements EU-level funding and	€173M via Important Projects of Common European Interest (IPCEIs).	20–50% co-funding.	**HyOffWind electrolyzer:** Electrolyzer project in Zeebrugge. **Antwerp-Ghent pipeline:** Hydrogen pipeline connecting Belgian ports. **VLAIO pilot ammonia project:** Pilot ammonia	The infrastructure being investigated within this study is not eligible for direct regional funding. However, it may enable future infrastructure—such as pipelines or terminals—that could attract

		plays a key role in advancing ammonia transport infrastructure in industrial zones like Antwerp, Ghent, and Zeebrugge.			infrastructure project funded by VLAIO.	investment through regional innovation grants or co-financing programs in Flanders and Wallonia.

4 ECONOMIC FEASIBILTY ASSESSMENT

ECONOMIC FEASIBILITY ASSESSMENT SUMMARY

This section evaluates the long-term cost-effectiveness of pipeline transport compared to rail and inland shipping, focusing on unit costs, investment viability, and sensitivity to key variables.

Modal Cost Comparison

Average transport costs per tonne-kilometre (€/tkm) were benchmarked across modes to provide a high-level comparison of cost structures, not a like-for-like competitiveness ranking.

- Rail: €0.030/tkm
- Barge: €0.060/tkm
- NSP–Antwerp Pipeline: €0.076/tkm
- Antwerp–Germany Pipeline: €0.052/tkm

These values reflect fundamentally different cost bases:

- Rail and barge figures represent operational €/tkm charges only, which scale with distance and usage.
- Pipeline figures represent full lifecycle costs, combining capital investment with long-term operating expenditure amortised over the assumed design life.

As a result, pipeline appears more expensive on a €/tkm basis when viewed in isolation but becomes cost-competitive at higher volumes due to economies of scale and the low marginal cost of additional throughput. The figures presented are representative and intended only for broad comparison rather than direct ranking between modes.

Four transport scenarios were assessed:

- Rail: all volumes transported by rail
- Barge: all volumes transported by barge
- Constrained Allocation: rail used up to capacity, excess volumes by barge
- Mix: 25% rail, 75% barge

Economic Turning Point

The turning point is the volume at which pipeline transport becomes more cost-effective than other modes:

- Barge: Pipeline becomes more cost-effective at 1.1 million tonnes per annum (mtpa)
- Mix: Pipeline becomes more cost-effective at 1.8 mtpa
- Constrained Allocation: Pipeline becomes more cost-effective at 3.3 mtpa
- Rail: Pipeline never becomes more cost-effective; rail appears cheaper (€0.030/tkm vs. €0.076/tkm for pipeline), but is limited by infrastructure and policy constraints

The analysis assumes NSP terminal operators bear full pipeline investment and operating costs, while the Antwerp–Germany pipeline is treated as a shared asset with access charges.

Investment Payback Period

The study also assesses the pipeline's investment payback period under the central volume scenario. The results show that in most transport scenarios, the pipeline achieves payback within its 25-year design life, owing to the stability of pipeline operating costs once steady flows are reached.

The Constrained Allocation scenario is the only case where the payback period extends beyond 25 years. This is because the scenario assumes that rail and inland shipping continue to accommodate a substantial share of ammonia volumes over the long term. As set out elsewhere in the report, this would require ongoing access to rail wagons, train paths and terminal capacity, as well as a consistent supply of specialised barges and trained crews — all of which face competition from other commodities and corridors.

These factors illustrate that the long-term competitiveness of pipeline transport depends not only on cost but also on the availability of alternative modes.

This study applies a 25-year design life because this is the standard assumption used in pipeline design. In practice, with proper asset management and maintenance, pipelines often remain in safe operation for several decades longer, and many have operated for more than 70 years, further strengthening the long-term viability of pipeline transport.

Sensitivity Analysis

The feasibility is most sensitive to:

- Mix: Most sensitive to barge transport costs, followed by Antwerp–Germany pipeline access charges and pipeline CAPEX/OPEX, with ±10% changes shifting payback by up to ±7.9 years and turning point by ±0.92 mtpa.
- Barge: Highly sensitive to barge cost assumptions, where ±10% changes significantly alter the pipeline's relative advantage and payback period.
- Constrained Allocation: Sensitivity driven by rail capacity limits and barge costs, with moderate impact from pipeline investment variables.
- Rail: No meaningful sensitivity observed as pipeline never becomes more cost-effective; however, rail capacity and policy constraints remain critical non-cost factors.

Changes of ±10% in these variables significantly affect both the economic turning point and investment payback period, underscoring the importance of accurate forecasting and market stability.

4.1 MODAL COST COMPARISON

4.1.1. Based on the assumptions described in the previous chapters, the unit ammonia transport costs for each mode used within the economic feasibility assessment in the remainder of this chapter are shown in Table 4-1. The NSP-Antwerp pipeline costs are those under the central volume scenario for the Sluiskil route from Terneuzen through the Netherlands, which is the shortest and lowest cost route.

Table 4-1 - Unit ammonia transportation costs (€/tonnekm)

Mode	€/tkm
Rail	0.030
Barge	0.060
NSP-Antwerp Pipeline	0.076
Antwerp-Germany Pipeline	0.052

Source: WSP Analysis

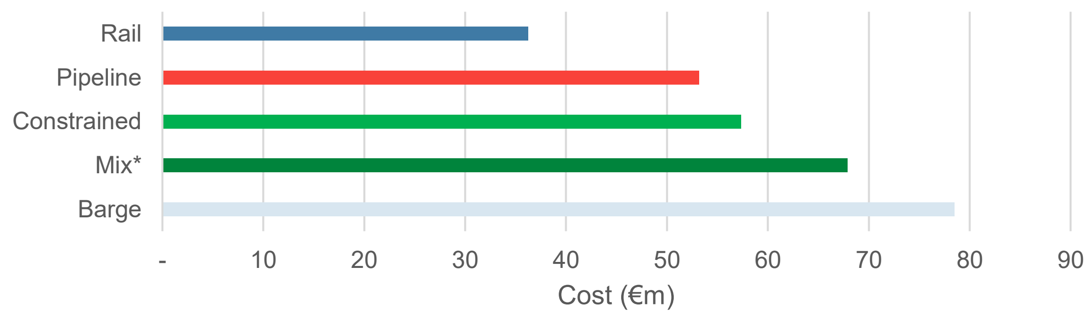
4.1.2. In reality ammonia transportation costs are likely to fluctuate and will be driven by a number of market, distance and operational factors; the figures used within our assessment are illustrative figures used for a high-level comparison of costs across different modes. Based on conversations with stakeholders, and the recent Royal Haskoning DHV study for the Port of Rotterdam, our understanding is that the absolute costs and relative comparisonof the costs between modes are representative at an industry-wide level.

4.1.3. The transportation scenarios included within the assessment and compared with the pipeline cost are as follows:

- 'Rail', where all volumes are transported by rail.
- 'Barge', where all volumes are transported by barge.
- 'Constrained Allocation', where all volumes are transported by rail up to the point where the rail capacity constraint (described in Chapter 2) is reached, and all volumes above this are transported by barge.
- 'Mix', where 25% of volumes are transported by rail and 75% are transported by barge.

4.1.4. A comparison of total annual transportation costs post-2040 once demand ramped up for each mode is shown in Figure 4-1, assuming a 25-year economic life for pipelines.

Figure 4-1 - Annual transportation cost comparison (peak demand, central volume scenario)



**Mix: Rail 25%, Barge 75%*
Source: WSP Analysis

4.1.5. The comparison shown in Figure 4-1 is based on the **Central Volume Scenario**, which assumes a single 12-inch pipeline and corresponding transport volumes as defined in Chapter 2.

4.2 ECONOMIC TURNING POINT

4.2.1. One of the objectives of the economic feasibility assessment is to identify the 'turning point' volume at which it is more cost effective to transport ammonia by pipeline than by rail or barge. The turning point arises because an ammonia pipeline will have high initial investment costs but relatively low ongoing operational costs, whereas some other modes have little to no initial investment costs but higher ongoing operational costs.

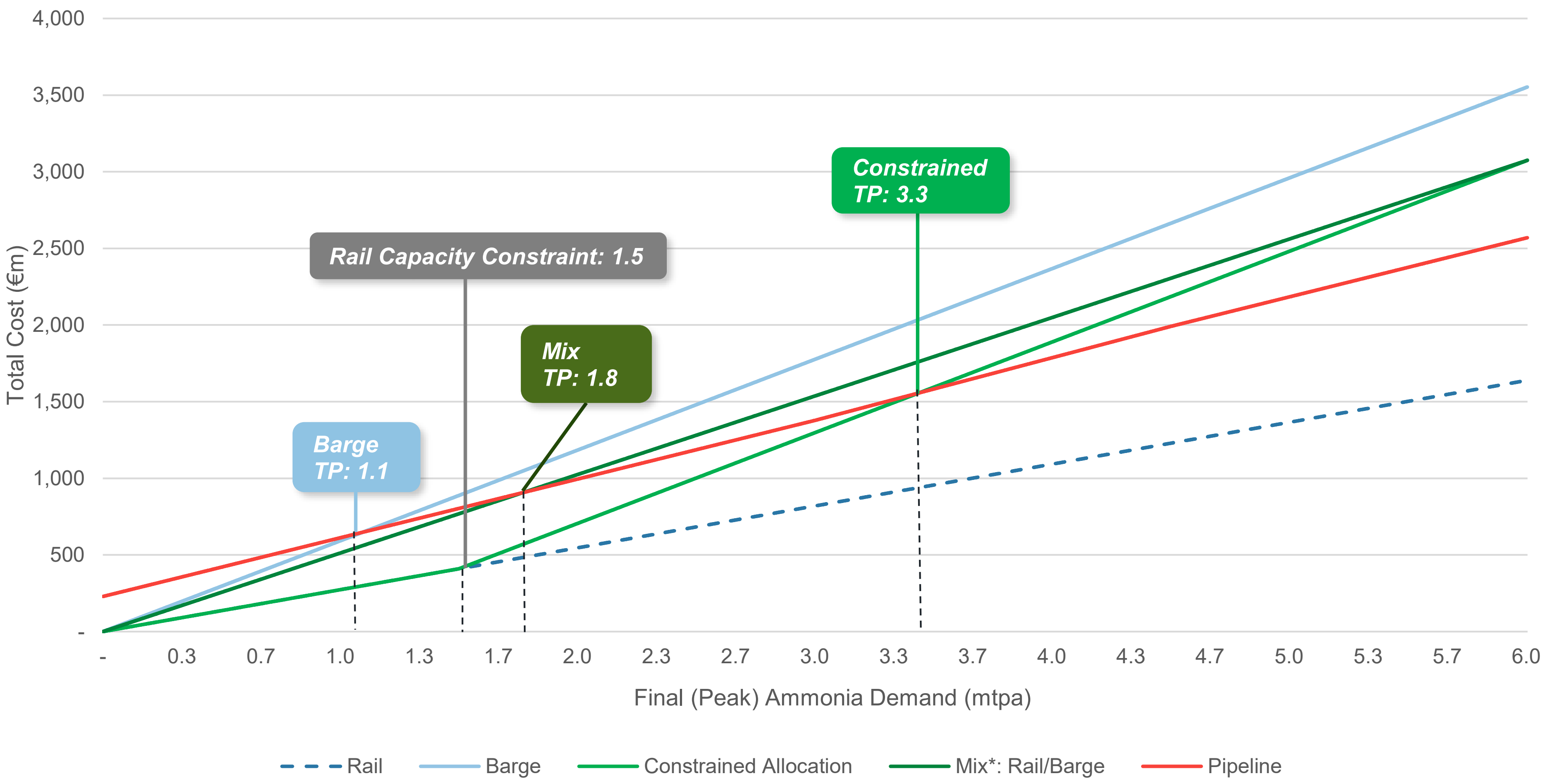
4.2.2. Were a pipeline from NSP to the Port of Antwerp to be constructed, it is currently unclear how and by which public and private sector parties the project would be financed, owned, operated and charged to users. It is possible that NSP operators using such a pipeline would only pay a pipeline access charge and incur no upfront investment costs, which would imply no economic turning point as the transportation costs for modes would increase in with volumes (where no volume implies no costs).

4.2.3. Therefore, as the pipeline feasibility and cost assessment assume the pipeline would serve only NSP terminal operators, all pipeline investment and operational costs have been included within the economic turning point assessment (the Antwerp-Germany pipeline uses an access charge approach as this study assumes this pipeline would also be used by other users). The economic feasibility assessment should therefore be viewed as an assessment of the turning point and pipeline viability for the wider ammonia industry and value chain, rather than pipeline owners/operators NSP terminal operators.

4.2.4. The final demand volume (based on the demand profile discussed in Chapter 2) at which it is more cost effective to transport ammonia by pipeline versus each of the transportation scenarios (based on average cost) are shown in Figure 4-2. Compared to the 'Barge' and Mix scenarios, the turning point is below the Low volume scenario at around 1 mtpa, compared to the 'Constrained Allocation' scenario the turning point is slightly above the Central volume scenario of 3 mtpa.

4.2.5. Compared to rail there is no turning point as rail is significantly cheaper than pipeline transport; however, as has been discussed above, capacity and policy constraints mean this scenario is highly unlikely in practice.

Figure 4-2 - Economic Turning Point: Turning Point Volume



**Mix: Rail 25%, Barge 75%*
TP – Turning Point
Source: WSP Analysis

The graph illustrates the economic turning point — the volume of ammonia transport (in mtpa) at which pipeline becomes more cost-effective than alternative modes, based on total transport costs (€/tN). Each turning point (e.g. “TP: 1.1”) represents the intersection between the pipeline cost curve and the cost curve of a competing mode.

- **Barge**: Pipeline becomes more cost-effective at ~1.1 mtpa. Below this volume, barge transport remains cheaper due to its lower upfront investment, despite higher operating costs.
- **Mix** (25% rail / 75% barge): Pipeline becomes more cost-effective at ~1.8 mtpa, as the combined cost of rail and barge begins to exceed the declining per-unit cost of pipeline transport.
- **Constrained Allocation**: Pipeline becomes more cost-effective at ~3.3 mtpa, as the scenario initially benefits from low-cost rail until capacity is maxed out, after which barge (a more expensive mode) is used for excess volumes.
- **Rail-only**: Pipeline never becomes more cost-effective in pure cost terms, as rail maintains the lowest unit cost (€0.030/tkm vs. €0.076/tkm for pipeline). However, rail capacity is constrained, typically around 1.5 mtpa, beyond which it cannot accommodate additional volumes, limiting its practical scalability.

The shape of the pipeline cost curve reflects its cost structure: high upfront CAPEX for construction and infrastructure, offset by low OPEX over its 25-year design life. This results in a relatively flat cost curve, as fixed costs are spread over increasing volumes, delivering economies of scale. In contrast, the steeper cost curves for barge and mix scenarios indicate rising marginal costs with volume, driven by variable operating expenses and capacity constraints.

This graph underscores the importance of volume certainty and infrastructure planning. It also highlights the need for early engagement with Dutch and Belgian authorities to clarify safety and regulatory positions — particularly around pipeline permitting and ammonia classification — which will be critical to unlocking the full potential of pipeline transport.

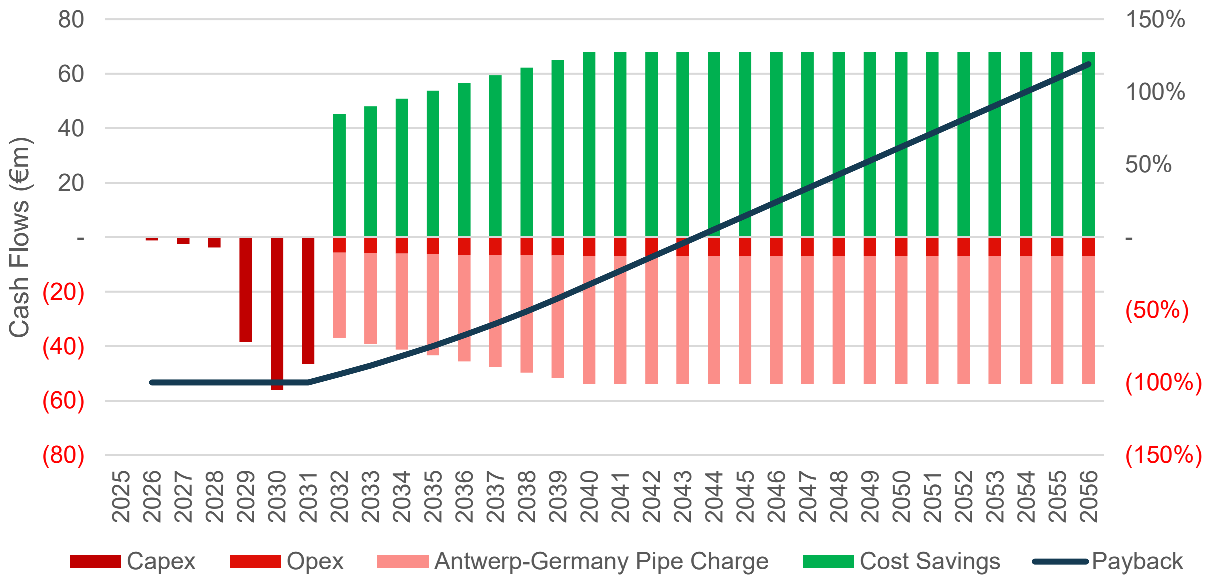
4.3 INVESTMENT PAYBACK PERIOD

4.3.1. A high-level investment payback assessment of the pipeline compared to the Mix scenario is shown below, based on the following assumptions:

- 25-year assessment period;
- Ammonia volumes consistent with the central volume demand scenario;
- Costs incurred include pipeline capex, pipeline opex and Antwerp-Germany access charges (entry and exit fees); and
- 'Revenues' equivalent to the cost savings from not transporting ammonia by barge and/or rail.

4.3.2. Compared to the Mix transport scenario, the investment payback period for the pipeline is 18.4 years. This compares to 13.7 years compared to the 'Barge' scenario and over 25 years compared to the 'Constrained Allocation' scenario, due in part to the fact lower rail transport costs are incurred in the earlier years when volumes are lower.

Figure 4-3 – Investment Payback Assessment Mix* Scenario



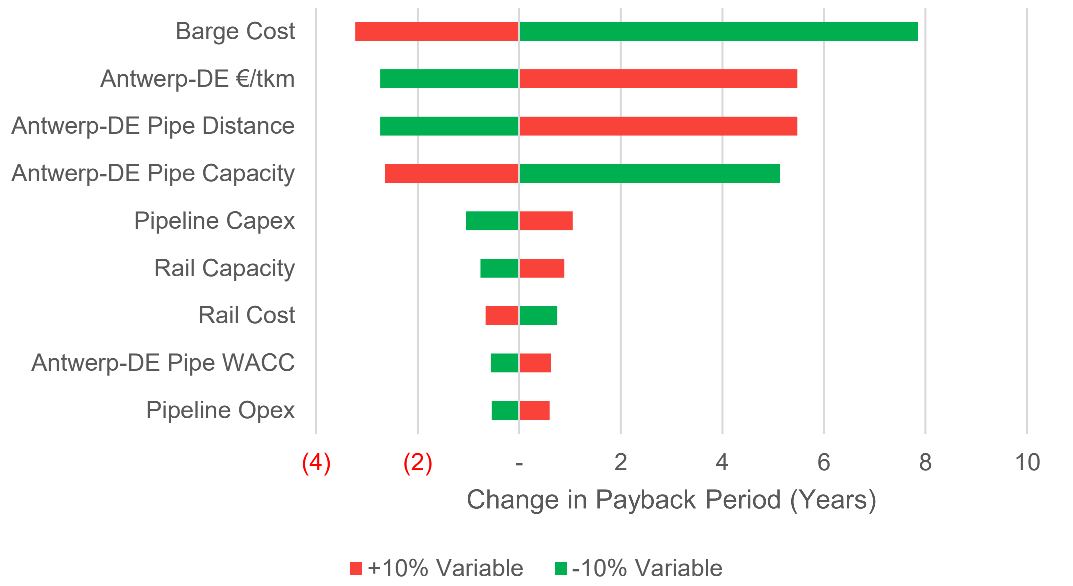
**Mix: Rail 25%, Barge 75%*
Source: WSP Analysis

4.4 SENSITIVITY ANALYSIS

4.4.1. To test the assumptions described above, we have undertaken sensitivity analysis on the economic turning point and investment payback period assessments (both under the Mix transport and central volume scenario). The figures below show the changes to the turning point and payback period based on +/-10% changes to a number of input assumptions

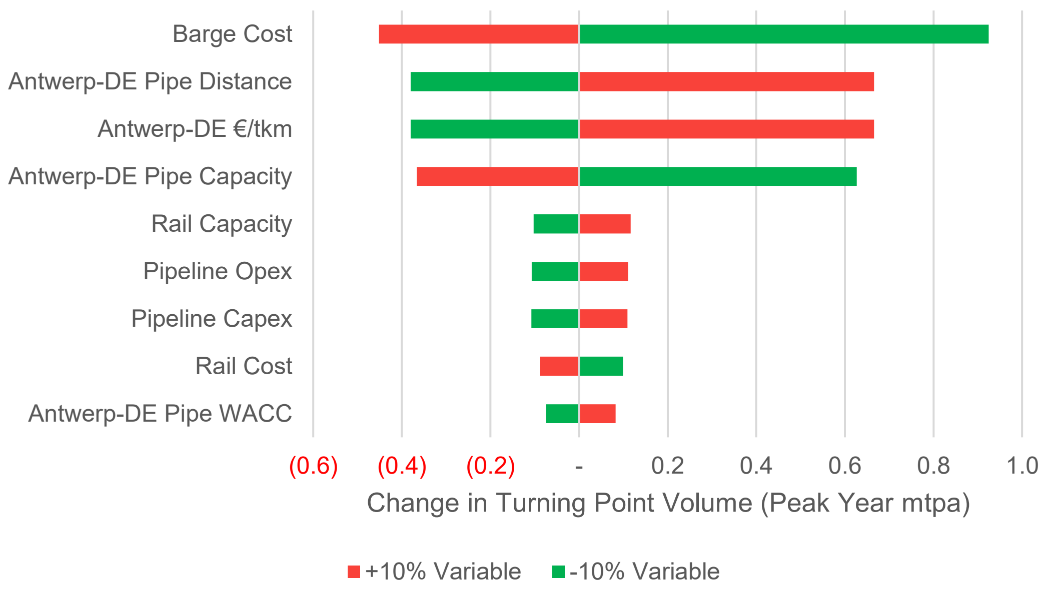
4.4.2. The results are most sensitive to the barge transportation cost – the more expensive competing transport mode that accounts for the majority of the Mix scenario volume – and the Antwerp-Germany pipeline assumptions – which account for the majority of the pipeline costs.

Figure 4-4 – Investment Payback Period Sensitivity Analysis



Source: WSP Analysis

Figure 4-5 - Economic Turning Point Sensitivity Analysis



Source: WSP Analysis

5 KEY TAKEAWAYS & RECOMMENDATIONS

KEY TAKEAWAYS & RECOMMENDATIONS SUMMARY

The construction of an ammonia pipeline from North Sea Port (NSP) to Antwerp is technically feasible and becomes economically viable only when volumes reach the point where pipeline costs overtake alternative modes. Based on lifecycle cost analysis and scenario modelling, the economic turning points are:

- Scenario 1 – Barge: Pipeline becomes more cost-effective than barge at **1.1 mtpa**, as barge has lower upfront costs but higher operating expenses.
- Scenario 2 – Mix (25% rail / 75% barge): Turning point at **1.8 mtpa**, where combined costs begin to exceed pipeline's declining per-unit cost.
- Scenario 3 – Constrained Allocation (rail used up to capacity, excess volumes by barge): Pipeline overtakes at **3.3 mtpa**, once rail capacity is maxed out and barge is used for excess volumes.
- Scenario 4 – Rail-only: Pipeline is never cheaper in pure cost terms (€0.030/tkm vs. €0.076/tkm), **but rail capacity is limited to 1.5 mtpa**, meaning it cannot handle higher volumes.

The central estimate for capital investment is approximately **€150 million**, with annual operating costs of **€6–7 million** and a comparative transport cost of **€0.076/tkm** to the NSP–Moerdijk route (2024 Study). Over a 25-year period, pipeline transport delivers the lowest long-term cost for high-volume ammonia movement, provided volumes exceed the thresholds above. While rail-only transport appears cheaper on a per-unit basis, infrastructure and policy constraints limit its scalability, reinforcing the need for a combined transport approach in the short to medium term.

In the short to medium term, **rail and barge will remain essential** to establish supply chains and serve off-pipeline users. However, neither mode alone can meet projected demand due to capacity and reliability constraints. This necessitates a combined transport approach and significant investment in supporting infrastructure and fleets. From a safety perspective, inland shipping currently offers the lowest risk, with no vulnerable buildings within its risk contours. Pipeline transport is compliant for up to 1.5 mtpa via the Sluiskil route under specific conditions; transporting 3.0 mtpa or more would exceed safety thresholds and require additional infrastructure. Each transport mode will likely raise societal discussions, requiring trade-offs between safety, cost, technical feasibility, and societal acceptance.

To support future ammonia transport, **all three modes (rail, barge and pipeline)** should be pursued in parallel, given their respective limitations. Engagement with Dutch and Belgian authorities is critical to clarify safety regulations, particularly regarding the application of the crater model and the classification of ammonia in risk assessments. Rail infrastructure upgrades are needed around Vlissingen, Terneuzen, and across the wider network, while barge transport requires OEM incentives for specialised vessels and regulatory easing at waterway bottlenecks.

Ultimately, a coordinated, cross-border strategy is essential to enable large-scale ammonia transport to Western Germany and support the EU's decarbonisation goals.

5.1 KEY TAKEAWAYS

5.1.1. Based on a technical assessment of a potential NSP-Antwerp pipeline routings, the construction of an ammonia pipeline based on currently-mandated specifications is feasible, subject to necessary approvals and cooperation of relevant stakeholders. Across the three pipeline routings, the central estimate for the required upfront investment costs is an average of approximately €150 million with ongoing operating costs of €7 million per annum. Across the three routings the average annualised €/tkm cost is €0.076, similar to the €0.073/tkm cost estimated for the NSP-Moerdijk pipeline within the 2024 study.

5.1.2. Based on the turning point assessment over a 25-year period, the NSP-Antwerp ammonia pipeline is the most cost-effective long means of transportation for volumes over 3.3 mpta when compared to all scenarios within this study (based on volume shares and estimated rail capacity constraints). Whilst rail-only transport may appear cheaper on a pure €/tkm basis, it is limited to around 1.5 mtpa due to infrastructure and operational constraints, meaning it cannot accommodate the volumes required and is therefore not a viable standalone solution.

5.1.3. Therefore, prior the ammonia and hydrogen industrial ecosystem developing and there being sufficient demand certainty from offtakers, projected ammonia volumes may not be sufficient to justify an investment in a dedicated ammonia pipeline. Rail and barge transport will therefore play an important role in the medium term, in order to establish supply chains and a market with end users. In addition to volume considerations, rail and barge transport will also be necessary to supply end users that are not connected to pipeline infrastructure. Ammonia pipeline infrastructure will also take several years to construct and will have limited capacity, which means rail and barge transport are likely to also play a role in the longer term.

5.1.4. Based on the assessment fleets and infrastructure, it is unlikely either rail or barge would be able to transport the projected ammonia volumes alone. Rail infrastructure capacity constraints (both in the vicinity of NSP and the wider rail network) mean the scope to transport large quantities of ammonia is limited and uncertainty around river closers and availability of suitable vessels mean barge transport cannot be relied upon entirely. A combination of both transport options is therefore likely to be required; both rail and barge infrastructure and/or fleets will need to be significantly expanded in order to meet projected demand.

5.1.5. Based on the mandated risk calculations, inland shipping transport is the safest means of transporting ammonia, as based on the location-specific risk assessment (which is required for permitting), there are no vulnerable or residential buildings within the risk contours on the route. While the location-specific risk assessment does not prohibit the transportation of ammonia by rail (based on current legislation), there is significant political opposition to transportation of hazardous substances by rail in the Netherlands (though not currently in Belgium), so it is unclear how transportation by rail will be treated in the future.

5.1.6. Assuming the crater model is used (and in spite of stricter regulation in Belgium), the construction of an ammonia pipeline from NSP to Antwerp is in line with safety requirements (when additional safety measures are used within the Netherlands) only when transporting 1.5 mtpa within a 10-inch pipe using the Sluiskil route through the Netherlands from Terneuzen. Transporting 3.0 mtpa or larger volumes using any of the assessed pipeline routes does not comply with the safety requirements in the Netherlands and Belgium. To transport all ammonia from NSP to Antwerp using the Sluiskil route through the Netherlands from Terneuzen would also require a MUK pipeline tunnel connecting Vlissingen to Terneuzen, which is still in the early stages of development.

5.2 RECOMMENDATIONS

5.2.1. While pipeline, barge and rail can all play a role in the transportation of ammonia, each of the three modes have potential safety, legislation and/or capacity-related risks that may affect their ability to transport significant quantities of ammonia in the longer term. It is therefore important to pursue all three modes simultaneously and for rail and inland shipping in particular, further investigation is required on where the infrastructure and equipment constraints will materialise and how these can be addressed.

5.2.2. For rail transport it will be important to address the infrastructure constraints in and around Vlissingen and Terneuzen ports (some capacity investment is currently planned) as well as on the wider network. For barge transport, the priorities should be providing enough demand certainty for OEMs to produce more specialised barges and alleviating congestion at waterway bottlenecks, for example by relaxing the regulations on multiple vessels allowed in locks when carrying hazardous goods.

5.2.3. For all transportation modes, much more clarity is required on safety legislation and guidelines. The Basisnet transportation guidelines used for rail and barge transportation are not well understood or easy to interpret, and it is not clear what the implications would be if the volume of ammonia transported were to increase significantly, particularly given the baseline level of transportation of hazardous substances is above the recommended level on rail transport in the Netherlands.

5.2.4. While barge transport complies with legislative safety requirements and faces less political opposition, rail transport complies with legislative safety requirements (though still breaches the vulnerable objects threshold) and faces significant political opposition within the Netherlands. In order to provide certainty to the market, the Dutch government should clarify its position, including in relation to routes that transport large volumes of ammonia Dutch ports to the nearest international border using the shortest possible route.

5.2.5. For pipeline transport, while the Dutch government has strengthened its recommendation on the use of the crater model, it is still not compulsory, which continues to create uncertainty around the feasibility of pipeline investments. The Belgian government should also clarify its position on the safety calculations for the pipeline transportation of hazardous substances (calculations are currently based on flammable substances) as this is likely to have an impact on the feasibility of pipeline investments.

5.2.6. In order to meet EU targets, industries in Western Germany need to transport large volumes of ammonia through the Netherlands and Belgium; however, current legalisation appears not to permit this at large volumes for some transport modes and there is also significant political opposition in some cases. Across national governments, industry and the ammonia transportation supply chain, there therefore needs to be more coordinated and strategic approach if ammonia and other hydrogen-based fuels will be successful in enabling heavy industry to transition away from fossil fuels.

Appendix A

AMMONIA PIPELINE LEGISLATION & STAKEHOLDERS

POTENTIAL BOTTLENECKS

The construction of each pipeline requires an overview of the different objects that need to be crossed and the different parties that are affected. The objects can be waterways, railways, roads, cables or pipelines, while the parties can consist of the different type of governments, waterboards, local groups and landowners. Depending on the rules and requirements of these parties, the pipeline design has to be adjusted.

Outside of the physical objects to be crossed and the parties that are present in the area, other bottlenecks are also present. The construction of this pipeline will likely coincide with other pipeline initiatives within the Netherlands and Belgium, for instance the European hydrogen network. This will likely affect the capacity of the available workforce and can postpone the construction of the pipeline.

A nitrogen deposition calculation for the construction of this pipeline will be required. This is needed to assess the impact of the construction on the local environment. Due to the strict rulings, special equipment will be needed in addition to other methods, to reducing the amount of nitrogen deposition during the works. This can influence the planning and the cost of the work.

PIPELINE THIRD PARTIES

In the routing of a pipeline a number of third parties are present. In most cases a construction method can be used to ensure minimal impact on the assets for these third parties.

Four different types of third parties have been identified at this stage: governmental bodies, special entities owners of special crossings, land owners, and cable and pipeline owners.

Governmental bodies

The pipeline will be constructed throughout a large part of the Netherlands and Belgium which means that each level of government (national, provincial and local) will be involved for the permitting of this pipeline construction. While the national governments and provinces will provide the general requirements for the pipeline, the local governments will be the voice of the local residents and their requirements.

Specific entities within the area

In the Netherlands and Belgium several specific entities are present that serve special purposes. The following specific entities are present:

- WSBD (Waterschap Brabantse Delta): Waterboard for the West of Brabant that is responsible for the local dykes, small waterways and bodies of water in the area;
- Scheldestromen (Waterschap Scheldestromen): Waterboard for most of Zeeland that is responsible for the dykes, small waterways and bodies of water in the area;
- Prorail and Infrabel: Entities that is responsible for the railways in the area; and
- RWS (Rijkswaterstaat) and AWV (Het Agentschap Wegen en Verkeer): Governmental entities that is responsible for main highways and main waterways in the area.

Each of these entities has specific rulings that are contained within their regulations. In most cases specific requirements are given to which the pipeline design should adhere. This can be a specific construction type or specific measures for the area they are responsible for.

Cable and pipeline (K&L) owners

Within the routing of the pipeline several cables and pipelines are present which need to be crossed. Specific requirements can be present on these crossings. These requirements can include the minimum required distance, required techniques or additional required measures. The intention of these requirements is to make sure that relevant assets can continue to serve their purpose without interference or other negative impact.

Multiple K&L owners are present within the area, which all have their own requirements. Of these owners some parties are mentioned, at this stage of , due to their specific requirements:

- TenneT: Owner of most of the below-and aboveground cables in the Netherlands;
- Gasunie: Owner of the natural gas pipeline network within the Netherlands;
- Fluxys Belgium: Owner of the natural gas pipeline network within Belgium;
- Elia: wner of most of the below-and aboveground cables in Belgium;
- Evides: Owner of the water pipelines in the area of Zeeland; and
- PZEM: Owner of a big pipeline within the SvB-corridor of Zeeland.

The required space between this pipeline and the adjacent cables and pipelines should be determined to assess the amount of space needed for the construction of this pipeline. This distance must be coordinated with the owners of these adjacent cables and pipelines.

Private land owners

Some of the pipeline will be constructed within the SvB-corridors, which are situated on mostly privately owned lands. LSNED owns a big part of the SvB-corridor in Noord-Brabant, while the SvB-corridors in Zeeland are mostly on privately owned lands. This distinction is notable for the prices for the use of these grounds and the construction methods needed to be used. Within the LSNED corridor these costs and construction methods are clearly defined. Outside of the LSNED corridor, these costs have to be arranged with multiple different private land owners, which could negatively impact the costs or construction methods. As an example, the cost of constructing a pipe in open excavation through a orchid may be very expansive, which means that at these locations it is necessary to construct the pipeline via drillings. For the cost estimation within this study, a surcharge has been taken into account for this.

PIPELINE LEGISLATION

The legislation for the construction of a pipeline differs depending and the amount of risk this pipeline poses to the environment. An ammonia pipeline has such a risk that several different legislation have to be followed.

Zoning plans

In the Netherlands zoning plans (omgevingsplannen) are designated for each type of land within each local government. A zoning plan gives an indication for which purpose the ground can be used, for instance: agriculture, industry, residences or transportation purposes. In some cases, zoning plans have a secondary status, like the SvB corridors. While the SvB-corridors have a general ruling within the legislation, local governments can have additional requirements.

Environmental management law

The Environmental Management Law (EML) (Wet milieubeheer) sets requirements for an Environmental Impact Assessment Milieu Effect Rapportage (MER)). It states that for all new activities that have an effect upon the environment a MER needs to be performed. A MER is required when a pipeline exceeds a size of 0.8 m and a length of 40 km, which this pipeline does not exceed . However, there is a very high probability that the Dutch government will require an MER study for such a dangerous pipeline, regardless of the length and diameter.

Planning act

The Planning Act (NL: Omgevingswet) is legislation that encompasses everything for the space in which we live and work. This act gives most of the legislation to which one should adhere for the permitting of the construction and operation of the pipeline. For example, it provides the legislation for the external safety of the pipeline.

National coordination regulation

In the current legislation the transport of ammonia has not yet been designated by the Dutch government or the European Interest, as a pipeline of national importance. It is expected that with the construction of the ammonia pipeline within the DRC and related project, that these particular types of pipelines will be designated as such.

The National Coordination Regulation (NL: Rijkscoördinatieregeling) referenced to as RCR, is applicable for projects of national importance in which case the Netherlands Enterprise Agengy (Rijksdienst voor Ondernemend Nederland (RVO), part of the Ministry of Economic Affairs) will coordinate the project, being part of the energy infrastructure.

Appendix B

PIPELINE COST ESTIMATE ASSUMPTIONS

KEY ASSUMPTIONS

The following assumptions were used for the estimation of costs:

- The estimate has been prepared in accordance with the SSK 2018 systematics (CROW publication 137) version 2.4;
- Deterministic business economics principles;
- Based on key figures and experience from cost experts of similar projects;
- A high level estimation (conceptual) due to the initial stage of this investigation;
- The estimation has included contingencies that allow for risk and unknowns that are not detailed at this stage;
- Lifecycle costs (including maintenance, ongoing fees, power use etc.) have been derived assuming an infrastructure design life of 25 years;
- Includes costs for yearly maintenance of both the pipework and pumpstation infrastructure at a rate of 3.8% of the respective initial investment costs, in line with the Hydrogen Backbone[35];
- An additional pumpstation may be required to sustain higher transport volumes – this would see an additional investment cost of approximately €4.5m and additional lifecycle costs for maintenance and power use
- Additional contingency of 10% was allowed for pipework within the Zeeland region due to the higher risk/less know ground conditions in this section;
- Includes fees for construction and ongoing corridor rights for pipework within the LSNED pipe corridor where applicable;
- Allows for consultant fees such as pre-construction investigations, engineering design, environmental management and construction management;
- Two cross-sectional trench dimensions have been assumed (all including 0.4m deep x 10m wide stripped working surface):
  - For the single pipe scenarios, the average dimensions as follows: 2m wide base x 2m deep, with 2W:3H trench slope;
  - For the dual pipe scenarios, the average dimensions as follows: 3m wide base x 2m deep, with 2W:3H trench slope;
- Road crossings allowed for based on approximately 1 crossing per kilometre assuming a 6m crossing length and 2m wide trench;
- Allows for permitting costs, property access rights fees, business rights fees, and crop damage repair[36];

[35] Evaluation of the levelised cost of hydrogen based on proposed electrolyser projects in the Netherlands
[36] Rates derived from *Evides Waterbedrijf*.

- Assumption that only 1 pump station is required, one at the harbour connection of Vlissingen or Sluiskil respectively, to main pressure through the system – an energy consumption cost of €0.125/kWh has been conservatively used; and
- Valve stations have been allowed for every 3 km for safety measures.

COST CATEGORIES

Construction Costs

Construction costs can be divided into direct and indirect costs. The direct construction costs are the costs for the physical construction of the design including the labour and materials. These activities are carried out by one contractor or on his behalf in subcontracting. Construction costs are further broken up between the main pipework and the two expected pumpstations that will be required at each end of the new pipeline.

Indirect Costs

Indirect costs are included as percentages and are an addition to direct costs. These costs allow for establishment, management overheads, general costs, profit and risk incurred by the contractor.

Ongoing Costs

Ongoing costs include maintenance of the pipe network and pumpstations, ongoing fees to be paid to LSNED, for the presence and management of pipelines within the LSNED area. A significant part of the ongoing costs arise from the electricity use of the pumpstations for the transport of the Ammonia.

Risk Reserve

As this a high-level estimate, there are contingencies taken into account in the form of a percentage of the construction costs:

- Not yet detailed – 30%; and
- Unknown risk – 10%.

This totals a contingency of 40% for the entire construction phase.

Estimated Costs

For the substantiation of the costs, see the SSK estimates in the tables below.

The total cost figures for each volume scenario are included in the tables below, with Table B-1 showing the total CAPEX costs, Table B-2 showing the total OPEX costs, and Table B-3 showing total overall costs.

Table B-1 - Investment cost estimate (CAPEX)

SCENARIO	TOTAL INVESTMENT COSTS EXCL. VAT	EXPECTED COSTS	RISK RESERVE
	LOW SCENARIO (10" PIPE)		
VLISSINGEN ROUTE	€ 162,300,000	€ 133,900,000	€ 28,400,000
SLUISKIL (VIA ZEELAND)	€ 129,200,000	€ 106,300,000	€ 22,900,000

SCENARIO	TOTAL INVESTMENT COSTS EXCL. VAT	EXPECTED COSTS	RISK RESERVE
SLUISKIL (VIA FLANDERS)	€ 150,400,000	€ 122,200,000	€ 28,200,000
CENTRAL SCENARIO (12" PIPE)			
VLISSINGEN ROUTE	€ 174,700,000	€ 144,300,000	€ 30,400,000
SLUISKIL (VIA ZEELAND)	€ 139,200,000	€ 114,700,000	€ 24,500,000
SLUISKIL (VIA FLANDERS)	€ 162,800,000	€ 132,600,000	€ 30,200,000
HIGH SCENARIO (10" + 12" PIPES)			
VLISSINGEN ROUTE	€ 273,700,000	€ 225,300,000	€ 48,400,000
SLUISKIL (VIA ZEELAND)	€ 218,300,000	€ 179,400,000	€ 38,900,000
SLUISKIL (VIA FLANDERS)	€ 260,800,000	€ 212,800,000	€ 48,000,000
EXTENDED SCENARIO (2 X 12" PIPES)			
VLISSINGEN ROUTE	€ 283,700,000	€ 233,300,000	€ 50,400,000
SLUISKIL (VIA ZEELAND)	€ 228,700,000	€ 187,800,000	€ 40,900,000
SLUISKIL (VIA FLANDERS)	€ 270,900,000	€ 221,000,000	€ 49,900,000

Table B-2 - Ongoing costs (OPEX)

SCENARIO	TOTAL ONGOING COSTS EXCL. VAT	EXPECTED COSTS	RISK RESERVE
LOW SCENARIO (10" PIPE)			
VLISSINGEN ROUTE	€ 142,000,000	€ 131,600,000	€ 10,400,000
SLUISKIL (VIA ZEELAND)	€ 118,700,000	€ 110,300,000	€ 8,400,000
SLUISKIL (VIA FLANDERS)	€ 140,800,000	€ 130,500,000	€ 10,300,000
CENTRAL SCENARIO (12" PIPE)			
VLISSINGEN ROUTE	€ 175,300,000	€ 163,900,000	€ 11,400,000
SLUISKIL (VIA ZEELAND)	€ 149,900,000	€ 140,800,000	€ 9,100,000
SLUISKIL (VIA FLANDERS)	€ 174,100,000	€ 162,800,000	€ 11,300,000
HIGH SCENARIO (10" + 12" PIPES)			
VLISSINGEN ROUTE	€ 284,800,000	€ 265,500,000	€ 19,300,000
SLUISKIL (VIA ZEELAND)	€ 242,100,000	€ 226,700,000	€ 15,400,000
SLUISKIL (VIA FLANDERS)	€ 282,700,000	€ 263,700,000	€ 19,000,000
EXTENDED SCENARIO (2 X 12" PIPES)			
VLISSINGEN ROUTE	€ 318,000,000	€ 297,800,000	€ 20,200,000
SLUISKIL (VIA ZEELAND)	€ 275,300,000	€ 259,000,000	€ 19,300,000

SCENARIO	TOTAL ONGOING COSTS EXCL. VAT	EXPECTED COSTS	RISK RESERVE
SLUISKIL (VIA FLANDERS)	€ 316,000,000	€ 296,000,000	€ 20,000,000

Table B-3 - Lifecycle costs (25yr)

SCENARIO	LIFECYCLE COST EXCL. VAT	LIFECYCLE COST INCL. VAT
LOW SCENARIO (10" PIPE)		
VLISSINGEN ROUTE	€ 304,300,000	€ 368,200,000
SLUISKIL (VIA ZEELAND)	€ 247,800,000	€ 299,900,000
SLUISKIL (VIA FLANDERS)	€ 291,200,000	€ 352,300,000
CENTRAL SCENARIO (12" PIPE)		
VLISSINGEN ROUTE	€ 350,000,000	€ 423,500,000
SLUISKIL (VIA ZEELAND)	€ 289,100,000	€ 349,800,000
SLUISKIL (VIA FLANDERS)	€ 336,800,000	€ 407,600,000
HIGH SCENARIO (10" + 12" PIPES)		
VLISSINGEN ROUTE	€ 558,500,000	€ 675,800,000
SLUISKIL (VIA ZEELAND)	€ 460,400,000	€ 557,100,000
SLUISKIL (VIA FLANDERS)	€ 543,600,000	€ 657,700,000
EXTENDED SCENARIO (2 X 12" PIPES)		
VLISSINGEN ROUTE	€ 601,700,000	€ 728,000,000
SLUISKIL (VIA ZEELAND)	€ 504,000,000	€ 609,800,000
SLUISKIL (VIA FLANDERS)	€ 586,900,000	€ 710,100,000

Lifecycle Costs

Lifecycle costs are based on a 25-year design life and includes the initial investment cost in the pipeline infrastructure, one-off and yearly fees, maintenance, and management of the pipeline network. The costs also include the power use of the pumpstations required to maintain pressure throughout the system. The lifecycle costs will vary from year to year, particularly during the initial construction phase and as the volume of ammonia transported increases with demand.

Cost Estimate Exclusions

The following items have also been explicitly excluded from the cost estimate due to the high-level of this study.

- Excluding the costs of decommissioning and emptying existing wells or pipes; and
- No allowance for public consultation with regards to ammonia transport.

Additional items may not have been explicitly mentioned in the above exclusions or included in the list of assumptions. Further potential costs that have been excluded from this cost estimate follow.

Potential Additional Costs

Additional safety measures may be required within the Antwerp-Ruhr pipeline corridor. These measures have not been taken into account in this cost estimation. If these features have to be implemented, these could have a substantial impact on the overall cost. The additional measures may include:

- Pipe-in-pipe casing; and
- Secondary piping laid parallel.

Due to the sceptical public perception of ammonia transport, additional costs may be incurred in public consultation to address general concerns about the construction of a new hazardous chemical pipeline in proximity to nearby high-density living areas. These potential costs have not been specifically allowed for in this estimate.

There are specific environmental services that operate within the Netherlands called *Omgevingsdienst NL*, which specialise in environmental permitting, supervision and enforcement.[37] These services may require specific training and/or tools to support in safe pipeline transport of ammonia to aid in their offerings, particularly in the event of emergency response. This could potentially incur further costs to the construction of the pipeline.

PIPELINE PROJECT TIMELINE

The following project timeline is theoretical only and based on best estimates. It is expected that work could begin in the LSNED section within 2 years, however the timeline for construction within Zeeland is quite ambitious and may take up to 5 years from project inception to construction start. This longer construction lead-in for the Zeeland section is primarily due to additional design work, landowner consultation and environmental management required.

Consulting and Design Phase

It is assumed that the project would start in 2026, with project costs starting the following year for consultancy and design fees. The permitting and design phase is expected to take around 2 years, with the tender phase beginning in 2029. It should be noted that there has been no allowance for public consultation costs, which may be incurred due to the current negative public perception of ammonia transport.

Construction Phase

Within this study, it is assumed that the contract will be awarded by 2030, with construction to take approximately 3 years. This will see project costs ramp up significantly for the next 3 years while the infrastructure is constructed and installed.

Operation Phase

After construction is completed by end of 2032, it is assumed that the pipeline will be in operation by 2033. Ongoing operational costs in the form of maintenance and fees will remain relatively constant for the rest of the 25-year design life. It has been assumed for all three ammonia transport volume scenarios, the ammonia demand will start off lower and gradually ramp up over 9 years, to the full

[37] Refer to Omgevingsdienst NL for further details at https://www.omgevingsdienst.nl/omgevingsdiensten/.

scenario volume. This means that the pumpstation power consumption costs will also increase respectively.

SSK MANAGEMENT OVERVIEWS

The following tables show the Management Overview sheets from each scenario's SSK estimate. The initial investment costs are summed up within the yellow columns, while the ongoing costs are shown in the green columns. Each of the initial investment and ongoing costs are broken down into "Voorziene kosten" (or Foreseen Costs), "Risicoreservering" (or Risk Reserve) and "Totaal" (or Total), a sum of the foreseen cost and risk reserve. The overall lifecycle costs are totalled up in the end column in blue. Note: the values in **bold** reflect costs including "BTW" (or VAT), refer to the row below for costs excluding BTW.

Route: Vlissingen

Figure B-1 - SSK Management Overview – Low Scenario (Vlissingen Route)

Managementoverzicht SSK-2018								*Rekenmodel SSK-2018 versie 2.4.002*
		Investeringskosten (rekenhorizon 6 jaar, reële kosten)			Instandhoudingskosten (rekenhorizon 25 jaar, reële kosten)			Levenscycluskosten (rekenhorizon 25 jaar, reële kosten)
Object	Geactiveerd	Voorziene kosten	Risicoreservering	Totaal	Voorziene kosten	Risicoreservering	Totaal	
Deelraming Labour + Maint. + Fees	JA	€ 132.325.612	€ 13.362.530	€ 145.688.141	€ 126.466.328	€ 12.646.633	€ 139.112.961	€ 284.801.102
Deelraming Materials - 10in	JA	€ 24.906.715	€ 2.533.335	€ 27.440.050	€ -	€ -	€ -	€ 27.440.050
Deelraming Pumpstation	JA	€ 4.797.807	€ 479.781	€ 5.277.588	€ 32.764.875	€ -	€ 32.764.875	€ 38.042.463
Objectoverstijgende risicoreservering incl. verschuiving	JA		€ 18.013.210	€ 18.013.210		€ -	€ -	€ 18.013.210
Kosten incl. BTW		**€ 162.030.133**	**€ 34.388.856**	**€ 196.418.989**	**€ 159.231.203**	**€ 12.646.633**	**€ 171.877.836**	**€ 368.296.825**
Excl. BTW		*€ 133.909.201*	*€ 28.420.542*	*€ 162.329.743*	*€ 131.596.036*	*€ 10.451.763*	*€ 142.047.798*	*€ 304.377.542*
Bandbreedte: met een 70%-betrouwbaarheidsinterval liggen de kosten incl. BTW tusse kosten incl. BTW tussen			*€ en €*			*€ en €*		*€ en €*
De variatiecoëfficiënt bedraagt			*± - -*			*± - -*		*± - -*
Geraamde kosten incl. BTW				€ 196.418.989			€ 171.877.836	€ 368.296.825
Onzekerheidsreserve (opgave financier)				€ -			€ -	€ -
Reservering scopewijzigingen (opgave financier)				€ -			€ -	€ -
Gerealiseerde kosten (opgave financier)				€ -			€ -	€ -
Aan te houden budget incl. BTW				**€ 196.418.989**			**€ 171.877.836**	**€ 368.296.825**
Excl. BTW				€ 162.329.743			€ 142.047.798	€ 304.377.542

Figure B-2 - SSK Management Overview – Central Scenario (Vlissingen Route)

Managementoverzicht SSK-2018								*Rekenmodel SSK-2018 versie 2.4.002*
		Investeringskosten (rekenhorizon 6 jaar, reële kosten)			Instandhoudingskosten (rekenhorizon 25 jaar, reële kosten)			Levenscycluskosten (rekenhorizon 25 jaar, reële kosten)
Object	Geactiveerd	Voorziene kosten	Risicoreservering	Totaal	Voorziene kosten	Risicoreservering	Totaal	
Deelraming Labour + Maint. + Fees	JA	€ 138.152.761	€ 13.845.495	€ 151.998.256	€ 137.810.063	€ 13.781.006	€ 151.591.069	€ 303.589.325
Deelraming Materials - 12in	JA	€ 31.651.842	€ 3.194.122	€ 34.845.964	€ -	€ -	€ -	€ 34.845.964
Deelraming Pumpstation	JA	€ 4.797.807	€ 479.781	€ 5.277.588	€ 60.516.042	€ -	€ 60.516.042	€ 65.793.630
Objectoverstijgende risicoreservering incl. verschuiving	JA		€ 19.271.337	€ 19.271.337		€ -	€ -	€ 19.271.337
Kosten incl. BTW		**€ 174.602.410**	**€ 36.790.735**	**€ 211.393.145**	**€ 198.326.105**	**€ 13.781.006**	**€ 212.107.111**	**€ 423.500.256**
Excl. BTW		*€ 144.299.512*	*€ 30.405.566*	*€ 174.705.079*	*€ 163.905.872*	*€ 11.389.261*	*€ 175.295.133*	*€ 350.000.212*
Bandbreedte: met een 70%-betrouwbaarheidsinterval liggen de kosten incl. BTW tussen			*€ en €*			*€ en €*		*€ en €*
De variatiecoëfficiënt bedraagt			*± - -*			*± - -*		*± - -*
Geraamde kosten incl. BTW				€ 211.393.145			€ 212.107.111	€ 423.500.256
Onzekerheidsreserve (opgave financier)				€ -			€ -	€ -
Reservering scopewijzigingen (opgave financier)				€ -			€ -	€ -
Gerealiseerde kosten (opgave financier)				€ -			€ -	€ -
Aan te houden budget incl. BTW				**€ 211.393.145**			**€ 212.107.111**	**€ 423.500.256**
Excl. BTW				€ 174.705.079			€ 175.295.133	€ 350.000.212

Figure B-3 - SSK Management Overview – High Scenario (Vlissingen Route)

Managementoverzicht SSK-2018								*Rekenmodel SSK-2018 versie 2.4.002*
		Investeringskosten (rekenhorizon 6 jaar, reële kosten)			Instandhoudingskosten (rekenhorizon 25 jaar, reële kosten)			Levenscycluskosten (rekenhorizon 25 jaar, reële kosten)
Object	Geactiveerd	Voorziene kosten	Risicoreservering	Totaal	Voorziene kosten	Risicoreservering	Totaal	
Deelraming Labour + Maint. + Fees	JA	€ 208.502.820	€ 21.434.684	€ 229.937.504	€ 233.022.091	€ 23.302.209	€ 256.324.300	€ 486.261.804
Deelraming Materials - 10+12in	JA	€ 59.277.681	€ 5.997.840	€ 65.275.521	€ -	€ -	€ -	€ 65.275.521
Deelraming Pumpstation	JA	€ 4.797.807	€ 479.781	€ 5.277.588	€ 88.267.209	€ -	€ 88.267.209	€ 93.544.797
Objectoverstijgende risicoreservering incl. verschuiving	JA		€ 30.703.535	€ 30.703.535		€ -	€ -	€ 30.703.535
Kosten incl. BTW		**€ 272.578.309**	**€ 58.615.840**	**€ 331.194.148**	**€ 321.289.299**	**€ 23.302.209**	**€ 344.591.508**	**€ 675.785.657**
Excl. BTW		*€ 225.271.330*	*€ 48.442.843*	*€ 273.714.172*	*€ 265.528.347*	*€ 19.258.024*	*€ 284.786.371*	*€ 558.500.543*
Bandbreedte: met een 70%-betrouwbaarheidsinterval liggen de kosten incl. BTW tussen			*€ en €*			*€ en €*		*€ en €*
De variatiecoëfficiënt bedraagt			*± - -*			*± - -*		*± - -*
Geraamde kosten incl. BTW				€ 331.194.148			€ 344.591.508	€ 675.785.657
Onzekerheidsreserve (opgave financier)				€ -			€ -	€ -
Reservering scopewijzigingen (opgave financier)				€ -			€ -	€ -
Gerealiseerde kosten (opgave financier)				€ -			€ -	€ -
Aan te houden budget incl. BTW				**€ 331.194.148**			**€ 344.591.508**	**€ 675.785.657**
Excl. BTW				€ 273.714.172			€ 284.786.371	€ 558.500.543

Figure B-4 - SSK Management Overview – Extended Scenario (Vlissingen Route)

Managementoverzicht SSK-2018								*Rekenmodel SSK-2018 versie 2.4.002*
		Investeringskosten (rekenhorizon 6 jaar, reële kosten)			Instandhoudingskosten (rekenhorizon 25 jaar, reële kosten)			Levenscycluskosten (rekenhorizon 25 jaar, reële kosten)
Object	Geactiveerd	Voorziene kosten	Risicoreservering	Totaal	Voorziene kosten	Risicoreservering	Totaal	
Deelraming Labour + Maint. + Fees	JA	€ 210.431.497	€ 21.841.651	€ 232.273.148	€ 244.302.300	€ 24.430.230	€ 268.732.530	€ 501.005.679
Deelraming Materials - 2 x 12in	JA	€ 67.102.531	€ 6.710.253	€ 73.812.785	€ -	€ -	€ -	€ 73.812.785
Deelraming Pumpstation	JA	€ 4.797.807	€ 479.781	€ 5.277.588	€ 116.018.375	€ -	€ 116.018.375	€ 121.295.964
Objectoverstijgende risicoreservering incl. verschuiving	JA		€ 31.934.853	€ 31.934.853		€ -	€ -	€ 31.934.853
Kosten incl. BTW		**€ 282.331.836**	**€ 60.966.538**	**€ 343.298.374**	**€ 360.320.676**	**€ 24.430.230**	**€ 384.750.906**	**€ 728.049.280**
Excl. BTW		*€ 233.332.096*	*€ 50.385.569*	*€ 283.717.665*	*€ 297.785.683*	*€ 20.190.273*	*€ 317.975.955*	*€ 601.693.620*
Bandbreedte: met een 70%-betrouwbaarheidsinterval liggen de kosten incl. BTW tussen			*€ en €*			*€ en €*		*€ en €*
De variatiecoëfficiënt bedraagt			*± - -*			*± - -*		*± - -*
Geraamde kosten incl. BTW				€ 343.298.374			€ 384.750.906	€ 728.049.280
Onzekerheidsreserve (opgave financier)				€ -			€ -	€ -
Reservering scopewijzigingen (opgave financier)				€ -			€ -	€ -
Gerealiseerde kosten (opgave financier)				€ -			€ -	€ -
Aan te houden budget incl. BTW				**€ 343.298.374**			**€ 384.750.906**	**€ 728.049.280**
Excl. BTW				€ 283.717.665			€ 317.975.955	€ 601.693.620

Route: Sluiskil via Zeeland

Figure B-5 - SSK Management Overview – Low Scenario (Zeeland Route)

Managementoverzicht SSK-2018								*Rekenmodel SSK-2018 versie 2.4.002*
		Investeringskosten (rekenhorizon 6 jaar, reële kosten)			Instandhoudingskosten (rekenhorizon 25 jaar, reële kosten)			Levenscycluskosten (rekenhorizon 25 jaar, reële kosten)
Object	Geactiveerd	Voorziene kosten	Risicoreservering	Totaal	Voorziene kosten	Risicoreservering	Totaal	
Deelraming Labour + Maint. + Fees	JA	€ 103.954.051	€ 10.687.093	€ 114.641.144	€ 100.750.650	€ 10.075.065	€ 110.825.715	€ 225.466.859
Deelraming Materials - 10in	JA	€ 19.851.194	€ 2.019.123	€ 21.870.317	€ -	€ -	€ -	€ 21.870.317
Deelraming Pumpstation	JA	€ 4.797.807	€ 479.781	€ 5.277.588	€ 32.764.875	€ -	€ 32.764.875	€ 38.042.463
Objectoverstijgende risicoreservering incl. verschuiving	JA		€ 14.504.596	€ 14.504.596		€ -	€ -	€ 14.504.596
Kosten incl. BTW		**€ 128.603.053**	**€ 27.690.593**	**€ 156.293.645**	**€ 133.515.525**	**€ 10.075.065**	**€ 143.590.590**	**€ 299.884.236**
Excl. BTW		*€ 106.283.515*	*€ 22.884.787*	*€ 129.168.302*	*€ 110.343.409*	*€ 8.326.500*	*€ 118.669.909*	*€ 247.838.211*
Bandbreedte: met een 70%-betrouwbaarheidsinterval liggen de kosten incl. BTW tussen			*€ en €*			*€ en €*		*€ en €*
De variatiecoëfficiënt bedraagt			*± - -*			*± - -*		*± - -*
Geraamde kosten incl. BTW				€ 156.293.645			€ 143.590.590	€ 299.884.236
Onzekerheidsreserve (opgave financier)				€ -			€ -	€ -
Reservering scopewijzigingen (opgave financier)				€ -			€ -	€ -
Gerealiseerde kosten (opgave financier)				€ -			€ -	€ -
Aan te houden budget incl. BTW				**€ 156.293.645**			**€ 143.590.590**	**€ 299.884.236**
Excl. BTW				€ 129.168.302			€ 118.669.909	€ 247.838.211

Figure B-6 - SSK Management Overview – Central Scenario (Zeeland Route)

Managementoverzicht SSK-2018								*Rekenmodel SSK-2018 versie 2.4.002*
		Investeringskosten (rekenhorizon 6 jaar, reële kosten)			Instandhoudingskosten (rekenhorizon 25 jaar, reële kosten)			Levenscycluskosten (rekenhorizon 25 jaar, reële kosten)
Object	Geactiveerd	Voorziene kosten	Risicoreservering	Totaal	Voorziene kosten	Risicoreservering	Totaal	
Deelraming Labour + Maint. + Fees	JA	€ 108.763.797	€ 11.084.068	€ 119.847.865	€ 109.898.250	€ 10.989.825	€ 120.888.075	€ 240.735.940
Deelraming Materials - 12in	JA	€ 25.225.079	€ 2.545.650	€ 27.770.729	€ -	€ -	€ -	€ 27.770.729
Deelraming Pumpstation	JA	€ 4.797.807	€ 479.781	€ 5.277.588	€ 60.516.042	€ -	€ 60.516.042	€ 65.793.630
Objectoverstijgende risicoreservering incl. verschuiving	JA		€ 15.520.448	€ 15.520.448		€ -	€ -	€ 15.520.448
Kosten incl. BTW		**€ 138.786.684**	**€ 29.629.947**	**€ 168.416.631**	**€ 170.414.292**	**€ 10.989.825**	**€ 181.404.117**	**€ 349.820.748**
Excl. BTW		*€ 114.699.739*	*€ 24.487.559*	*€ 139.187.298*	*€ 140.838.258*	*€ 9.082.500*	*€ 149.920.758*	*€ 289.108.056*
Bandbreedte: met een 70%-betrouwbaarheidsinterval liggen de kosten incl. BTW tussen			*€ en €*			*€ en €*		*€ en €*
De variatiecoëfficiënt bedraagt			*± - -*			*± - -*		*± - -*
Geraamde kosten incl. BTW				€ 168.416.631			€ 181.404.117	€ 349.820.748
Onzekerheidsreserve (opgave financier)				€ -			€ -	€ -
Reservering scopewijzigingen (opgave financier)				€ -			€ -	€ -
Gerealiseerde kosten (opgave financier)				€ -			€ -	€ -
Aan te houden budget incl. BTW				**€ 168.416.631**			**€ 181.404.117**	**€ 349.820.748**
Excl. BTW				€ 139.187.298			€ 149.920.758	€ 289.108.056

Figure B-7 - SSK Management Overview – High Scenario (Zeeland Route)

Managementoverzicht SSK-2018								*Rekenmodel SSK-2018 versie 2.4.002*
		Investeringskosten (rekenhorizon 6 jaar, reële kosten)			Instandhoudingskosten (rekenhorizon 25 jaar, reële kosten)			Levenscycluskosten (rekenhorizon 25 jaar, reële kosten)
Object	Geactiveerd	Voorziene kosten	Risicoreservering	Totaal	Voorziene kosten	Risicoreservering	Totaal	
Deelraming Labour + Maint. + Fees	JA	€ 164.989.946	€ 17.155.350	€ 182.145.297	€ 186.032.963	€ 18.603.296	€ 204.636.259	€ 386.781.556
Deelraming Materials - 10+12in	JA	€ 47.284.936	€ 4.785.498	€ 52.070.433	€ -	€ -	€ -	€ 52.070.433
Deelraming Pumpstation	JA	€ 4.797.807	€ 479.781	€ 5.277.588	€ 88.267.209	€ -	€ 88.267.209	€ 93.544.797
Objectoverstijgende risicoreservering incl. verschuiving	JA		€ 24.662.692	€ 24.662.692		€ -	€ -	€ 24.662.692
Kosten incl. BTW		**€ 217.072.689**	**€ 47.083.320**	**€ 264.156.010**	**€ 274.300.171**	**€ 18.603.296**	**€ 292.903.468**	**€ 557.059.477**
Excl. BTW		*€ 179.398.917*	*€ 38.911.835*	*€ 218.310.752*	*€ 226.694.356*	*€ 15.374.625*	*€ 242.068.981*	*€ 460.379.733*
Bandbreedte: met een 70%-betrouwbaarheidsinterval liggen de kosten incl. BTW tussen			*€ en €*			*€ en €*		*€ en €*
De variatiecoëfficiënt bedraagt			*± - -*			*± - -*		*± - -*
Geraamde kosten incl. BTW				€ 264.156.010			€ 292.903.468	€ 557.059.477
Onzekerheidsreserve (opgave financier)				€ -			€ -	€ -
Reservering scopewijzigingen (opgave financier)				€ -			€ -	€ -
Gerealiseerde kosten (opgave financier)				€ -			€ -	€ -
Aan te houden budget incl. BTW				**€ 264.156.010**			**€ 292.903.468**	**€ 557.059.477**
Excl. BTW				€ 218.310.752			€ 242.068.981	€ 460.379.733

Figure B-8 - SSK Management Overview – Extended Scenario (Zeeland Route)

Managementoverzicht SSK-2018								*Rekenmodel SSK-2018 versie 2.4.002*
		Investeringskosten (rekenhorizon 6 jaar, reële kosten)			Instandhoudingskosten (rekenhorizon 25 jaar, reële kosten)			Levenscycluskosten (rekenhorizon 25 jaar, reële kosten)
Object	Geactiveerd	Voorziene kosten	Risicoreservering	Totaal	Voorziene kosten	Risicoreservering	Totaal	
Deelraming Labour + Maint. + Fees	JA	€ 168.934.242	€ 17.758.709	€ 186.692.951	€ 197.340.413	€ 19.734.041	€ 217.074.454	€ 403.767.405
Deelraming Materials - 2 x 12in	JA	€ 53.479.033	€ 5.347.903	€ 58.826.937	€ -	€ -	€ -	€ 58.826.937
Deelraming Pumpstation	JA	€ 4.797.807	€ 479.781	€ 5.277.588	€ 116.018.375	€ -	€ 116.018.375	€ 121.295.964
Objectoverstijgende risicoreservering incl. verschuiving	JA		€ 25.945.032	€ 25.945.032		€ -	€ -	€ 25.945.032
Kosten incl. BTW		**€ 227.211.083**	**€ 49.531.425**	**€ 276.742.508**	**€ 313.358.788**	**€ 19.734.041**	**€ 333.092.829**	**€ 609.835.337**
Excl. BTW		*€ 187.777.754*	*€ 40.935.062*	*€ 228.712.816*	*€ 258.974.205*	*€ 16.309.125*	*€ 275.283.330*	*€ 503.996.146*
Bandbreedte: met een 70%-betrouwbaarheidsinterval liggen de kosten incl. BTW tussen			*€ en €*			*€ en €*		*€ en €*
De variatiecoëfficiënt bedraagt			*± - -*			*± - -*		*± - -*
Geraamde kosten incl. BTW				€ 276.742.508			€ 333.092.829	€ 609.835.337
Onzekerheidsreserve (opgave financier)				€ -			€ -	€ -
Reservering scopewijzigingen (opgave financier)				€ -			€ -	€ -
Gerealiseerde kosten (opgave financier)				€ -			€ -	€ -
Aan te houden budget incl. BTW				**€ 276.742.508**			**€ 333.092.829**	**€ 609.835.337**
Excl. BTW				€ 228.712.816			€ 275.283.330	€ 503.996.146

Route: Sluiskil via Flanders

Figure B-9 - SSK Management Overview - Low Scenario (Flanders Route)

Managementoverzicht SSK-2018								*Rekenmodel SSK-2018 versie 2.4.002*
		Investeringskosten (rekenhorizon 6 jaar, reële kosten)			Instandhoudingskosten (rekenhorizon 25 jaar, reële kosten)			Levenscycluskosten (rekenhorizon 25 jaar, reële kosten)
Object	Geactiveerd	Voorziene kosten	Risicoreservering	Totaal	Voorziene kosten	Risicoreservering	Totaal	
Deelraming Labour + Maint. + Fees	JA	€ 118.374.219	€ 13.229.755	€ 131.603.973	€ 125.112.488	€ 12.511.249	€ 137.623.736	€ 269.227.710
Deelraming Materials - 10in	JA	€ 24.699.761	€ 2.512.581	€ 27.212.342	€ -	€ -	€ -	€ 27.212.342
Deelraming Pumpstation	JA	€ 4.797.807	€ 479.781	€ 5.277.588	€ 32.764.875	€ -	€ 32.764.875	€ 38.042.463
Objectoverstijgende risicoreservering incl. verschuiving	JA		€ 17.844.328	€ 17.844.328		€ -	€ -	€ 17.844.328
Kosten incl. BTW		**€ 147.871.787**	**€ 34.066.444**	**€ 181.938.231**	**€ 157.877.363**	**€ 12.511.249**	**€ 170.388.612**	**€ 352.326.843**
Excl. BTW		*€ 122.208.089*	*€ 28.154.086*	*€ 150.362.175*	*€ 130.477.159*	*€ 10.339.875*	*€ 140.817.034*	*€ 291.179.209*
Bandbreedte: met een 70%-betrouwbaarheidsinterval liggen de kosten incl. BTW tussen			*€ en €*			*€ en €*		*€ en €*
De variatiecoëfficiënt bedraagt			*± - -*			*± - -*		*± - -*
Geraamde kosten incl. BTW				€ 181.938.231			€ 170.388.612	€ 352.326.843
Onzekerheidsreserve (opgave financier)				€ -			€ -	€ -
Reservering scopewijzigingen (opgave financier)				€ -			€ -	€ -
Gerealiseerde kosten (opgave financier)				€ -			€ -	€ -
Aan te houden budget incl. BTW				**€ 181.938.231**			**€ 170.388.612**	**€ 352.326.843**
Excl. BTW				€ 150.362.175			€ 140.817.034	€ 291.179.209

Figure B-10 - SSK Management Overview – Central Scenario (Flanders Route)

Managementoverzicht SSK-2018									*Rekenmodel SSK-2018 versie 2.4.002*
			Investeringskosten (rekenhorizon 6 jaar, reële kosten)			Instandhoudingskosten (rekenhorizon 25 jaar, reële kosten)			Levenscycluskosten
Object	Geactiveerd	Geactiveerd	Voorziene kosten	Risicoreservering	Totaal	Voorziene kosten	Risicoreservering	Totaal	eële kosten)
Deelraming Labour + Maint. + Fees	JA	JA	€ 124.312.144	€ 13.719.597	€ 138.031.741	€ 136.451.700	€ 13.645.170	€ 150.096.870	€ 288.128.611
Deelraming Materials - 12in	JA	JA	€ 31.383.981	€ 3.167.277	€ 34.551.259	€ -	€ -	€ -	€ 34.551.259
Deelraming Pumpstation	JA	JA	€ 4.797.807	€ 479.781	€ 5.277.588	€ 60.516.042	€ -	€ 60.516.042	€ 65.793.630
Objectoverstijgende risicoreservering incl. verschuiving	JA	JA		€ 19.103.321	€ 19.103.321		€ -	€ -	€ 19.103.321
Kosten incl. BTW			**€ 160.493.933**	**€ 36.469.976**	**€ 196.963.909**	**€ 196.967.742**	**€ 13.645.170**	**€ 210.612.912**	**€ 407.576.821**
Excl. BTW			*€ 132.639.614*	*€ 30.140.476*	*€ 162.780.090*	*€ 162.783.258*	*€ 11.277.000*	*€ 174.060.258*	*€ 336.840.348*
Bandbreedte: met een 70%-betrouwbaarheidsinterval liggen de kosten incl. BTW tussen		*tussen*		*€ en €*			*€ en €*		
De variatiecoëfficiënt bedraagt				*± - -*			*± - -*		
Geraamde kosten incl. BTW					€ 196.963.909			€ 210.612.912	€ 407.576.821
Onzekerheidsreserve (opgave financier)					€ -			€ -	€ -
Reservering scopewijzigingen (opgave financier)					€ -			€ -	€ -
Gerealiseerde kosten (opgave financier)					€ -			€ -	€ -
Aan te houden budget incl. BTW				**€ 196.963.909**			**€ 210.612.912**		**€ 407.576.821**
Excl. BTW				€ 162.780.090			€ 174.060.258		€ 336.840.348

Figure B-11 - SSK Management Overview – High Scenario (Flanders Route)

Managementoverzicht SSK-2018								*Rekenmodel SSK-2018 versie 2.4.002*
								Levenscycluskosten
		Investeringskosten (rekenhorizon 6 jaar, reële kosten)			Instandhoudingskosten (rekenhorizon 25 jaar, reële kosten)			(rekenhorizon 25 jaar, reële kosten)
Object	Geactiveerd	Voorziene kosten	Risicoreservering	Totaal	Voorziene kosten	Risicoreservering	Totaal	
Deelraming Labour + Maint. + Fees	JA	€ 194.025.653	€ 21.240.458	€ 215.266.111	€ 230.754.563	€ 23.075.456	€ 253.830.019	€ 469.096.130
Deelraming Materials - 10+12in	JA	€ 58.709.356	€ 5.941.008	€ 64.650.364	€ -	€ -	€ -	€ 64.650.364
Deelraming Pumpstation	JA	€ 4.797.807	€ 479.781	€ 5.277.588	€ 88.267.209	€ -	€ 88.267.209	€ 93.544.797
Objectoverstijgende risicoreservering incl. verschuiving	JA		€ 30.427.371	€ 30.427.371		€ -	€ -	€ 30.427.371
Kosten incl. BTW		**€ 257.532.817**	**€ 58.088.617**	**€ 315.621.435**	**€ 319.021.771**	**€ 23.075.456**	**€ 342.097.228**	**€ 657.718.662**
Excl. BTW		*€ 212.837.039*	*€ 48.007.122*	*€ 260.844.161*	*€ 263.654.356*	*€ 19.070.625*	*€ 282.724.981*	*€ 543.569.142*
Bandbreedte: met een 70%-betrouwbaarheidsinterval liggen de kosten incl. BTW tussen		*€ en €*			*€ en €*			*€ en €*
De variatiecoëfficiënt bedraagt		*± - -*			*± - -*			*± - -*
Geraamde kosten incl. BTW				€ 315.621.435			€ 342.097.228	€ 657.718.662
Onzekerheidsreserve (opgave financier)				€ -			€ -	€ -
Reservering scopewijzigingen (opgave financier)				€ -			€ -	€ -
Gerealiseerde kosten (opgave financier)				€ -			€ -	€ -
Aan te houden budget incl. BTW				**€ 315.621.435**			**€ 342.097.228**	**€ 657.718.662**
Excl. BTW				€ 260.844.161			€ 282.724.981	€ 543.569.142

Figure B-12 - SSK Management Overview – Extended Scenario (Flanders Route)

Managementoverzicht SSK-2018								*Rekenmodel SSK-2018 versie 2.4.002*
								Levenscycluskosten
		Investeringskosten (rekenhorizon 6 jaar, reële kosten)			Instandhoudingskosten (rekenhorizon 25 jaar, reële kosten)			(rekenhorizon 25 jaar, reële kosten)
Object	Geactiveerd	Voorziene kosten	Risicoreservering	Totaal	Voorziene kosten	Risicoreservering	Totaal	
Deelraming Labour + Maint. + Fees	JA	€ 196.106.421	€ 21.662.648	€ 217.769.070	€ 242.093.775	€ 24.209.378	€ 266.303.153	€ 484.072.222
Deelraming Materials - 2 x 12in	JA	€ 66.462.918	€ 6.646.292	€ 73.109.210	€ -	€ -	€ -	€ 73.109.210
Deelraming Pumpstation	JA	€ 4.797.807	€ 479.781	€ 5.277.588	€ 116.018.375	€ -	€ 116.018.375	€ 121.295.964
Objectoverstijgende risicoreservering incl. verschuiving	JA		€ 31.667.593	€ 31.667.593		€ -	€ -	€ 31.667.593
Kosten incl. BTW		**€ 267.367.147**	**€ 60.456.314**	**€ 327.823.461**	**€ 358.112.150**	**€ 24.209.378**	**€ 382.321.528**	**€ 710.144.989**
Excl. BTW		*€ 220.964.584*	*€ 49.963.896*	*€ 270.928.480*	*€ 295.960.455*	*€ 20.007.750*	*€ 315.968.205*	*€ 586.896.685*
Bandbreedte: met een 70%-betrouwbaarheidsinterval liggen de kosten incl. BTW tussen		*€ en €*			*€ en €*			*€ en €*
De variatiecoëfficiënt bedraagt		*± - -*			*± - -*			*± - -*
Geraamde kosten incl. BTW				€ 327.823.461			€ 382.321.528	€ 710.144.989
Onzekerheidsreserve (opgave financier)				€ -			€ -	€ -
Reservering scopewijzigingen (opgave financier)				€ -			€ -	€ -
Gerealiseerde kosten (opgave financier)				€ -			€ -	€ -
Aan te houden budget incl. BTW				**€ 327.823.461**			**€ 382.321.528**	**€ 710.144.989**
Excl. BTW				€ 270.928.480			€ 315.968.205	€ 586.896.685

ADDITIONAL WALL THICKNESS SENSITIVITY

There is a possibility that further discussions with Government entities may lead to additional safety requirements for certain portions or the full length of the proposed pipeline. A high-level sensitivity analysis on the estimated costs resulting from these requirements has been conducted (for the Central Scenario only). For this sensitivity check the following additional assumptions have been applied:

- Pipeline wall thickness will need to be increased by 50 percent (from SCH 60 to SCH 100);
- Material costs are derived from the unit weight of each pipe (kg/m);

— Higher weld costs due to extra time for welding;

— No allowance for higher pump power usage; and

— Any other costs are expected to be negligible or covered under the general risk allowance.

SCENARIO	TOTAL INVESTMENT COSTS EXCL. VAT	EXPECTED COSTS	RISK RESERVE
CENTRAL ***SCENARIO (12" PIPE)***			
VLISSINGEN ROUTE	€ 174,700,000	€ 144,300,000	€ 30,400,000
VLISSINGEN (+50% WT)	*€ 193,800,000*	*€ 159,100,000 (+10%)*	*€ 34,700,000*
SLUISKIL (VIA ZEELAND)	€ 139,200,000	€ 114,700,000	€ 24,500,000
SLUISKIL (VIA ZE. +50% WT)	*€ 154,500,000*	*€ 126,500,000 (+10%)*	*€ 28,000,000*
SLUISKIL (VIA FLANDERS)	€ 162,800,000	€ 132,600,000	€ 30,200,000
SLUISKIL (VIA FL. +50% WT)	*€ 181,700,000*	*€ 147,300,000 (+11%)*	*€ 34,400,000*
VERY HIGH SCENARIO (2 X 12" PIPES)			
VLISSINGEN ROUTE	€ 283,700,000	€ 233,300,000	€ 50,400,000
VLISSINGEN (+50% WT)	*€ 321,200,000*	*€ 262,200,000 (+12%)*	*€ 59,000,000*
SLUISKIL (VIA ZEELAND)	€ 228,700,000	€ 187,800,000	€ 40,900,000
SLUISKIL (VIA FLANDERS)	€ 270,900,000	€ 221,000,000	€ 49,900,000

Appendix C

EXTERNAL SAFETY LEGISLATION

THE NETHERLANDS

The external safety assessment has been conducted within the framework of the Environment and Planning Act (Omgevingswet (Ow)). The Environment and Planning Act combines and modernises laws for spatial planning, housing, infrastructure, the environment, nature and water. From an external safety perspective, the social goal of "protecting the physical living environment" that is most relevant.

This goal in concerned with achieving and maintaining a safe and healthy physical environment. To achieve this goal, the Act provides public authorities with various instruments such as environmental visions, environmental plans, and general rules of central government such as the Environmental Activities Decree (Besluit activiteiten leefomgeving (Bal)) and the Environmental Quality Decree (Besluit kwaliteit leefomgeving (Bkl)). These can be used to make policy on external safety, or to set rules that provide for a certain level of protection.

For this certain level of protection certain external safety distances are used and these distances seek to maintain sufficient distance between installations carrying hazardous substances and external third-party objects. In the Bkl these external safety distances are differentiated into a distance for location-specific risk and for focus areas.

For both the location-specific risk and the focus areas, it has been legally established (Bal and Bkl) how the external safety distances must be determined or calculated, and with which calculation program these contours must be calculated (Environmental Regulation (Omgevingsregeling)). The results depend on the type of environmentally harmful activity, type of hazardous material, the amount of material, type of installation etc. A calculation in which both the location-specific risk and the focus areas are calculated in a single calculation is called a quantitative risk analysis (QRA).

The safety calculations within our assessment have been made using the mandated risk calculation software. For the rail and barge transport this is RBM II. The mandated risk calculation software for the pipeline is SAFETI-NL.

It should be noted equivalent legislation in Germany is different with respect to the transportation of ammonia, and the scope of the safety assessment is therefore only within the Netherlands.

LOCATION-SPECIFIC RISK

According the Bkl art. 5.6 *“The location-specific risk is the risk of death of an unprotected person who is continually present outside the boundary of the location where an activity is performed, as a direct consequence of an unusual occurrence caused by that activity.”*.

One of the assessment rules for an application of an environmental permit for an environmentally harmful activity is the location-specific risk (plaatsgebonden risicocontour). The environmental permit will only be issued if a limit value for the location-specific risk of the activity is taken into account of not more than 10^{-6} per year for vulnerable and very vulnerable buildings and vulnerable locations. This value can be indicated as a contour on a map; this is then called the "PR 10^{-6} contour". 10^{-6}/yr means a chance of once in a million per year. Houses and other residential buildings may not be present within this contour belonging to new environmentally harmful activities and may not be built within this contour. This is laid down in legislation (Bal and Bkl). If this standard cannot be met, the permit will not be granted.

FOCUS AREAS

Focus areas are areas around risk sources (environmentally harmful activities) in which people indoors are possibly insufficiently protected without additional measures against the dangers that can occur in the vicinity, in other words, can die as a result of an incident involving hazardous substances. Examples of these life-threatening hazards are heat radiation from a fire, overpressure from an explosion and inhalation of poisonous substances from a toxic cloud. The danger therefore depends on the substance and the type of effect.

Gasoline, for example, only has a fire risk area (fire is the only hazard); ammonia only has a toxic cloud risk area (toxicity is the dominant hazard); LNG has a fire risk area and also an explosion risk area (spillage forms a flammable cloud that can explode). Therefore three focus areas are defined: fire focus area; explosion focus area; and toxic cloud focus area. Within the focus areas, extra attention may be needed to protect those present.

- A fire focus area (brandaandachtsgebied (BAG)) is the location bounded by the distance where, as a consequence of an unusual occurrence that results in a pool fire or jet fire, the thermal radiation is not more than 10 kW/m^2.
- An explosion focus area (explosie aandachtsgebied (EAG)) is the location bounded by the distance where, as a consequence of an unusual occurrence that results in:
  - a Boiling Liquid Expanding Vapor Explosion (BLEVE), the thermal radiation is not more than 35 kW/m^2; or
  - an explosion other than a BLEVE, the overpressure is not more than 10 kPa.
- A toxic cloud focus area (gifwolk aandachtsgebied (GAG)) is the location bounded by the distance where, as a consequence of an unusual occurrence that results in a toxic cloud, persons in a building die as a consequence of exposure to the maximum concentration of a dangerous substance determined by ministerial order during the duly designated period. A toxic cloud focus area for special planning is bounded by a distance of 1.5 km from the location within the boundary of the activity, if the calculated distance is greater than 1.5 km. This does not occur for an application of an environmental permit. In that case the entire GAG has to be presented.

For protection measures can be taken to allow people to take shelter safely or to escape safely. Whether this is necessary is a decision for the competent authority. The competent authority must provide an assessment of the probability of more than 10 people dying at once due to an incident involving hazardous substances. This assessment is necessary in the case of a new situation involving hazardous substances (for example, a new pipeline for transportation of ammonia) or the construction of a new building within a focus area.

Under the Environmental Act, the competent authority assigns functions to locations in the environmental plan. The competent authority may choose to assign locations where focus areas are permitted and to assign functions to the land within a focus area where people can stay. Because it is within a focus area, the competent authority must consider whether persons are sufficiently protected and, if necessary, specify restrictions in land use, such as a maximum building height, or take additional measures.

SAFETY REGION

According to the Environment Decree (Omgevingsbesluit (Ob)) art. 4.33 the board of the safety region in whose territory all or most of an environmentally harmful activity is performed will be an advisor for an application for an environmental permit in as much as the application relates to an environmentally harmful activity such as transport of ammonia through pipeline.

Local authorities also ask, in case of a non-planned environment plan activity, the board of the safety region to advise them about the need for additional measures within new focus areas. The advice is not legally binding, but the local competent authority rarely deviates from it.

One point to note is that the board of the safety region mainly looks at the effects of incidents involving hazardous substances and less at the probability. They assess the degree of manageability of the effects and the ability of people in the vicinity to shelter or flee. It's important to include them in the process and keep them informed of the choices made and the technical measures implemented.

DETERMINATION AND CALCULATION EXTERNAL SAFETY DISTANCES

In this project we are looking at three ways of transporting ammonia, by rail, inland waterway and pipeline (EHB has not been included in the safety assessment as the infrastructure will already exist). All three are environmentally harmful activities for which, according to Bal and Bkl, external safety distances must be determined.

Transport by rail and inland waterway

Rules on external safety for the transport of hazardous substances are included in the Transport of Hazardous Substances Act (Regeling Basisnet). The 'Basisnet' is a nationally designated network for the transport of hazardous substances. It consists of the motorways, waterways and railways that are important for the transport of hazardous substances. It involves transport between chemical companies and ports in the Netherlands and neighbouring countries. Since 1 April 2015, rules have applied here.

The rules for Basisnet are about establishing and controlling the risks of transporting hazardous substances (transport side)[38]. Within limits, it remains possible to transport hazardous substances by road, inland waterways and rail. Basisnet is there to protect people living or staying close to these main roads, inland waterways and main railways. The level of protection is sufficient if the risk from transport does not exceed what is defined as socially acceptable.

The location-specific risk for routes that are part of Basisnet are determined in the Regeling Basisnet. Annex I up to III contains tables where, for each section of the route, the distances to the location-specific risk are given. These so-called risk ceilings are distances, expressed in metres from the infrastructure. These are fixed distances. The Ministry of Infrastructure and Water Management periodically monitors these distances based on transport realisation numbers.

All routes that are part of Basisnet have a fire and explosion and toxic cloud focus area. The roads, railways and inland waterways with a focus area are designated in Article 2.23 of the Environmental

[38] Rules for the transport as such and the means of transport are contained in the Règlement concernant le transport international ferroviaire des marchandises dangereuses (RID for railtransport) and Accord européen relatif au transport des marchandises dangereuses par voies de navigation intérieures (ADN for water)

Regulations (Omgevingsregeling). And that refers to the tables for road, rail (and water) in the annexes of the Regeling Basisnet.

The fire, explosion and toxic cloud focus areas along Basisnet have a fixed distance (Bkl Annex VII part C) and will be geometrically delimited. The extent is:

- of a fire focus area: 30 m;
- of an explosion focus area: 200 m; and
- of a toxic cloud focus area: distance to be determined (probably 300 m).

Transport figures show that there is transport of toxic substances over almost the entire Basisnet. Basisnet allows toxic transport, regardless of the degree of toxicity. For this reason, toxic cloud focus areas may be designated along the entire Basisnet. This will be in the Environment Regulation.

The presence and distances of all the focus areas are independent of fluctuations in transport. The volume and composition of dangerous goods transport do not lead to adjustment of the focus areas. The varying origin and destination of dangerous goods transport also does not affect the focus areas.

Transport by pipeline

The environmentally harmful activity ‘Pipeline with hazardous substances’ is included in the Bal Paragraph 3.4.3 and 4.108. The transport of ammonia through pipelines is covered by the description in these paragraphs. The articles in this section of the Bal state that the PR 10^{-6} contour must be adhered to as a limit value, with a minimum distance of 5 metres. A pipeline shall not be operated if in non-compliance with the PR 10^{-6} contour (art. 4.1114 Bal).

According to Bkl Annex VII part D under 2 the location-specific risk and toxic cloud focus area along the Pipeline must be calculated. Calculating the distance for the location-specific risk for the activity 'operating a pipeline, as referred to in Section 3.101 of the Decree on activities in the living environment' must be carried out in accordance with Module V of the Environmental Safety Calculation Regulations and using the SAFETI-NL calculation program (Environmental Regulations Art. 4.11).

To calculate the distance for the toxic cloud focus area, one must use the Roadmap Determining Fire Focus Areas, the Environmental Safety Calculation Regulations and SAFETI-NL ((Environmental regulation art. 4.11).

BELGIUM

The external safety study for the Flemish part of the route is different from the Dutch part. In Belgium, there is no legislation governing external safety in relation to the transport of hazardous substances, as there is in the Netherlands. In Belgium, the rules are laid down in separate laws in federal or Flemish legislation and regulations for each type of risk source. In this project, we are looking at two methods of ammonia transport for the part of the route through Belgium, namely by rail and by pipeline.

RAIL TRANSPORTATION

The basis for safe transport by rail through Belgium is the Règlement concernant le transport international ferroviaire des marchandises dangereuses (RID for rail transport). In addition, the Act of 30/08/2013 containing the Railway Code (Wet houdende de Spoorcodex) applies. Among other things, this code describes the rules for the railway infrastructure manager with regard to safety on the railways. For example, it states that in the event of an accident on the railways, the railway infrastructure manager is responsible for taking the appropriate measures to restore normal conditions. It must also establish a safety management system containing procedures and methods for assessing and controlling risks when new risks arise for the infrastructure or activities due to a change in operating conditions or new equipment. However, unlike in the Netherlands, there are no external safety distances for the transport of dangerous goods by rail in Belgium. As a result, there is no legal aspect relating to external safety in the consideration of the route through Belgium/Flanders for the transport of ammonia by rail.

PIPELINE TRANSPORTATION

The federal decree entitled: "19 MARCH 2017. - Royal Decree on safety measures relating to the construction and operation of installations for the transport of gaseous products and other products by pipeline" (Koninklijk besluit betreffende de veiligheidsmaatregelen inzake de oprichting en de exploitatie van installaties voor vervoer van gasachtige producten en andere door middel van leidingen) lays down the safety measures relating to transport installations in terms of the design, construction, operation and decommissioning of these transport installations and defines the scope and amendment procedure of the Technical Codes for transport installations. This decree also stipulates (Chapter 4, Section 6) that a risk analysis must be carried out for the route of each new transport pipeline for which a transport permit is required, in order to confirm the acceptability of the route.

This risk analysis must contain at least the following elements:

1. a description of the pipeline and the product transported;
2. a detailed description of the route of the pipeline;
3. a quantitative risk analysis;
4. an assessment of the risks to humans arising from the presence of the pipeline.

The risk analysis must be attached to the transport permit application, which must be submitted in accordance with Chapter III of the Royal Decree of 14 May 2002 on transport permits for gaseous products and other products transported by pipeline. The "Technical Code on Risk Analysis of Transport Installations for Flammable and Oxidizing Products Rev. 1 – 1 December 2020" has been drawn up for the implementation of the risk analysis. The risk analysis for the transport of toxic products by pipeline is not yet included in the code.

In this case, the decree of 19 March 2017 states that:

In the absence of rules in the Technical Codes, the holder of the transport permit (the applicant for the permit) may apply a special measure or method insofar as that measure or method is approved by the designated officials of the Energy Board and the Quality and Safety Administration on the basis of a substantiated technical file submitted to them.

The technical code only concerns the risk analysis for the transport of flammable and oxidizing products. In the absence of a described methodology, the risk analysis for a toxic product must therefore be based on the same principles as those described in this code and on the same acceptable risk levels.

Section 4.2 of the technical code sets out the acceptable risk levels:

The acceptability of the transport installation in relation to its environment is determined by four criteria linked to the calculation methodology, which must all be met simultaneously:

1. The "POK" may not exceed 10^{-5} within the reserved zone.
2. The "POK" may not exceed 10^{-6} in residential areas.
3. The "vulnerable locations" along the transport facility must be outside the zone defined by the criterion that defines zone 1 in the Action Map.
4. The "public locations" along the transport facility must be outside the zone defined by the criterion that defines zone 1 in the Action Map.

Here, the "POK" stands for the Local Probability of Death. This is the probability that a person who is present at a certain location for one year, clothed but unprotected, will die as a direct result of an uncontrolled loss of the product transported in the pipeline. The POK for the ammonia pipeline is calculated using the principles from the technical code and can be shown as contours around the pipeline.

Points 3 and 4 relate to 'the criterion that defines zone 1 in the Action Map'. Zone 1 relates to the so-called house burning distance. This is a zone based on heat radiation effects resulting from a fire. This does not apply to ammonia. In the risk analysis, only the toxic effect of ammonia is considered. Only criteria 1 and 2 apply to the ammonia pipeline.

The reserved zone is a zone with a total width of 10 m within which the transport pipeline is centrally located (valid for all diameters). For pipelines with a maximum permissible operating pressure ≤ 16 bar, the width of the reserved zone is reduced to 4 m. Within this zone, the POK may not exceed 10^{-5}. In residential areas, the POK may not exceed 10^{-6}. These distances must be observed (section 4.2 of the Technical Code).

Additional requirements

The applicant for the transport permit for the transport of ammonia through a long-distance pipeline in Belgium is additionally obliged to take repressive measures in the event of a leak involving the release of the contents of two pipeline segments. In addition, the pipeline operator must ensure that firefighters in all stations along the route are trained to deal with an incident involving the ammonia pipeline. All this stems from new rules on non-contractual liability in Book 6 of the Civil Code, which has come into effect in 2025.

From 2025 onwards, auxiliary persons (such as subcontractors, implementing agents, pipeline operators) can be held directly liable for errors that cause damage, even if there is no direct contractual relationship. Book 6 Article 6.3, paragraph 2 of the Belgium Civil Code explicitly states that non-contractual liability also applies between the injured party and the auxiliary person of his co-contracting party. This means that, for example, a pipeline operator may be liable for damage to third parties, including emergency services, as a result of negligence or inadequate risk management.

Appendix D

ASSUMPTIONS FOR RISK CALCULATIONS

PIPELINE PARAMETERS FOR RISK CALCULATIONS FOR PIPELINES IN THE NETHERLANDS

The risk calculations for Dutch part of the pipeline are made in accordance with the calculation requirements set in the “Rekenmethodiek Omgevingsveiligheid Module V”. In this document all the scenario’s, frequencies and risk reducing measures are given. Table D-1 shows the four different volume scenario’s and used pipeline parameters. Shutoff valves will be implemented every 3 km along the pipeline route.[39]

Table D-1 – Pipeline parameters for risk calculations Netherlands

Volume scenario	Pipe diameter [inch]	Wall thickness[mm]	Depth [m]
1,500,000 ton/yr	10	12.7	2
3,000,000 ton/yr	12	15[40]	2
4,500,000 ton/yr	14	15.09	2
6,000,000 ton/yr	16	16.66	2

The risk calculations are made with additional measures to reduce the failure frequency. These measures are:

- Pipeline complies with state of the art technology
- Active reminder
- Warning tape
- In-line inspection
- Extensive measures whereby unacceptable settlement or stress can reasonably be ruled out by means of an evaluation.
- Safety Integrity Level +1

The last three measures can only be implemented after approval by the competent authority.

All calculations are done with the crater model implemented in the safety calculation software Safeti-NL 9.2. This crater model is not prescribed in the calculation methodology, but is heavily recommended in the methodology.

[39] The Dutch authorities indicated that in the near future they want to implement rules regarding the number of shutoff valves in a ammonia pipeline near residential area’s. An increases in number of valves per distance might be needed in the future.

[40] Pipelines with a wall thickness of 15 mm or more have a reduced failure frequency. That is why the 12 inch pipeline is modeled with 15 mm wall thickness.

PIPELINE PARAMETERS FOR RISK CALCULATIONS FOR PIPELINES IN BELGIUM

The risk calculations for Belgian part of the pipeline are made in accordance with the calculation requirements set in the “Technische code betreffende de risicoanalyse van vervoersinstallaties voor brandbare en oxiderende producten”. Whilst this document is not made for toxic substances like ammonia, the central government (FOD) specifically advised to use this document for determining the scenario’s, frequencies and risk reducing measures. Table D-2 shows the four different volume scenario’s and used pipeline parameters. Shutoff valves will be implemented every 3 km along the pipeline route.

Table D-2 - Pipeline parameters for risk calculations Belgium

Volume scenario	Pipe diameter [inch]	Wall thickness[mm]	Depth [m]
1,500,000 ton/yr	10	12.7	2
3,000,000 ton/yr	12	14.27	2
4,500,000 ton/yr	14	15.09	2
6,000,000 ton/yr	16	16.66	2

The risk calculations are made with additional measures to reduce the failure frequency. These measures are:

- Pipeline complies with state of the art technology
- Active reminder
- Warning tape
- In-line inspection Ultrasonic
- Extensive measures whereby unacceptable settlement or stress can reasonably be ruled out by means of an evaluation.

All calculations are done with the crater model implemented in the safety calculation software Safeti-NL 9.2. Also all other effect calculation parameters used in the Dutch safety calculation are used. These parameters and crater model is not prescribed in the calculation methodology, but the central government advised to use the same parameters as used in The Netherlands as they plan to prescribe these in a new “Technische Code” specifically made for toxic substances.

RAILWAY PREDICTED NUMBER OF TRANSPORTS

The risk calculations for the 2030 and 2050 base scenarios are made based on the realised figures of 2021[41] [4] and Reconnaissance Transport of Hazardous Substances (RTHS) of 2024[42]. Table 3.5 of RTHS indexes transport between 2021 and 2033. This index has been recalculated for the 2050 scenarios and is shown in Table D-1.

Table D-1 - Indexed rail transports of hazardous goods

Hazardous goods category	Index '21-'33	Index per year	Factor 2050
A (flammable gas)	1.51	1.03	2.71
B2 (toxic gas)	2.87	1.09	12.82
B3 (very toxic gas)	1.00	1.00	1.00
C3 (flammable liquid)	2.70	1.09	11.03
D3 (toxic liquid)	1.52	1.04	2.75
D4 (very toxic liquid)	1.46	1.03	2.50

INLAND SHIPPING PREDICTED NUMBER OF TRANSPORTS

The risk calculations for the 2030 and 2050 base scenarios are made based on the realised figures of 2021 and the RTHS of 2024. Table 4.3 of RTHS indexes transport between 2021 and 2033. This index has been recalculated for the 2050 scenarios and is shown in Table D-2.

Table D-2 - Indexed inland shipping transports of hazardous goods

Hazardous goods category	Index '21-'33	Index per year	Factor 2050
LF1 (flammable liquid)	1.12	1.01	1.32
LF2 (very flammable liquid)	1.27	1.02	1.78
LT1 (toxic liquid)	1.37	1.03	2.14
LT2 (very toxic liquid)	1.35	1.03	2.07
GF2 (flammable gas)	1.20	1.02	1.55
GF3 (very flammable gas)	1.12	1.01	1.09
GT3 (toxic gas)	3.19	1.10	2.39

[41] Rapport toetsing realisatiecijfers vervoer gevaarlijke stoffen over het spoor aan de risicoplafonds Basisnet Versie inclusief alle realisatiecijfer
[42] Verkenning vervoer gevaarlijke stoffen

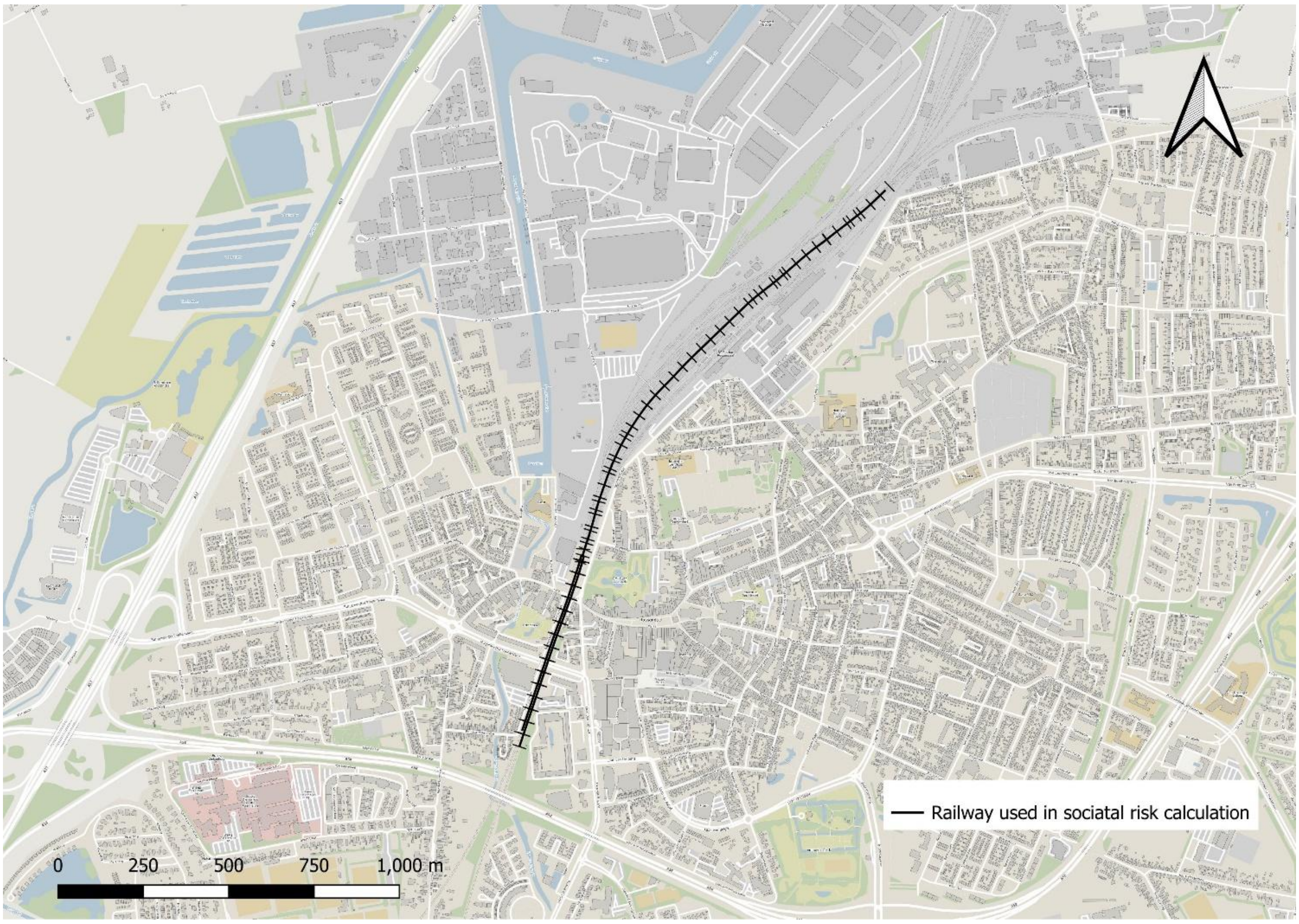
RAILWAY PARAMETERS SOCIETAL RISK CALCULATIONS

ROUTE FROM VLISSINGEN ROOSENDAAL

LOCATION RAILROADS

This chapter describes the method and the parameters used in the calculation. Figure D-1 visualizes the location of the railroads Vlissingen – Roosendaal and Roosendaal – Antwerpen.

Figure D-1 - Location railroads Vlissingen – Roosendaal and Roosendaal – Antwerpen



Railroads

The railroads Vlissingen – Roosendaal and Roosendaal – Antwerpen are used for the transport of hazardous goods. These railroads are designated routes 11 and 35 of the Dutch railroad network of hazardous goods (Basisnet). The risk of the transport of these hazardous goods are calculated using the risk calculation program RBM II, version 2.3. The calculation is carried out in accordance with the Hart. The calculation requires the following:

- The transport intensity of hazardous goods.
- Railroad track properties, e.g. the outflow frequency, the chance of a railway tank car (rtc) containing hazardous goods getting involved in an accident, causing an outflow of these hazardous goods, measured per kilometre.

- The (presumed) population along the railroad that will be exposed to the effects of an accident. The population densities will de indicated with squares, each square using an uniform density. The presumed day and night presence of the population will be indicated per individual square.
- The meteorological data used in the calculation are derived from the weather station Vlissingen.

TRANSPORT INTENSITY

Table D-3 contains the used transport intensities. The standard assumption in the risk calculation is that 29% of the hazardous goods are transported during the daytime, between 8:00 and 18:30, spread evenly throughout the week.

Table D-3 - Transport intensity

Main category	Class	Substance example	Intensity used for risk calculation				
			11.1	35.7a	35.7b	35.7c	35.8
Flammable gas	A	Propane	27495	41885	41934	41885	14390
Toxic gas	B2	Ammonia	0	10122	10122	10097	10097
(Very) Toxic gas	B3	Chlorine	0	0	0	0	0
Flammable liquid	C3	Pentane	0	49771	49876	49760	49760
Toxic liquid	D3	Acrylonitrile	0	1439	1441	1433	1433
(Very) Toxic liquid	D4	Acrolein	0	193	193	193	\]

The population within 995 m (the affected area of hazardous good category B2) of the railroads has been inventoried. Even though the hazardous good category D4 has an area of at least 4 km, the impact of a toxic cloud to the population past 995 m has practically no influence on the societal risk.

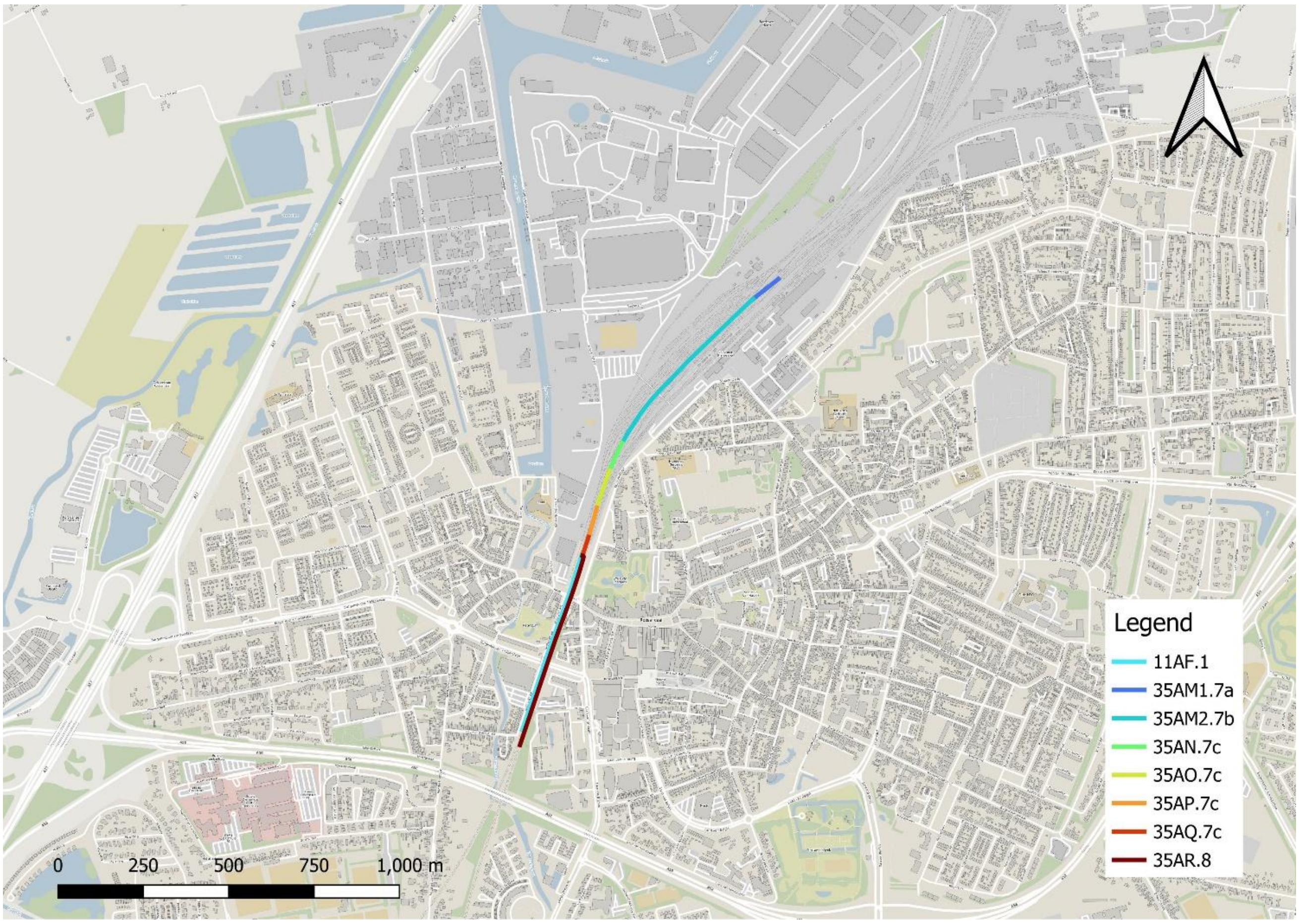
TRACK PARAMETERS

The parameters of the railroads largely consist of track in the category 0-24 m. The width used in the calculation for these parts is therefore 9 m [3]. The other track sections have different widths, which are visualized in Table D-4. The risk calculation uses the standard outflow frequency, for track sections designated for high speed transport (> 40 km/h) with turnout addition, of 6.072 10^{-8} /rtc-km. Other track sections uses the standard outflow frequency, for track designated for low speed transport (< 40 km/h) with turnout addition, of 4.664 10^{-8} /rtc-km. The track sections are visualized in Figure D-2.

Table D-4 - Parameters per track section

Track section	Width category [m]	Calculation width [m]	Track speed	Turnout addition	Outflow frequency
11AF	0-24	9	High speed	Y	$6.072\ 10^{-8}$
35AM1	75-99	99	Low speed	Y	$4.664\ 10^{-8}$
35AM2	75-99	99	Low speed	Y	$4.664\ 10^{-8}$
35AN	50-74	74	Low speed	Y	$4.664\ 10^{-8}$
35AO	25-49	49	Low speed	Y	$4.664\ 10^{-8}$
35AP	0-24	9	Low speed	Y	$4.664\ 10^{-8}$
35AQ	0-24	9	High speed	Y	$6.072\ 10^{-8}$
35AR	0-24	9	High speed	Y	$6.072\ 10^{-8}$

Figure D-2 - Track sections Roosendaal

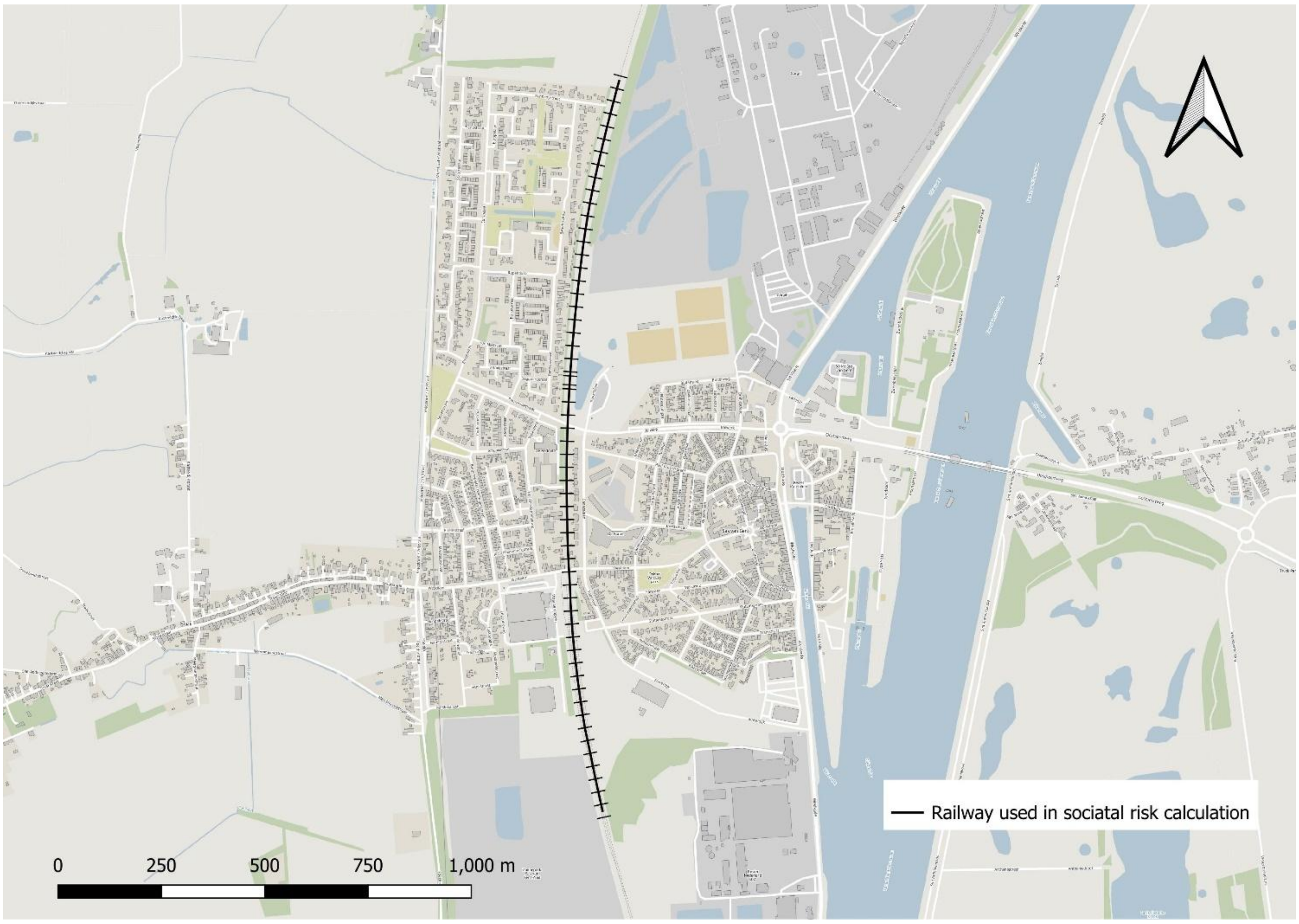


ROUTE FROM TERNEUZEN

LOCATION RAILROADS

This chapter describes the method and the parameters used in the calculation. Figure D-3 visualizes the location of the railroad Terneuzen – Sas van Gent.

Figure D-3 - Location railroad Terneuzen – Sas van Gent



Railroads

The railroad Terneuzen – Sas van Gent is used for the transport of hazardous goods. These railroads are designated route 180 of the Dutch railroad network of hazardous goods (Basisnet). The risk of the transport of these hazardous goods are calculated using the risk calculation program RBM II, version 2.3. The calculation is carried out in accordance with the Hart. The calculation requires the following:

- The transport intensity of hazardous goods;
- Railroad track properties, e.g. the outflow frequency, the chance of a railway tank car (rtc) containing hazardous goods getting involved in an accident, causing an outflow of these hazardous goods, measured per kilometre;
- The (presumed) population along the railroad that will be exposed to the effects of an accident. The population densities will de indicated with squares, each square using an uniform density.

The presumed day and night presence of the population will be indicated per individual square; and

- The meteorological data used in the calculation are derived from the weather station Vlissingen.

TRANSPORT INTENSITY

Table D-5 contains the used transport intensities. The standard assumption in the risk calculation is that 29% of the hazardous goods are transported during the daytime, between 8:00 and 18:30, spread evenly throughout the week.

Table D-5 - Transport intensity

Main category	Class	Substance example	Intensity used for risk calculation
			180.2
Flammable gas	A	Propane	6549
Toxic gas	B2	Ammonia	3282
(Very) Toxic gas	B3	Chlorine	0
Flammable liquid	C3	Pentane	3198
Toxic liquid	D3	Acrylonitrile	2605
(Very) Toxic liquid	D4	Acrolein	0

The population within 995 m (the affected area of hazardous good category B2) of the railroads has been inventoried. hazardous good category B2 has the largest effect distance of all hazardous goods transported on this railroad.

TRACK PARAMETERS

The parameters of the railroads largely consists of track in the category 0-24 m. The width used in the calculation for these parts is therefore 9 m. The other track sections have different widths, which are visualized in Table D-6. The risk calculation uses the standard outflow frequency, for track sections designated for high speed transport (> 40 km/h) with turnout addition, of 6.072 10^{-8} /rtc-km. One track section uses the standard outflow frequency, for track designated for high speed transport (> 40 km/h) without turnout addition, of 2.77 10^{-8} /rtc-km. The track sections are visualized in Figure D-4.

Table D-6 - Parameters per track section

Track section	Width category [m]	Calculation width [m]	Track speed	Turnout addition	Outflow frequency
180C	0-24	9	High speed	Y	$6.072\ 10^{-8}$
180D	0-24	9	High speed	N	$2.772\ 10^{-8}$

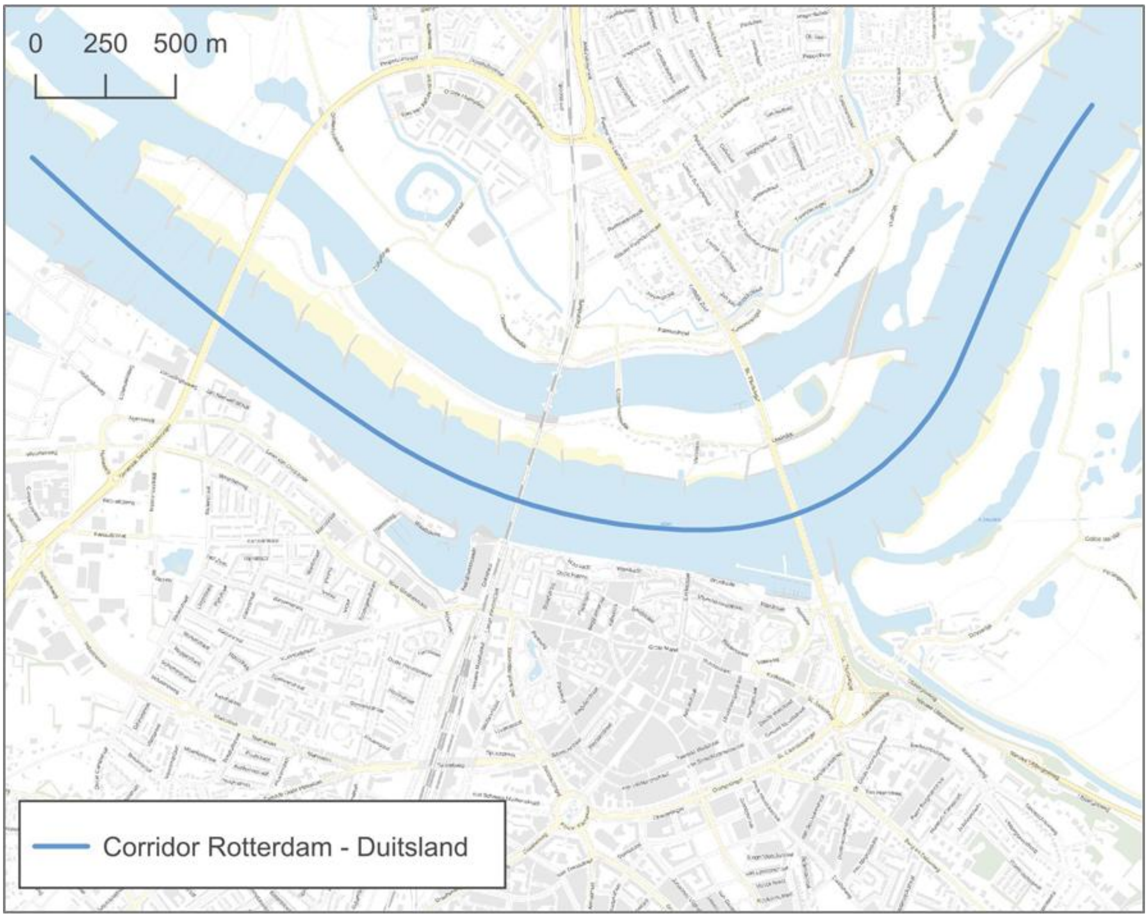
Figure D-4 - Track sections Sas van Gent

INLAND SHIPPING PARAMETERS SOCIETAL RISK CALCULATIONS

LOCATION WATERWAY

This chapter describes the method and the parameters used in the calculation. Figure D-5 visualizes the location of the waterway Corridor Rotterdam – Duitsland.

Figure D-5 - Location waterway Corridor Rotterdam – Duitsland



Inland shipping

The waterway Corridor Rotterdam – Duitsland is used for the transport of hazardous goods. These waterway is part of the Dutch waterway network of hazardous goods (Basisnet). The risk of the transport of these hazardous goods are calculated using the risk calculation program RBM II, version 2.3. The calculation is carried out in accordance with the Hart [3]. The calculation requires the following:

- The transport intensity of hazardous goods.
- Waterway properties, e.g. the outflow frequency, the chance of a river barge transport (rbt) containing hazardous goods getting involved in an accident, causing an outflow of these hazardous goods, measured per kilometre.
- The (presumed) population along the waterway that will be exposed to the effects of an accident. The population densities will de indicated with squares, each square using an uniform density. The presumed day and night presence of the population will be indicated per individual square.
- The meteorological data used in the calculation are derived from the weather station Deelen.

TRANSPORT INTENSITY

Table D-7 contains the used transport intensities. For calculations on waterway transport, a standard uniform distribution of transport over the 24-hour period is applied. This leads to a meteorological day/night ratio of 0.44/0.56. Of the total waterway transport, 71.4% of transport takes place during the working week (Monday to Friday) and 28.6% during the weekend.

Table D-7 - Transport intensity

Main category	Class	Substance example	Intensity used for risk calculation
Flammable gas	GF3	Propane	1508
Flammable gas	GF2	Butane	629
Toxic gas	GT2	Ammonia	1716
Flammable liquid	LF1 LF2	Pentane	11512
Toxic liquid	LT1	Acrylonitrile	248
(Very) Toxic liquid	LT2	Acrolein	0

The population within 1070 m (the affected area of hazardous good category GT2) of the waterway has been inventoried. Even though the hazardous good category LT2 has an area of at least 4 km, the impact of a toxic cloud to the population past 1070 m has practically no influence on the societal risk.

The waterway is calculated using a width of 375 metres, as prescribed in the calculation method 2022 (RIVM).

TRANSPORTS AMMONIA NSP 2030 AND 2050

Figure 2-1 from the main report shows the amount of ammonia transported yearly from NSP. To properly translate this to the amounts of rail transports or barges needed the tonnage per railtanker and barge is needed. For the cost calculation 50 tonnes per rail tanker and 2000 tonnes per barge was assumed. With these numbers the NSP transports were calculated. These are shown in Table D-8. For rail it is assumed that 1/3 will be transported from Terneuzen and 2/3 will be transported from Vlissingen.

Table D-8 - Number of transports from NSP

Scenario	Amount (mton/yr)	Railtankers	Barges
Low	1,5	30,000	750
Mid low	3	60,000	1500
Mid high	4,5	90,000	2250
High	6	120,000	3000

Appendix E

EXTERNAL SAFETY ASSESSMENT RESULTS – SOCIETAL RISK

SOCIETAL RISK

Rail

Figure E-1 below shows the societal risk comparison for the route from Vlissingen in 2050. As can be seen the societal risk is above the guide value. As stated before, this value is only used for guidance and is **not** a limit value. The increase of ammonia transport from NSP increases the societal risk between 10 and 100 fatalities. The risk for larger accidents does not increase for the 2050 scenarios.

Figure E-1 - Societal risk comparison rail route Vlissingen Roosendaal 2050

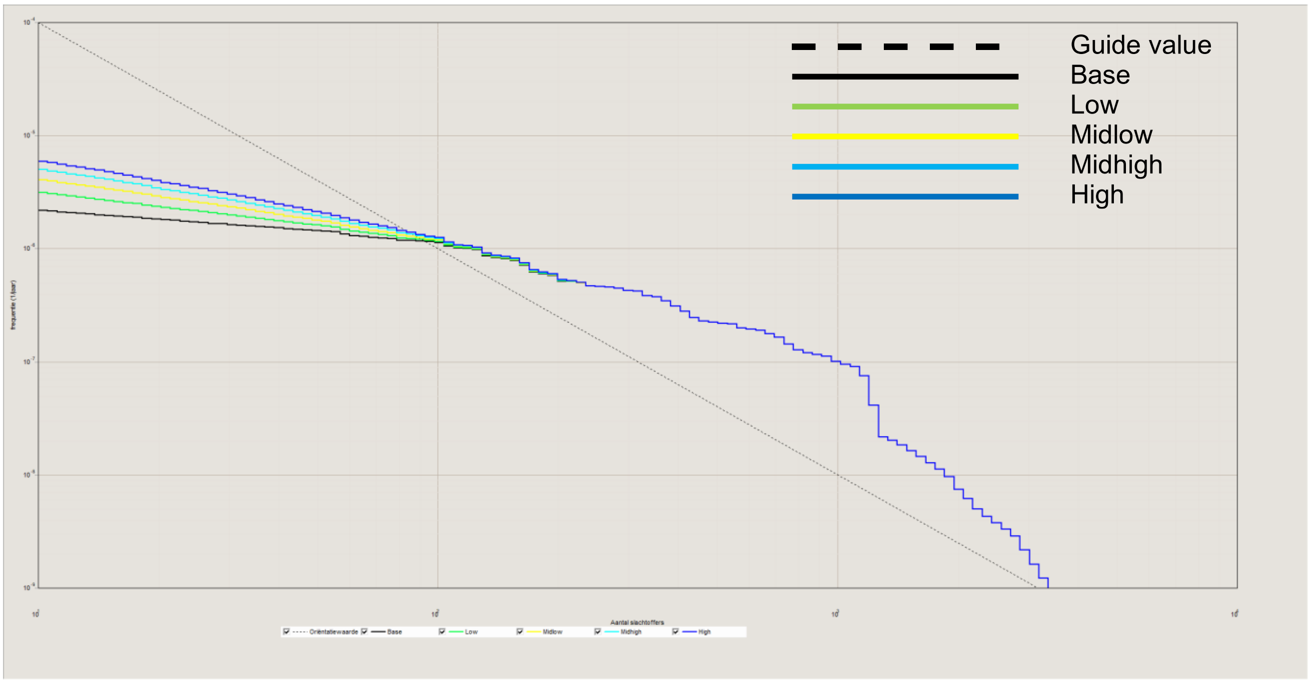
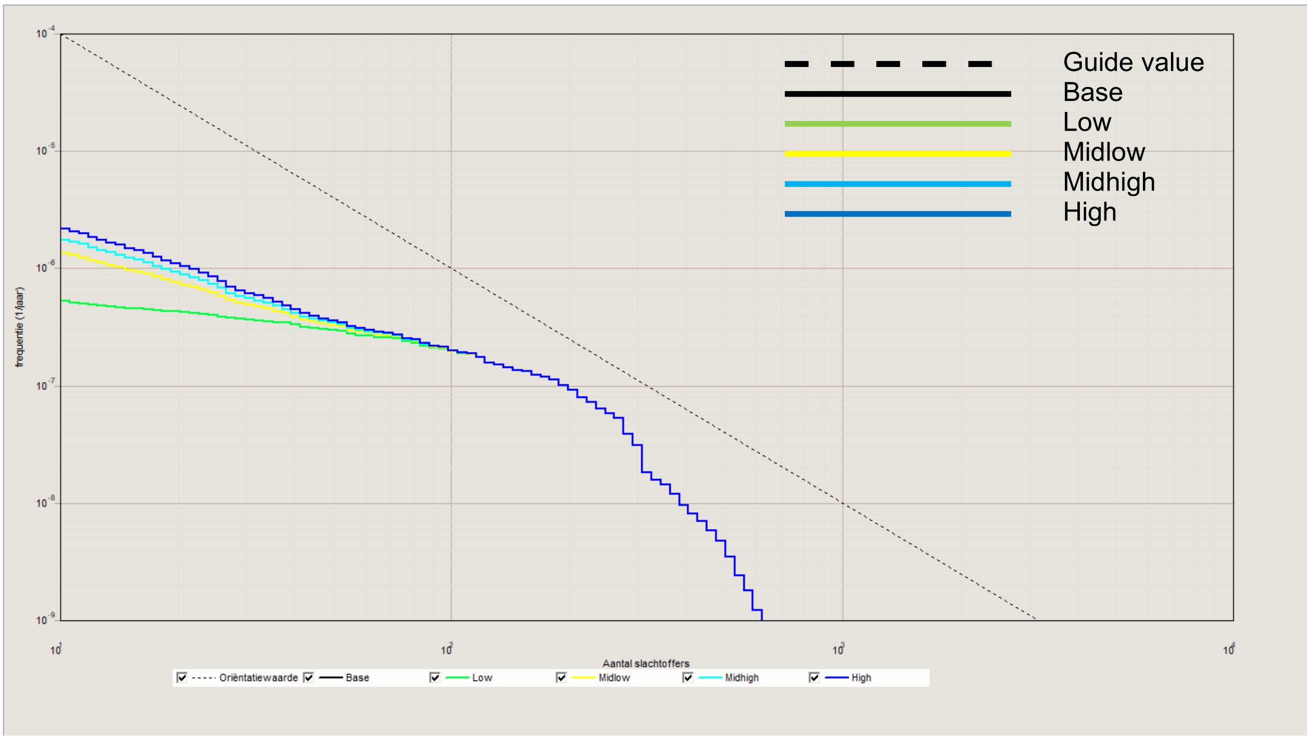


Figure E-2 show the societal risk comparison for the route from Terneuzen in 2050. These figure show the same kind of results as for the route from Vlissingen. The societal risk is biggest in Roosendaal.

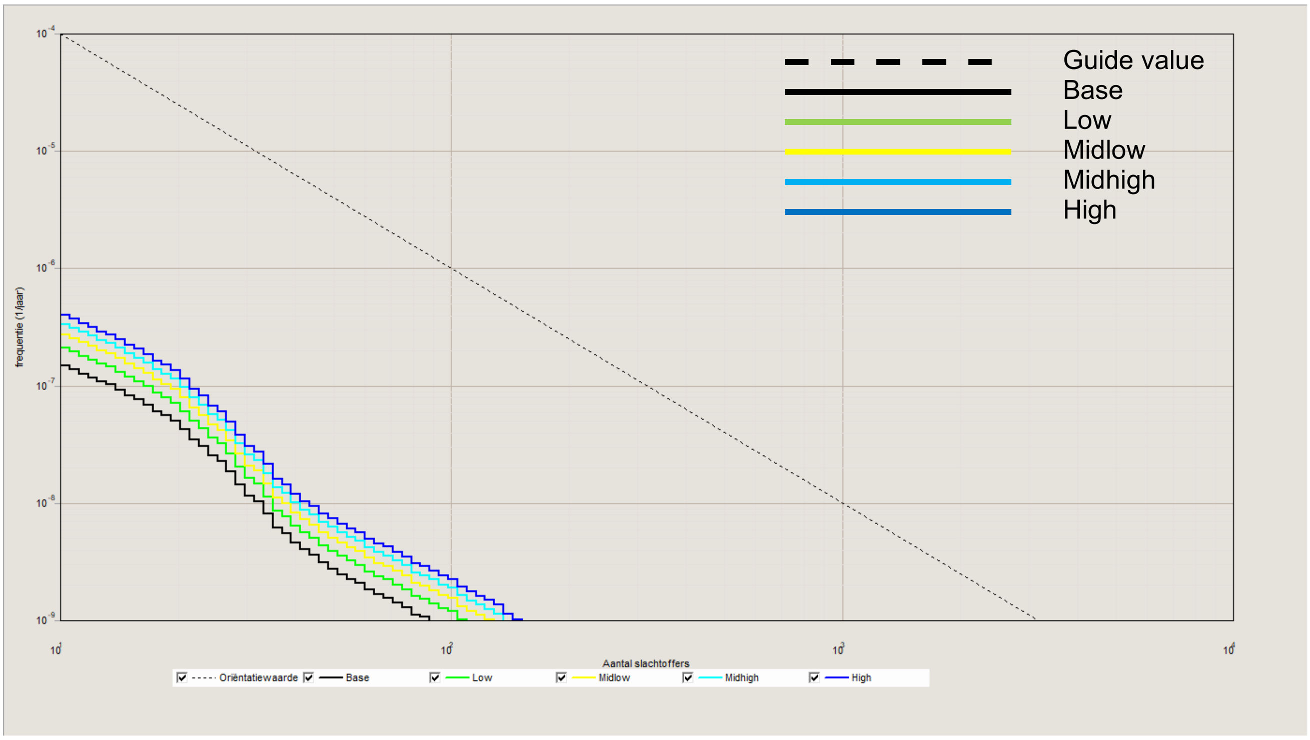
Figure E-2 - Societal risk comparison rail route Terneuzen 2050



Inland shipping

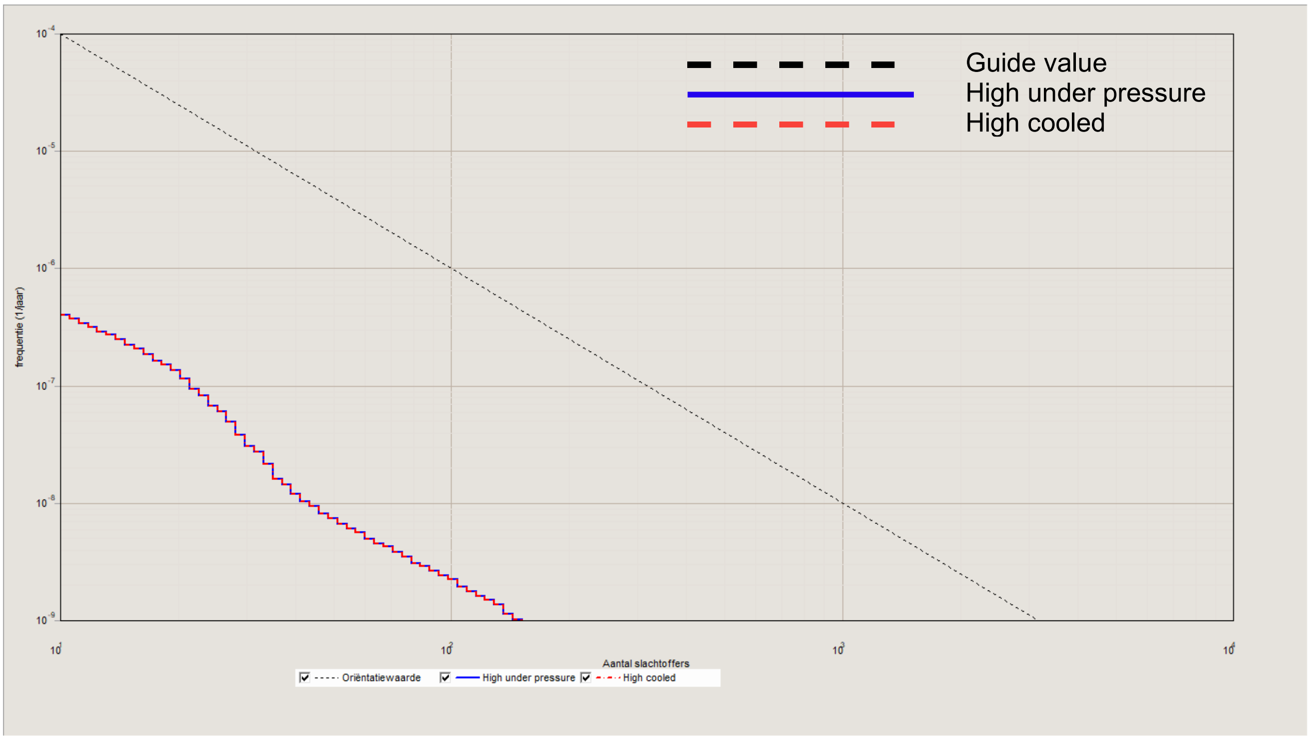
Figure E-3 show the societal risk comparison for the inland shipping route in 2050. As can be seen the societal risk is below the guide value for all scenarios. The increase of the societal risk is highest for the high 2050 scenario. Compared to the rail scenarios the societal risk is close to a factor 100 lower.

Figure E-3 - Societal risk comparison inland shipping route Nijmegen 2050



Additionally an extra societal risk calculation has been made to compare the transport of ammonia with barges under pressure or cooled. Figure E-4 show this comparison, made assuming the high scenario in Nijmegen. The societal risk is the same for both ways of transportation meaning there is no clear advantage for either way of transportation from an external safety risk point of view.

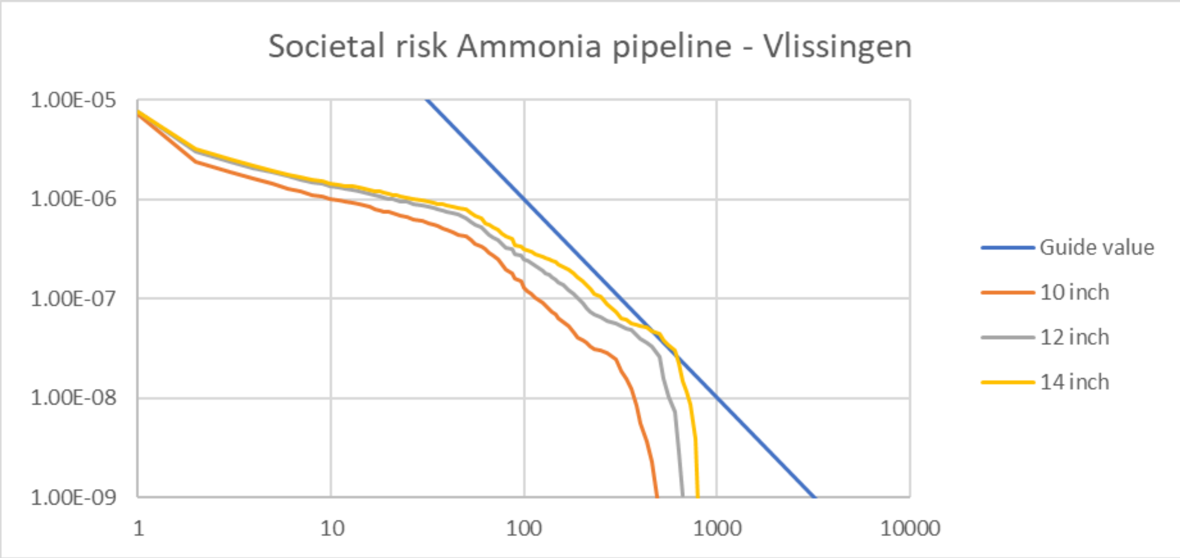
Figure E-4 - Societal risk comparison inland shipping route Nijmegen pressure vs cooled



Pipeline

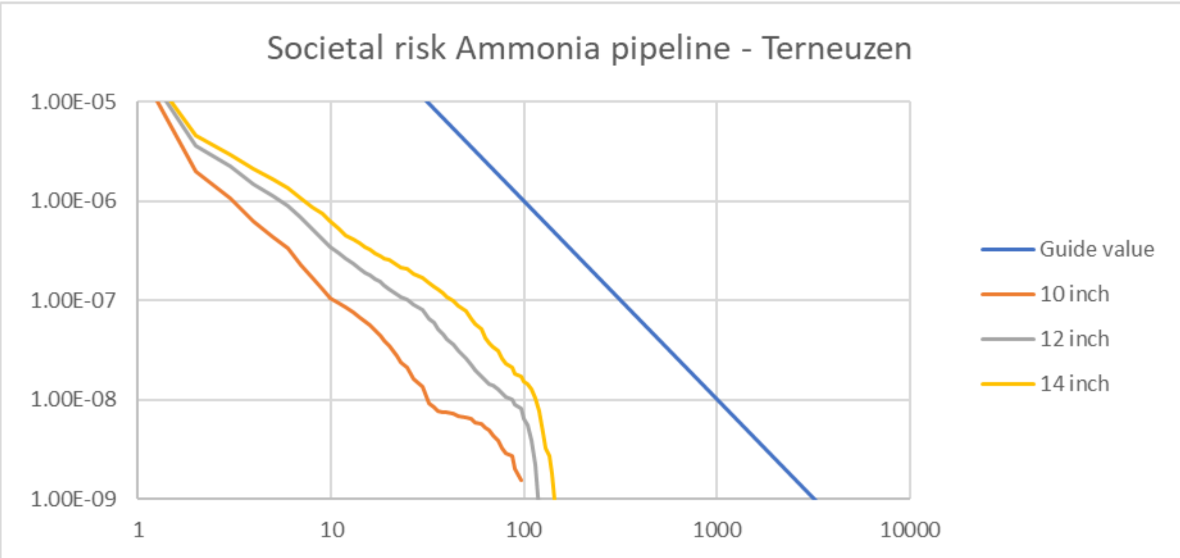
The figure below shows the societal risk comparison for pipeline route starting in Vlissingen. As can be seen the societal risk is below the guide value for most of the scenarios. The increase of the societal risk is highest for the 14 inch pipeline scenario. Compared to the rail scenarios the societal risk is lower and compared to the water scenarios the societal risk is higher.

Figure E-5 – Vlissingen Societal Risk Comparison



The figure below shows the societal risk comparison for pipeline route starting in Terneuzen. As can be seen the societal risk is below the guide value for all scenarios. The increase of the societal risk is highest for the 14 inch pipeline scenario. Compared to the rail scenarios the societal risk is lower and compared to the water scenarios the societal risk is higher. Also the Terneuzen pipeline has a lower societal risk compared to the Vlissingen pipeline.

Figure E-6 – Vlissingen Societal Risk Comparison



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