Value creation for Europe

A first study on the value creation for Europe's sustainable and competitive position by the combined ports of Rotterdam and Antwerp-Bruges

Erasmus Centre for Urban, Port and Transport Economics
and
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This study has been executed by the Erasmus Centre for Urban, Port and Transport Economics (Erasmus UPT) and the Vrije Universiteit Brussel, assigned by the Port of Rotterdam Authority and Port of Antwerp-Bruges.

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Disclaimer

This study has been realized in a short period of time, based upon data available. It is a first assessment of the joined value of the ports of Antwerp-Bruges and Rotterdam for Europe. It underlines and gives meaning to the value of the two ports if one looks beyond their function as merely a transshipment hub, seeing them as an integrated logistics and industrial complex that extends into the European hinterland and if one takes an integrative look at what these ports together bring for Europe. Especially in the actual challenging times with a climate crisis and geopolitical pressures Europe is facing.

Usage of this study

Questions?

For questions about this study, you can contact Larissa van der Lugt (vanderlugt@ese.eur.nl)

Executive summary

Key messages of the study

The way in which European policymakers look at the value that the ports of Rotterdam and Antwerp-Bruges generate, needs careful consideration. Their industries' competitive position is under pressure and so is their licence to operate, as they are still heavily fossil fuel based. But at the same time, the ports are surely part of the solution, providing valuable assets, space, connections and competencies essential for Europe's industries' competitive position, its energy and resource transition and its strategic autonomy.

The ports of Antwerp-Bruges and Rotterdam generate values that are at the same time economic, societal and strategic. With their strong connectivity and integrated industrial clusters, they clearly facilitate a value contribution to the wider European region. The ports together form a logistical and industrial complex with a for Europe unique combination of scale, deep-sea location, space, large overlapping hinterland network, existing integrated industrial cluster with a global scale, large inflow of green electricity and import of green energy carriers. This cluster forms a basis for the energy and resource transition, that is so hard needed for Europe's competitive and sustainable future.

The trade-offs that are made for investments in ports – both at national and European level – are important for Europe's ambitions and must take an integrated perspective, i.e. taking all relevant values that the ports bring into account. This is not an easy job because some of the value categories that ports generate - and that gain in importance - are more societal and strategic in nature and lie beyond the borders of the individual port regions. Given their wide European impact, these values should not be underestimated, even if their measurement and quantification is challenging.

Although the ports' industries add to the climate crisis and hence affect their own license-to-operate and competitive position, the future path is clearly stated, amongst others in the report of Draghi. Europe needs to focus on both the acceleration of decarbonization and on circularity, whilst simultaneously creating a level playing field with international competitors - especially those that are based upon different market models (like China): by investing in infrastructure and in innovation, and by streamlining the (cross-border) regulatory framework. The values that the ports and their industrial clusters can bring for Europe - also for its future - have been made clear in this study.

The present study also shows that there are benefits to be gained by applying an integrative perspective on the ports of Antwerp-Bruges and Rotterdam in particular. The synergy realized by their combined scale, overlapping networks, interconnections, complementarity and specialization makes that 'their whole is greater than the sum of their parts'. Strengthening their increasing collaboration could elevate these advantages further, also for Europe.

Introduction to the executive summary

Europe is exposed to major shifts in the world, which are threatening its global position (Mario Draghi, September 2024). "Its industries face heavy competitive pressure from countries with lower energy prices; its dependence for critical raw materials but also for digital technology is very high; it lags behind in new technologies and it is least ready to defend itself". And in addition, "Europe, like the rest of the world is facing a climate crisis that requires a complete energy and resources transition."

The seaports of Rotterdam and Antwerp-Bruges are amidst of this. The two ports, building upon a long history of port development since the twelfth century, developed from rather local points of transshipment for intercontinental trade flows, into an interconnected network of seaports, inland ports and logistical and industrial hotspots. The two ports together form a port-industrial region that combines large-scale logistics, a concentration of energy flows, industrial production and an integrated infrastructural network with a European coverage. They are both close to a hinterland with a high market demand. The combined industrial port cluster is unique in Europe for its diversity, and its sophisticated level of integration. One of the most striking outcomes of the integration of the two ports is the ARRRA petrochemical cluster (the port of Antwerp-Bruges, the port of Rotterdam and the Rhine-Ruhr area). It is an integrated and diverse petrochemical cluster, that produces and processes energy, fuels, chemicals and pharmaceuticals, that competes globally and that is important for Europe's internal demand and external competitive position. The strength of the cluster lies in both internal competition as well as in collaboration and integration, which creates synergy through cluster and agglomeration effects.

The ARRRA cluster - with the two ports at its core – clearly faces pressure on its competitive position and must undergo a gigantic transition towards zero emissions. At the same time, this cluster can also be quite instrumental in Europe's efforts for a sustainable and strong future. It has the space, assets, infrastructures, existing substantial demand, knowledge and competencies and availability of large-scale green energy from wind at (the North Sea), that enables a potentially strong role in facilitating the transitions and developments needed for a stronger and sustainable Europe, including strengthening its strategic autonomy.

Thus, the two seaports Rotterdam and Antwerp-Bruges are therefore of great value for Europe and its future: much more than the traditional economic indicators for the economic impact of seaports can measure. These indicators are often rather focused at the 'transport node' function of ports with transshipment central to it and are often limited to employment and added value. However, the value of the two ports lies rather in the integrated logistical and industrial complex, building upon positive cluster effects. This value is thus not only economic, but also societal and strategic in nature and goes far beyond the borders of their ports.

We advocate that the decisions for investments in and for support of the ports of Antwerp-Bruges and Rotterdam must be made based upon careful trade-offs, taking all (potential) values that the two ports together generate for Europe into account, especially those from the integrated industrial cluster.

Approach to the research

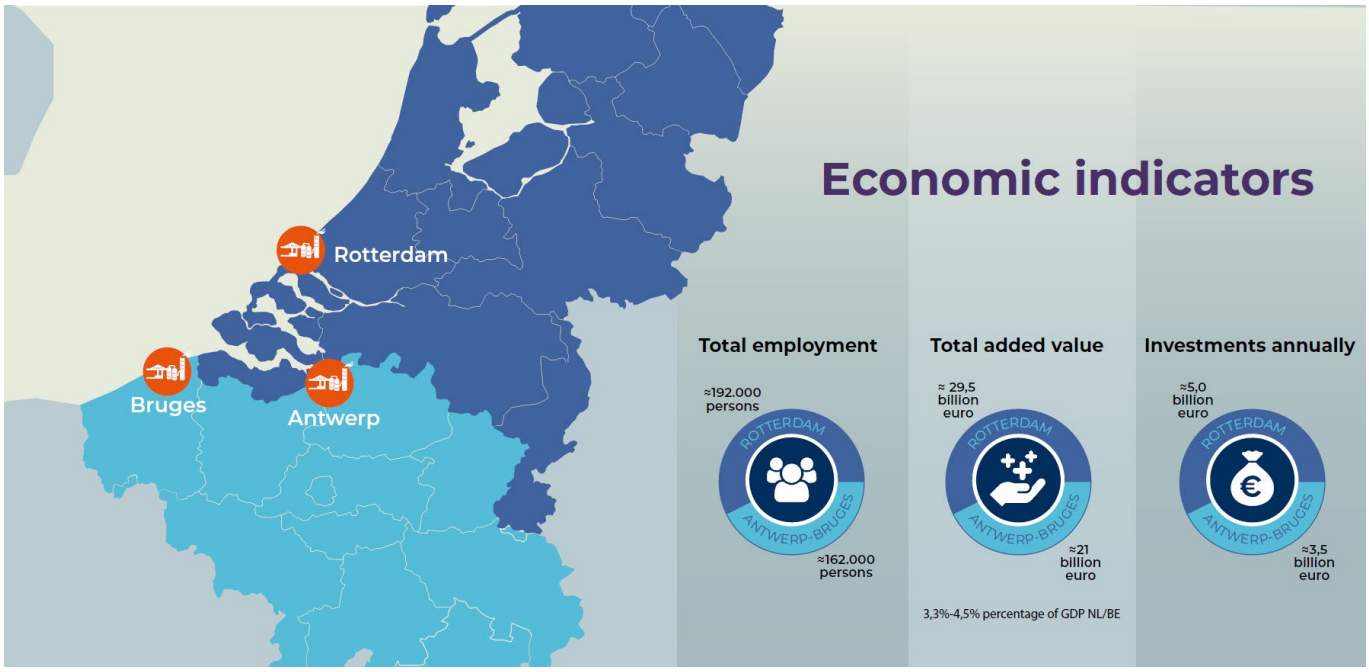
This analysis supports taking this broader value perspective, by applying a broad view on the functions and contributions that the two ports - as an integrated system - bring for Europe. It emphasizes the industrial function as this is crucial in the major challenges for Europe: its energy transition, its transition towards circularity and its strive for strategic autonomy. Table 1 visualizes the framework that was used for a structured scan of the (combined) values generated by the two ports.

Table 1: Value framework

Current and future earning capacity	Generating **Economic and societal outputs**	Added value and employment, realized both on a local, regional and on a European scale
	Providing **Connectivity**	Connections with determining factors for Europe's competitive advantage: both in a structural dimension via customer networks (importers, exporters, industrial clusters) but also in a strategic dimension through clusters of knowledge and innovation.
	Strengthening **Cluster Formation**	Clustering of European industry to gain agglomeration advantages, boosting innovation
Europe's recent strategic challenges	Facilitating the **Energy Transition**	Supply of green energy/feedstocks, capturing, storage and/or re-use of CO2
	Facilitating **Circularity**	Circular activities/chains across a wider region
	Supporting **Strategic Autonomy**	Critical resources/materials/energy for functioning of critical sectors and defense tasks Supporting the energy and resource transitions. Security of supply of critical products
Living environment	Managing **Externalities**	Effects that are harmful for nature and people's health, like emissions, noise, reduction of biodiversity Measures to improve impact on living environment

The value contributions of the combined ports of Rotterdam and Antwerp-Bruges

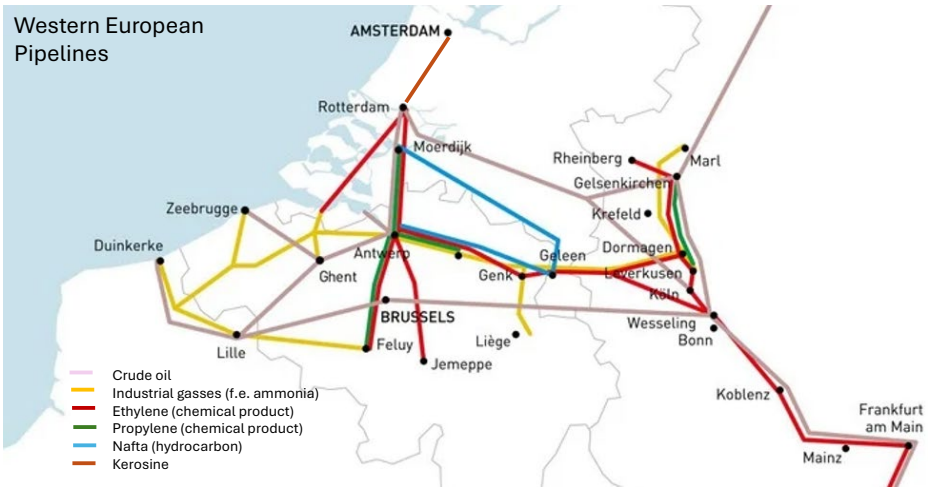
The first value contribution that we distinguish is **generating economic and societal output.** These are generated by the activities that take place in the ports and their related spill-over effects and expressed in economic indicators.



In total both ports generate about 50 billion euros in added value, i.e. 4,5% (PoAB) and 3,3% (PoR) of the national GDP's. Together, both ports generate employment for about 350.000 people and investments mount up to about 8,5 billion euro annually. The private investments largely exceed the public investment and are merely done in the industry (about 4 billion euro).

The second value contribution is in **providing connectivity for Europe**.

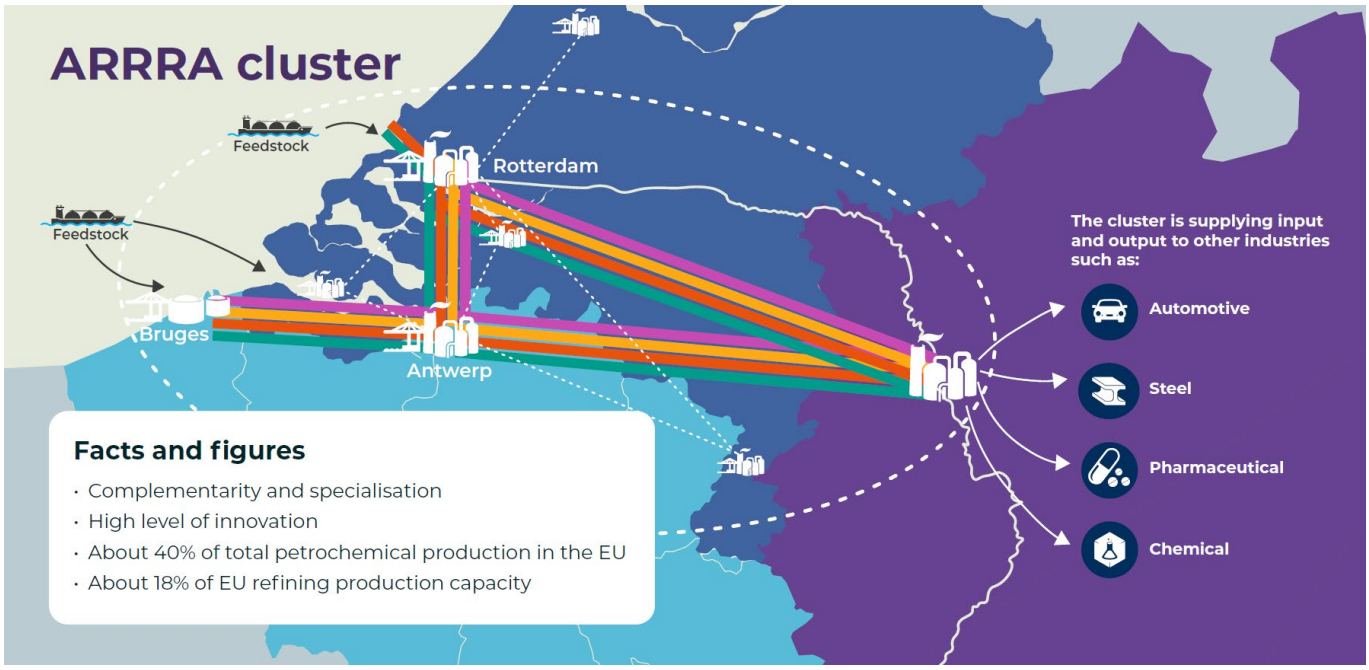
The two ports provide - through their combined multimodal transport networks - flexible and resilient connectivity for the wider European region: about 500 million consumers and customers can be reached within 24 hours in multiple ways. The network comprises the river Rhine, supporting 40% of the hinterland transport, a dense railroad network and connects two European rail freight corridors of the TEN-T network. A very important element is the pipeline system that connects the two industrial complexes of the ports, the industry in the Rhine-Ruhr area and wider Europe.



This connectivity provides access to and supports determinants for competitive advantage of businesses and industries in the wider European area. It feeds the welfare and resilience of a large share of European citizens.

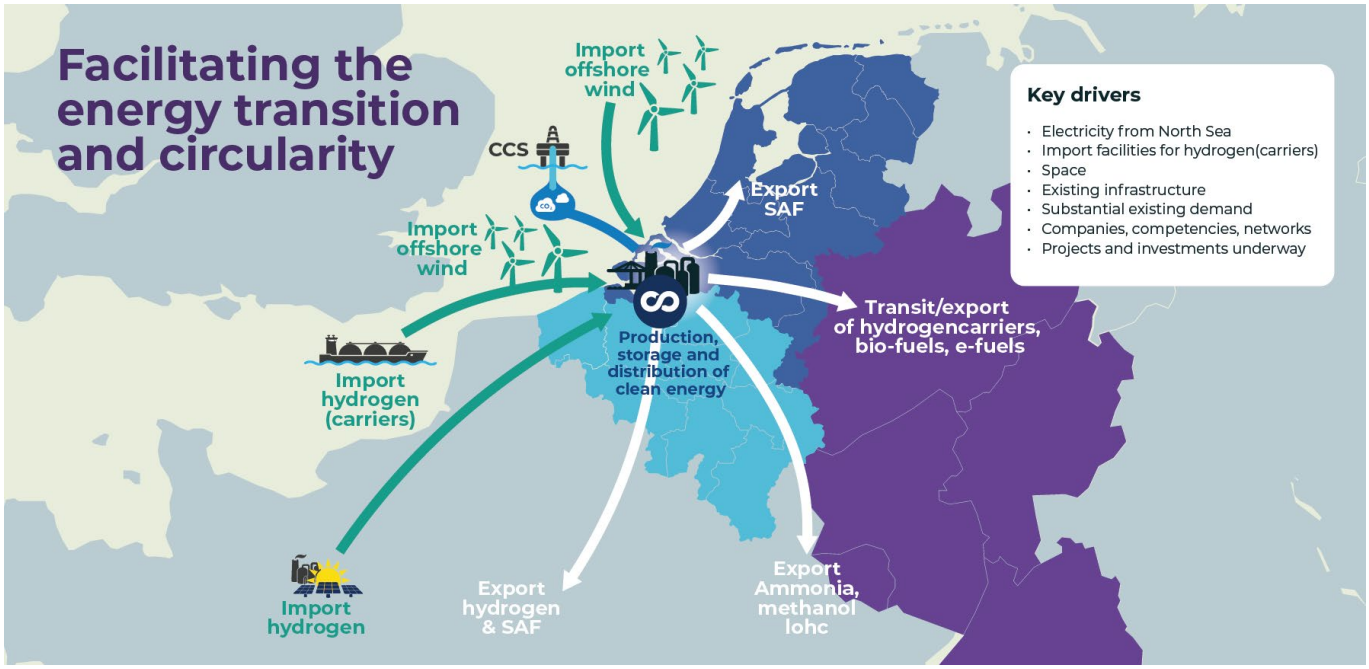
The connectivity also has, besides a structural dimension - that relates to the transport and logistics connections that are established - a strategic dimension that relates to interorganisational connectivity for cooperation, knowledge exchange and innovation, that has co-developed with the infrastructures and services that the ports provide. The collaboration of the ports of Antwerp-Bruges and Rotterdam in the joint development of a European hydrogen network is an example of such strategic connectivity. But also the links that the port managing bodies but also the companies in the ports have with other organisations in the network with whom they cooperate, exchange knowledge and innovate are part of this strategic connectivity.

The third value contribution is in **cluster formation.**



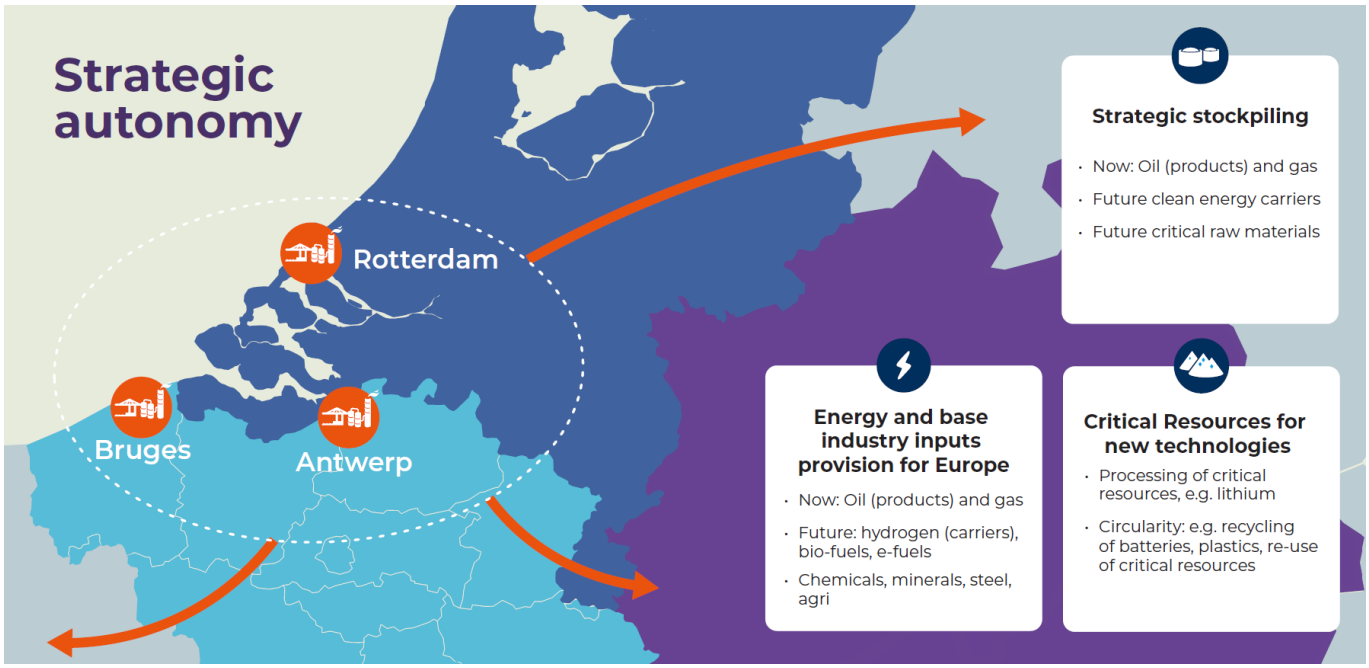
Building upon their location, space, and infrastructure and connectivity, the two ports together form a port-industrial region that combines large-scale logistics, a concentration of energy flows, industrial production and an integrated infrastructural (pipeline) network with a European coverage. The combined industrial port cluster is unique in Europe for its size but also for its diversity, complementarity and integration within the wider European continent, especially in the form of the trilateral ARRRA cluster, incorporating also the Rhine-Ruhr area's industry. With that integrated cluster they generate positive economic outcomes and earning capacity for the wider European region. Together both ports count for about 40% of Europe's petrochemical production in the EU (350.000 direct jobs and a turnover of 180 billion euro), delivering amongst other feedstocks, pharmaceuticals, plastics, inputs for automotive industry, textile industry, food industry, etc. The combined scale and variety of both industrial port clusters is also a unique source of cluster and agglomeration benefits leading to better service levels, reduced transaction costs and knowledge spillovers. They compete fiercely and hence discipline each other, triggering innovation, attracting talents, etc. to remain globally competitive. And while the ARRRA cluster - with the two ports central to it – clearly faces the pressure on its competitive position and needs to go through a gigantic transition towards zero emission, it must also be seen as a crucial potential factor in Europe's efforts in realizing a sustainable and competitive future.

The fourth value contribution is in **facilitating the energy transition and circularity.**



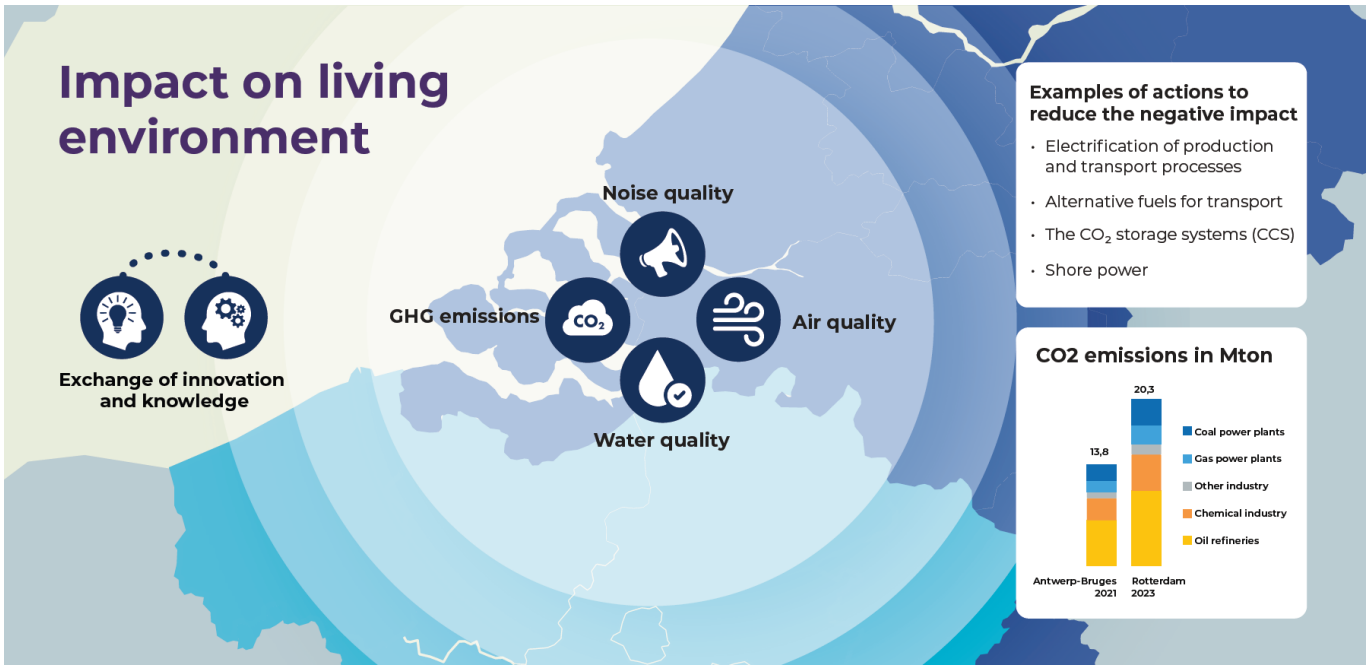
With their assets and building upon their strong logistical network and integrated industrial cluster the ports of Antwerp-Bruges and Rotterdam (can) play an important role in Europe's energy transition and need for circularity. First, their location enables the large-scale import of clean energy. This is both green electricity that lands from the large-scale wind farms in the North Sea (11% share in the ambitions of the nine North Sea Energy Cooperation countries), as green fuels and energy carriers that are imported by maritime transport. Second, with their widespread connectivity and their existing integrated industrial clusters they build upon assets, infrastructures and competencies enabling an efficient and effective transition, not only within the borders of their ports but in the wider hinterland. These existing industrial clusters can provide clean chemical and clean fuels like hydrogen, ammonium, biofuels, and e-fuels. Their centrality to networks of pipelines (but also barge and rail connections) enables the distribution of the green fuels and energy carriers to their destinations: consumers and industries in the European hinterland. Many initiatives are being undertaken for making the transitions towards clean energy production, distribution and usage. Amongst them are planned electrolysers and ammonia crackers, terminals and storage facilities for green hydrogen carriers, SAF production facilities; two large-scale CCS projects are being built in Rotterdam (Porthos) and Antwerp-Bruges (Antwerp@C), with a planned delivery respectively in 2026 and before 2030.

The fifth value is in **supporting strategic autonomy.**



Recent geopolitical and geo-economic developments ask for increased strategic autonomy for Europe. One of the priorities as stated by Draghi's report is "to react to a world of less stable geopolitics, where dependencies are becoming vulnerabilities, and it can no longer rely on others for its security". The more recent deteriorating evolution in geopolitical risks demonstrates the effects on disruptions of trade and security. With that, it is essential that Europe reacts with countermeasures that decrease the reliance for energy, base industrial inputs, critical raw materials but also enables catching up for its digital technology. Safeguarding the provision of base industrial inputs, development of processing facilities for important resources as lithium, strategic stockpiling and investment in circularity are such measures. The ports are logical places for that. They provide value for the strategic autonomy of Europe as energy providers and as facilitators of base industries that provide key inputs for Europe's industrial sectors, also the more technologically advanced. Their existing cluster and related facilities – including traders - make them potential locations for processing of critical resources, e.g. lithium. They are already strategic nodes for strategic oil(products) reserves and have the space, assets, routines, required certification and competencies to play an extended role for further and future strategic stockpiling. Circularity will – besides supporting decarbonization - help reducing the need for non-domestic critical resources.

The last value contribution is in the **impact on the living environment.**



The ports of Rotterdam and Antwerp-Bruges have a substantial impact on the living environment through the production of negative externalities, such as emissions of greenhouse gasses, noise or biodiversity are examples. These impacts are perceived as negative by the ports' stakeholders. The most important negative externalities are the ones impacting the climate, and the ones impacting health of persons living around the ports. This 'negative' value is increasingly - and logically - part of the discussion on the value of ports. Yet, there are positive initiatives undertaken by the ports. Both ports are actively working on reducing the negative externalities and impact on the living environment that they create with their activities. This includes, but is not limited to, actions with regards to emissions such as Carbon Capture and Storage/Usage (CCS/CCU), shore-power and electrification of terminals and transport. Also facilitating and enhancing modal shift can be seen as a measure to reduce emissions that the ports and their related transport generate.

Synergy between the two ports

There is a strong rationale in considering the ports of Rotterdam and Antwerp-Bruges in combination for their value for Europe. There is a clear (potential) synergy between the ports of Antwerp-Bruges and Rotterdam, especially seen from its industrial function and its potential role for Europe's energy and resources transition and its strategic autonomy. In terms of scale the combined ports of Rotterdam and Antwerp-Bruges provide for a quite unique port region in Europe. They are the number one and two in size within Europe, with direct deep-sea facilities; they are located only a hundred kilometers from each other; they have direct transport and pipeline connections between them; and they have an overlapping hinterland network. There are not only strong ties between the two ports, but also overlapping ties with strategic hubs in the hinterland. And, most importantly, they form an integrated industrial cluster that - combined with the connected Rhine Ruhr area – is a key global player. There are clear synergetic cluster effects. These go through internal competition, agglomeration effects, specialization and heterogeneity and collaboration.

Competitive dynamics drive both ports to strategically manage resources and invest in infrastructure and services, ensuring that their global competitiveness positions remain or improve further. In the Antwerp-

Rotterdam-Rhine-Ruhr industrial cluster several important global players such as TotalEnergies, ExxonMobil, Shell, BP, Vitol, BASF or Bayer have operations serving the same supply chains. This means that intra-firm cooperation is strong, resulting in efficiency and drivers for innovation.

Agglomeration advantages are a very powerful characteristic of the industrial clusters of the ports of Antwerp-Bruges and Rotterdam. These advantages occur in areas such as their industrial integration, availability of logistical infrastructures, diversity of supply networks, available innovation and knowledge infrastructure, a high-quality labour market, proximity to the North Sea (offshore wind) and quality of regulations and governance.

With respect to the chemical and industrial activities and flows, both port clusters are very complementary to each other. Within the trilateral region, the basic chemicals industry is largest and most important for the Port of Rotterdam. For specialty chemicals and pharmaceuticals Port of Antwerp-Bruges is a more important angle in the ARRRA triangle, and for plastics the Ruhr area is leading. Every partner in the trilateral region has its role to play and only together they can form this strong European cluster. And also for circularity, complementarity is an important feature of both port clusters. One of the most important conditions for enabling a circular economy is availability of suitable space and assets. Specialization in the different industrial clusters is very important for realizing this opportunity. This means that the right circular operation is at the right location and within the right industrial infrastructure were the re-use of existing installations for circular processes is possible. Having several large, very well-connected industrial sites within the ports and the larger hinterland, with a clear specialization can benefit the cluster as a whole.

Thus, besides the positive effects from competition, the increasing collaboration that the ports of Rotterdam and Antwerp-Bruges engage in and plan to develop further for the development of their industrial cluster and its transitions towards zero-emission and circularity brings synergetic benefits: It enhances specialization and therewith complementarity and it increases efficiency and effectiveness of operations, investments and innovations.

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1 Introduction

1.1 Rationale for this study

Europe is exposed to major shifts in the world, which are threatening its global position (Mario Draghi, September 2024). “Its industries face heavy competitive pressure from countries with lower energy prices; its dependence for critical raw materials but also for digital technology is very high; it lags behind in new technologies and it is least ready to defend itself”. And in addition, “Europe, like the rest of the world is facing a climate crisis that requires a complete energy and resources transition.”

The seaports of Rotterdam and Antwerp-Bruges are amidst of this. The two ports, building upon a long history of port development since the twelfth century, developed from rather local points of transshipment for intercontinental trade flows, into an interconnected network of seaports, inland ports and logistical and industrial hotspots. The two ports together form a port-industrial region that combines large-scale logistics, a concentration of energy flows, industrial production and an integrated infrastructural network with a European coverage. They are both close to a hinterland with a high market demand. The combined industrial port cluster is unique in Europe for its diversity, and its sophisticated level of integration. One of the most striking outcomes of the integration of the two ports is the ARRRA petrochemical cluster (the port of Antwerp-Bruges, the port of Rotterdam and the Rhine-Ruhr area). It is an integrated and diverse petrochemical cluster, that produces and processes energy, fuels, chemicals and pharmaceuticals, that competes globally and that is important for Europe’s internal demand and external competitive position. The strength of the cluster lies in both internal competition as well as in collaboration and integration, which creates synergy through cluster and agglomeration effects.

The ARRRA cluster - with the two ports at its core – clearly faces pressure on its competitive position and must undergo a gigantic transition towards zero emissions. At the same time, this cluster can also be quite instrumental in Europe’s efforts for a sustainable and strong future. It has the space, assets, infrastructures, knowledge and competencies and availability of large-scale green energy from wind at (the North Sea), that enables a potentially strong role in facilitating the transitions and developments needed for a stronger and sustainable Europe, including strengthening its strategic autonomy.

Thus, the two seaports Rotterdam and Antwerp-Bruges are therefore of great value for Europe and its future: much more than the traditional economic indicators for the economic impact of seaports can measure. These indicators are often rather focused at the ‘transport node’ function of ports with transshipment central to it and are often limited to employment and added value. However, the value of the two ports lies rather in the integrated logistical and industrial complex, building upon positive cluster effects. This value is thus not only economic, but also societal and strategic in nature and goes far beyond the borders of their ports.

We advocate that the decisions for investments in and for support of the ports of Antwerp-Bruges and Rotterdam must be made based upon careful trade-offs, taking all (potential) values that the two ports together generate for Europe into account, especially those from the integrated industrial cluster. Europe is exposed to major shifts in the world which are threatening its position (Mario Draghi, September 2024). “Its industries face heavy competitive pressure from countries with lower energy prices; its dependence for critical raw materials but also for digital technology is very high; it lags behind in new technologies and it is least ready to defend itself”. And in addition, Europe, like the rest of the world is facing a climate crisis that requires a complete energy and resources transition.

The seaports of Rotterdam and Antwerp-Bruges are amidst of this. The two ports, building upon a long history of port development since the twelfth century, developed from rather local points of transshipment for intercontinental trade flows, into an interconnected network of seaports, inland ports and logistical and

industrial hotspots. The two ports together form a port-industrial region that combines large-scale logistics, a concentration of energy flows, industrial production and an integrated infrastructural network with a European coverage. And they both lie close to a large market demand. The combined industrial port cluster is unique in Europe for its size, diversity and integration. One of the most striking outcomes of the integration of the two ports is the ARRRA petrochemical cluster (the port of Antwerp-Bruges, the port of Rotterdam and the Rhine Ruhr area). It is an integrated but diverse petrochemical cluster, that produces and handles energy, fuels, chemicals and pharmaceuticals, that competes globally and that is important for Europe's internal demand and external competitive position. The strength of the cluster lies in both internal competition as in collaboration and integration that creates synergy through cluster- and agglomeration effects.

While the ARRRA cluster - with the two ports central to it – clearly faces the pressure on its competitive position and needs to go through a giant transition towards zero emission, it can also be quite instrumental in Europe's fight for a sustainable and strong future. It has the space, assets, infrastructures, knowledge and competencies and availability of large-scale green energy from wind at (the North-) Sea, that enables a potentially strong role in facilitating the transitions and developments needed for a stronger and sustainable Europe, including its strategic autonomy.

Thus, the two seaports Rotterdam and Antwerp-Bruges provide for more value than the standard economic indicators that are traditionally used for expressing the economic impact of seaports can indicate. These indicators are often rather focused at the 'transport node' function of ports with transshipment central to it, and often limited to employment and added value. However, the value of the two ports rather lies in the integrated logistical and industrial complex, building upon positive cluster effects. This value is both economic, societal and strategic and goes far beyond the borders of their ports.

We advocate here that the decisions for investments in and for support of ports - from a European perspective - must be made based upon a careful trade-off, while taking a broad value perspective.

This analysis supports taking this broader value perspective, by applying a broad view on the functions and contributions that the two ports - as an integrated system - bring for Europe. It emphasizes the industrial function as this is crucial in the major challenges for Europe: its energy transition, its transition towards circularity and its strive for strategic autonomy.

1.2 The values of the two ports

The relevant value set comprises different types of values, of which some can be measured quantitatively others rather qualitatively. In the first place there is '**earning capacity**'. Earning capacity for companies and businesses, but also for people working in the ports which brings a societal aspect to it. This value is created by the functioning of the two ports individually, but even more together because of combined agglomeration economies. There are strong ties between the ports. Their combined transport networks cover a large part of the European hinterland and provide for structural and strategic connectivity. And their industrial clusters - connected with pipelines and extending towards the German Ruhr area (the ARRRA cluster) - build upon strong synergies. They create agglomeration effects in the form of reduced transaction costs and knowledge spillovers, but also through certain specializations in investments. This leads to positive economic outcomes and earning capacity for the wider European region.

On top of the earning capacity the two ports increasingly **contribute to some of the major strategic goals of Europe.** The climate crisis asks for transitions towards a zero-emission society, building upon the use of green energy and a circular economy. Both ports play and will play a role in facilitating the import, storage, production and distribution of green/zero emission energy needed for making the transition towards a zero-

emission society. And both ports will play a role in facilitating 'circular' activities, a transition that is also part of the route towards a zero-emission society. And then there is also the geo-political and geo-economical re-ordering that takes place in the world, asking for specific functions of ports. Both ports play a role in supporting strategic autonomy of their local economies and for Europe, by facilitating the import, storage, production and distribution of energy and other critical resources. And the ports may become instrumental for military purposes.

On the other hand, a societal impact of port development is that, although it enhances the use of greener modalities such as rail and inland shipping as opposed to truck transport, it has a negative **impact on the living environment**: the industrial and transportation activities themselves generate amongst others emissions, noise and a negative impact on biodiversity. While this certainly remains a negative variable in the equation, ports put substantial effort and invest in reducing their impact on the living environment.

1.3 The framework

The value framework that is used for a structured analysis of the values that the ports of Antwerp-Bruges and Rotterdam create is given in Table 2.

Table 2: Value framework

Current and future earning capacity	Generating **Economic and societal outputs**	Added value and employment, realized both local, regional and on a European scale
	Providing **Connectivity**	Connections with determining factors for Europe's competitive advantage: both in a structural dimension via customer networks (importers, exporters, industrial clusters) but also in a strategic dimension through clusters of knowledge and innovation.
	Strengthening **Cluster Formation**	Clustering of European industry to gain agglomeration advantages, boost innovation
Europe's recent strategic challenges	Facilitating the **Energy Transition**	Supply of green energy/feedstocks Capturing, storage and/or re-use of CO2
	Facilitating **Circularity**	Circular activities/chains across a wider region
	Supporting **Strategic Autonomy**	Critical resources/materials/energy for functioning of critical sectors and defense Supporting the energy and raw materials transitions. Security of supply of critical products
Living environment	Managing **Externalities**	Effects that are harmful for nature and people's health, like emissions, noise, reduction of biodiversity Measures to improve impact on living environment

1.4 The report

The report follows the structure of the value framework and illustrates in chapters two, three and four the different values that the port region generate. Chapter five goes into the synergy that is created and potentially can be strengthened by the two ports together. Chapter six ends with the take-aways.

2 Current and future earning capacity of the two ports

The first value contribution that we express is the earning capacity of the two ports. For this earning capacity we look at three elements: 1) the economic and societal outputs that can be mainly expressed in indicators as employment, added value, investments; 2) the connectivity that the ports establish and provide to other ports, consumers, industries and businesses in the wider hinterland, including strategic connectivity; 3) the industrial cluster formation that brings agglomeration effects, competitive advantage and thus earning capacity for a wider European area.

2.1 Added value, employment, investments and location effects

There are three major indicators that express the economic and societal outputs: added value, employment and investments. The ports generate these economic and societal value directly in the port area, but also in other parts of Europe. As efficient transport nodes in combination with large scale and diverse industrial and logistics clusters they attract business to their ports and as such create employment and added value. Competition between the two ports drive efficiency and effectiveness resulting in s healthy development of the two ports. The two ports have shown a steady growth over the last decades.

Two studies available describe the economic meaning of the ports in economic indicator: the Economic importance of the Belgian maritime and inland ports - Report 2020 (Working Paper N°407), NBB, and the Havenmonitor 2024, Erasmus UPT. On top of these indicators, we address in section 3.4.1 the impact of competition and collaboration as both having a positive impact on the earning capacity of the two ports, seen from an integrative perspective.

NB. It is important to realize that the methodologies applied to calculate the employment (and added value) by the NBB in Belgium (for Port of Antwerp-Bruges) and Erasmus UPT in The Netherlands (Port of Rotterdam) are not completely the same. The authors believe that the scope of the activities considered, is narrower in the Havenmonitor, especially in the indirect effects, causing the employment/added value to be smaller than it would be with the same scope as the NBB-report.

2.1.1 Added value

Both ports generate a significant amount of added value, both direct and indirect. Table 3 provides an overview of the direct and indirect added value in both ports.[1] In total both ports generate about 50 billion euros in added value. Direct added value is the added value at companies directly active in the port, such as terminals, industrial locations or logistical activities. Indirect added value is the added value because of the direct added value: the purchase of goods or services by the companies that are generating the direct effect. In total the port of Antwerp-Bruges has an added value of 20,8 billion euro. This is about 4,5% of the Belgian GDP. The port of Rotterdam has a total added value of 29,5 billion euro. This is about 3,3% of the Dutch GDP.

[1] The last annual calculations for the port of Antwerp-Bruges on these socio-economic indicators were done by the National Bank of Belgium (NBB) for 2020, in Working Paper N°407 (NBB, 2022). Currently, a new measuring methodology is being developed to calculate the socio-economic value of ports in Flanders.

Table 3: Added value in the port of Antwerp-Bruges and the port of Rotterdam

	Direct added value	Indirect added value	Total added value
Port of Antwerp-Bruges (in 2020)	12,3 billion euro	8,5 billion euro	20,8 billion euro
Port of Rotterdam (in 2023)	18,6 billion euro	10,9 billion euro	29,5 billion euro

2.1.2 Employment

Both ports generate a significant amount of employment, both direct and indirect. Table 4 provides an overview of the direct and indirect employment in both ports. Together, both ports generate employment for about 350.000 people. Direct employment is the employment at companies directly active in the port, such as terminals, industrial locations or logistical activities. Indirect employment is the employment in and beyond the port area because of the direct employment; the purchase of goods or services by direct companies. In total the port of Antwerp-Bruges has an employment of 162.000 FTE. This is about 3,8% of the working population in Belgium. The port of Rotterdam has a total employment of 192.000. This is about 1,6% of the working population in the Netherlands.

Table 4: Employment in the port of Antwerp-Bruges and the port of Rotterdam

	Direct employment	Indirect employment	Total employment
Port of Antwerp-Bruges (in FTE's, in 2020)	73.000	89.000	162.000
Port of Rotterdam (in employees, in 2023)	107.000	85000	192.000

2.1.3 Investments

Investments are an important indicator of the future earnings of the clusters in a port. Investments prepare the port and its clusters for future challenges and are necessary for maintaining the competitive position of the activities. These investments can be made by public institutes such as the ministries or port authorities or by private companies. In Table 3 the public and private investments in both ports are displayed. NB this refers to different years of reporting. But it indicates that together a vast amount is invested in the ports annually. A recent European Seaports Organisation (ESPO) study provides a good overview of what kind of facilities ports invest in.

Table 5: Public and private investments in the port of Antwerp-Bruges and the port of Rotterdam

	Public investments	Private investments
Port of Antwerp-Bruges (in 2020)	3,55 billion euro	
Port of Rotterdam (in 2022/2023)[2]	0,23 billion euro	4,50 billion euro

In terms of investments, the non-maritime cluster in Port of Antwerp-Bruges accounted for about 3 billion euro, of which 1,2 billion euro (or 42% of the total for the non-maritime cluster) related to the chemicals industry in 2020. A total of 0,23 billion euro of investments related to fuel production sector. The energy sector comes third in the investments ranking within the non-maritime cluster and accounted for 0,22 billion euro.

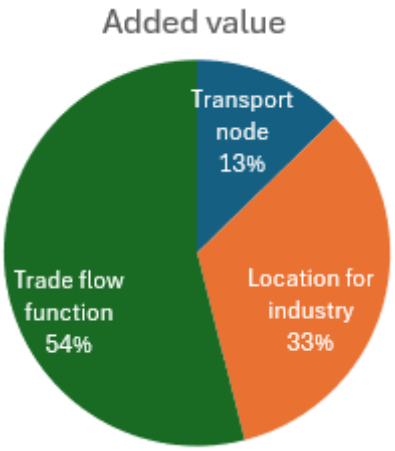
[2] Public investments are available for 2023, private investments are only available for 2022

The private investments in the port of Rotterdam are mainly done by the industry (2,5 billion euro) and the transport/distribution clusters (1,8 billion euro). Within the industry, electricity production is the biggest contributor (1,56 billion euro). Within the transport/distribution cluster, the services related to transport are the biggest contributor (1,31 billion euro).

2.1.4 Location effects

Both ports function as important transport nodes for the national and European hinterland. A lot of companies and activities in the hinterland receive or send their goods via the two ports all over the world. Import and export flows are facilitated by the ports. These activities generate economic impact, meaning employment and added value. Erasmus UPT and the Central Bureau of Statistics (2022) calculated this 'trade flow function' of the port of Rotterdam and showed that it was even larger than the economic impact of the transport node and place as a location for industry. Figure 1 shows the distribution of added value for the port of Rotterdam over the three differentiated port functions

Figure 1: Share of added value different port functions (source: Erasmus UPT)



This breakdown shows that on top of the economic impact of the transport node and the place as a location for industry, more than 50% is added to the economic impact by looking at this 'trade flow function'. Though the authors are not aware of a study that quantifies this 'trade flow function' for the port of Antwerp-Bruges, the authors are convinced that this function and effect is also the case and present for the port of Antwerp-Bruges.

2.2 Connectivity

The ports of Rotterdam and Antwerp-Bruges provide critical connectivity for the wider European region. This connectivity provides access to and supports determinants for competitive advantage in the wider European area: its businesses and industries. And it feeds the welfare and resilience of a large share of European citizens. The connectivity has two dimensions: a structural and a strategic dimension.

The *structural dimension* is expressed in the centrality of the two ports as hubs in the European networks. On the one hand there is access for the largest container ships – both ports have over 40 deep-sea calls a week - and access for non-containerized maritime cargo ships, i.e. tankers, dry bulk carriers, RoRo and general cargo vessels. This maritime network centrality provides scale advantages and leads to hub development. On the other hand, there is an extensive, dense network of short sea, road, rail, barge and pipeline services to a wide

range of destinations in the European hinterland, reaching Europe's important industrial clusters and hundreds of millions of consumers. The *strategic dimension* relates to connections and networks for innovation and knowledge exchange. It is about the cooperative relationships that the ports and their companies have in their relevant networks that enhances innovation and strengthens knowledge as such strengthening the port, its functions and its competitive position. In this section we first present the structural connectivity, showing how both ports are physically connected with the wider European hinterland and with each other. Then we elaborate on their more strategic connectivity, related to collaborative knowledge building, knowledge exchange and innovation.

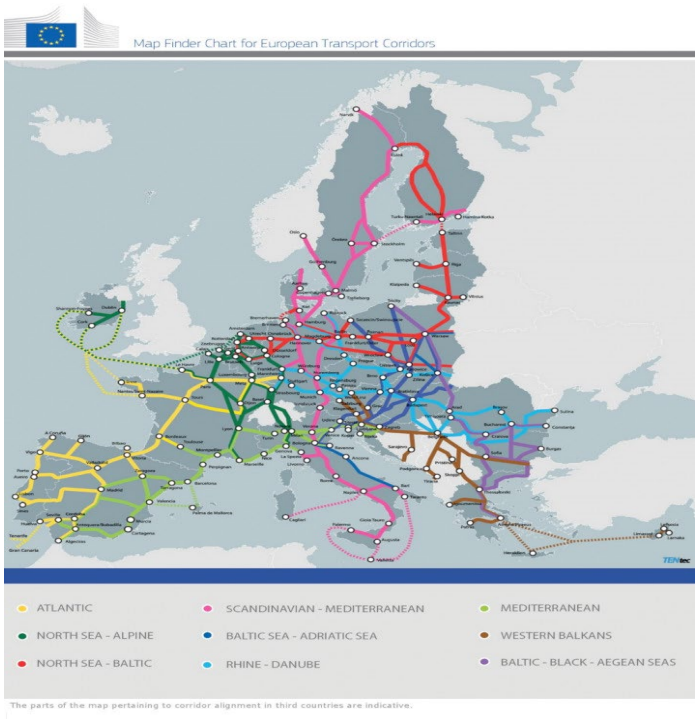
2.2.1 Structural connectivity

Both ports are located in the heart of Europe and are important nodes within the multi-port gateway region of the Rhine-Meuse-Scheldt Delta. They offer a sustainable major gateway to the European hinterland through a wide network of intermodal connections. Moreover, 60% of Europe's purchasing power is within 500 kilometres of both ports: over 500 million consumers can be reached within 24 hours. The ports are connected to European rail freight corridors of the TEN-T network: North Sea-Alpine and North-Sea Baltic. (see Figure 2).

The multimodal network

The integrated multimodal network of the two ports covers a significant area of Europe with a concentration in the Benelux, Germany and Northern France. In the first place it has large scale river connections of which the Rhine is the most important, allowing for a 30-40% share in inland transport; Then there is a dense rail network with links as the Betuweroute and the Montzenroute as important raillinks towards the German hinterland. But the rail-network goes also further into Europe, all together taking a 10-15% share in the total hinterland transport. There is an extensive pipeline network, connecting both ports with each other and with the European hinterland, providing consumers and the industry with fuels, chemicals and feedstocks, which in future can be green. And of course, the dense road connections, flexibly providing access to every single destination in Europe.

Figure 2: TEN-T core corridors



The services

From the ports, over 800 barge services operate weekly, transporting cargo to more than 90 European destinations across 6 countries. About 25% of these calls concern barge container shuttles that have a weekly schedule to fixed destinations. Both ports have a combined total of 176 direct barge connections to European inland ports (see Figure 3).

Figure 3: Direct barge connections to European ports and the hinterland (Source: Port of Rotterdam, Port of Antwerp-Bruges, routescanner.com)[3]

From the port of Rotterdam	From the port of Antwerp-Bruges
	

Weekly, about a 1000 loaded cargo trains run between the ports and the hinterland. These trains reach almost all countries in Europe. The non-containerized trains directly connect industries in the hinterland providing them with cost-efficient transport for their raw materials and other inputs. About 550 of the trains are container shuttles, that operate on a regular schedule connecting a wide European network of inland terminals, from where companies and consumers in a wide European hinterland are reached. The ports have, combined together, a total of 124 direct rail connections to ports located within the European hinterland (see Figure 4).

[3] The results in the Routescanner tool relate to containers and other intermodal units. RORO and breakbulk cargo are not included in the current version of Routescanner.

Figure 4: Direct rail connections to European ports in the hinterland (Source: Port of Rotterdam, Port of Antwerp-Bruges, routescanner.com[4])

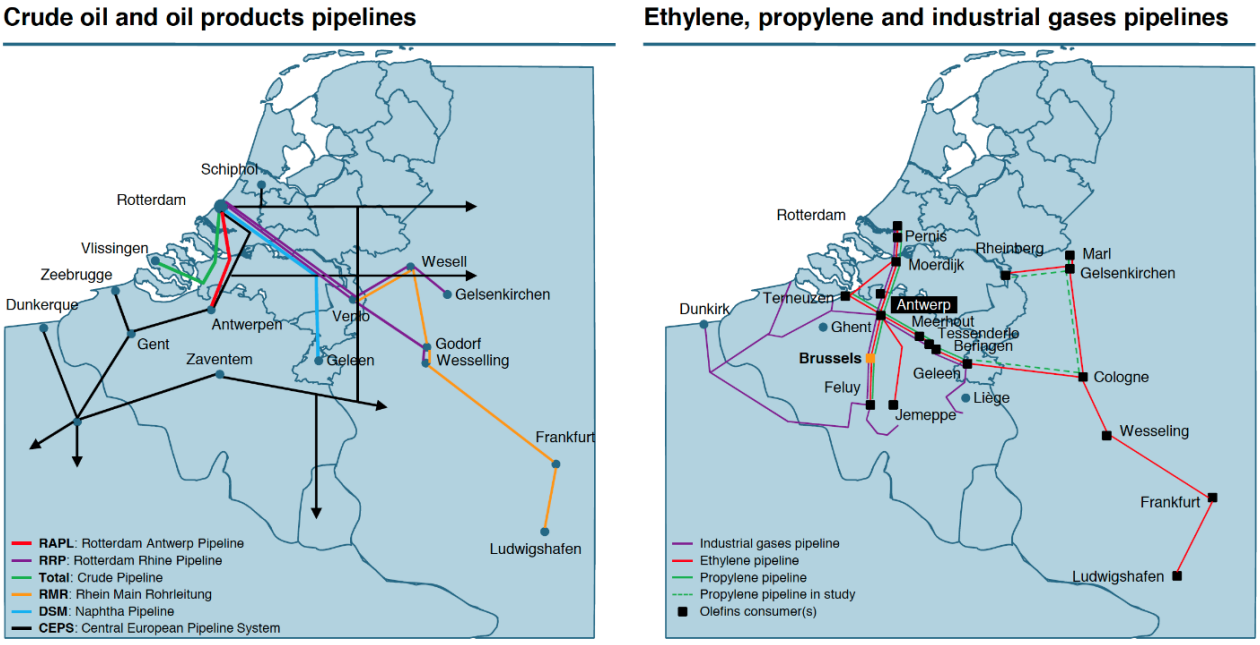
From the port of Rotterdam	From the port of Antwerp-Bruges
	

At the European continent the ports of Rotterdam and Antwerp-Bruges together reach more than 70 ports with regular container feeder-services (CBS info). The scale and concentration of deep-sea lines and the wide hinterland network make the two ports into hubs for feeder-lines to other destinations in Europe that provide cost advantages for shippers. In total the two ports connect to over 400 European ports at the European continent which then also comprises bulk services.

An important element in the transport network is the western European pipeline system of which the two ports are key nodes. These pipeline networks can carry a wide variety of products (see Figure 5). There is a strong interconnection for crude and all feedstocks that integrate the two petrochemical clusters in the two ports. While this is an integrated network there is also specialization in the pipelines that resembles the specialization and complementarity of the two clusters. Where Rotterdam has a focus on crude and products, Antwerp-Bruges has pipeline facilities for more fine chemicals.

[4] The results in the Routescanner tool relate to containers and other intermodal units. RORO and breakbulk cargo are not included in the current version of Routescanner.

Figure 55: Pipeline infrastructure ARRRA cluster



2.2.2 Strategic connectivity: networks for innovation and knowledge development

The *strategic dimension* relates to innovation and knowledge exchange. It is about the relationships that the ports and their companies have in their relevant networks that enhances the innovation and development of knowledge. It is an important layer on top of the physical developments that are key to the role of the port managing bodies: it strengthens the efficiency and effectiveness of both the physical networks, the transport and logistical services as the industrial clusters. It centers around digitalization and new technologies for the energy transition. Digital twins, specific drone applications, AI tools for smart energy matching solutions, autonomous shipping and driving but also hydrogen technologies, are a few examples.

Both ports engage in various platforms (e.g. Smart Digital Ports of the Future Conference) and EU funded initiatives relevant to them that develop knowledge for and stimulate innovation on various terrains. Good examples of such EU funded initiatives are PIONEERS (coordinated by the Port of Antwerp-Bruges) and its sister project MAGPIE (coordinated by the Port of Rotterdam), which are both funded under the Horizon2020 Green Ports call. But the individual companies in the port also have their links and relations: with each other or with other companies at the European continent, even globally. Such links that the port managing bodies but also the companies in the port have with platforms, network organisations or specific other companies for knowledge exchange and innovation strengthens the overall performance and development of the ports.

And there is also strategic connectivity between the ports of Antwerp-Bruges and port of Rotterdam. For example in Magpie and Pioneers, instead of working aside each other, both ports have chosen to actively engage with each other by transferring knowledge, connecting their partners and working jointly on a roadmap for the greening of European ports, instead of writing and presenting their own separate version to the EC. In 5G Blueprint, the possibilities for Connected, Cooperative and Automated Mobility (CCAM) are investigated on the axis Antwerp-Rotterdam. Furthermore, the port of Antwerp-Bruges and the port of Rotterdam collaborate in terms of innovations in, amongst others: the application of drones in the port area, security, resilience and business continuity (e.g. in the EU funded CLARION project), the implementation of the International Ship and Port facility Security Code (ISPS) code, subversive crime and energy transition. A recent

example of 2024 is the fruitful collaboration between the ports of Antwerp-Bruges, Rotterdam and Hamburg and the European Chemical Industry Council (Cefic), in the automated sharing of critical security information to strengthen overall port security and operational effectiveness, using federated identities. PoR and POAB also both take part in HydrogenEurope aiming at the development of this green energy carrier. Furthermore, such initiatives demonstrate the role that collaboration between these (and other) ports has in supporting the EC's strategy to enhance digital and information communications technology, digital public administration, and transport. NB the two ports bring in their knowledge in networks such as ESPO, Ecoports, IAPH or chainPORT.

Thus, despite the fact that innovation in ports does not always show off once looking at number of patents or direct investments and also despite the fact that the real initial innovation many times takes place at the headquarters or specific labs of the multinational port companies, the ports of Rotterdam and Antwerp-Bruges have innovation ecosystems in which (low TRL level) innovations are (further) developed, can be applied, tested and scaled up. This strengthens their networks and industrial clusters and can generate spill-over effects to other European ports and industrial clusters.

2.3 Cluster Formation: the Antwerp-Bruges – Rotterdam industrial cluster

A unique cluster based upon scale, diversity and connectivity

This section shows the strong cluster formation of the two ports with a European footprint that builds upon the two ports' individual industrial complexes, the strong transport connections between both ports and the industrial hinterland and the cooperative relations for development, knowledge building and innovation. The petrochemical and energy clusters in the ports of Antwerp-Bruges and Rotterdam are particularly important because of their economic and strategic value. NB, a key element of strategic value is a difficult to copy, often qualitative contribution to the sustainable international competitiveness of countries - here countries in the EU (van den Bosch et al, 2018). These sources of strategic value are based on cluster-related factor conditions. Some factor conditions are based on their geography ("the lower countries"), but many also on their historical and continued investments to remain the most productive logistics heart of Europe. The combined scale and variety of both industrial port clusters is a unique source of cluster and agglomeration benefits. Building upon Porter (1990 and 2008) clusters such as the port of Antwerp-Bruges and the port of Rotterdam are the main building blocks of a region's welfare. They compete fiercely and hence discipline each other constantly, trigger innovation, attract talents, etc. to remain globally competitive. At the same time these clusters, being close to one another and extremely well connected, also collaborate on distinct domains where they both benefit more from that collaboration, such as for chemicals and together serving the industry in the Ruhr area.

2.3.1 Ports of Rotterdam and Antwerp-Bruges are part of ARRRA-cluster

The industrial clusters of the two ports are integrated into the larger Antwerp-Rotterdam-Rhine-Ruhr area (ARRRA) cluster, also called the 'Trilateral Chemical region', which is responsible for 40% of the total petrochemical production in the EU and 350.000 direct jobs and a turnover of 180 billion euro (Trilateral Chemical Region, 2024). In addition, with 11 oil refineries, the cluster is responsible for some 18% of EU refining production capacity (Oilandgasclub.com). From the ports of Antwerp-Bruges and Rotterdam about 53 million tons of crude oil, oil products, chemicals and related products (e.g. LNG) are transported to the industrial clusters of North-Rhine Westphalia and Rhineland-Palatinate in 2023, mostly by barge and pipeline. This strongly interrelated and cross-border cluster is of such a maturity that it is recognised as one of the most prominent ones for Europe's wider industrial and production infrastructure. This cluster is at the very heart of

Europe's prosperity and value creation. It provides Europe with essential products such as pharmaceuticals, inputs for the steel and metals, automotive and building industries and inputs for all kinds of specialized industrial sectors producing intermediate and consumer products (Dechema, 2024).

Today, after over 150 years of development, the chemical industry in the ARRRA still holds the fourth-largest chemical industry cluster position in the world. When it comes to operating excellence, the region ranks in first position, far ahead of the USA, Japan and China (Trilateral Chemical Region, 2024) Yet, ARRRA has the ambition to keep up the quality of its factor conditions, such as new pipeline investments, in view of its ongoing and necessary transition to green chemistry (Catalisti, 2024) and carbon neutrality.

2.3.2 The strength of the cluster: accelerating to new developments

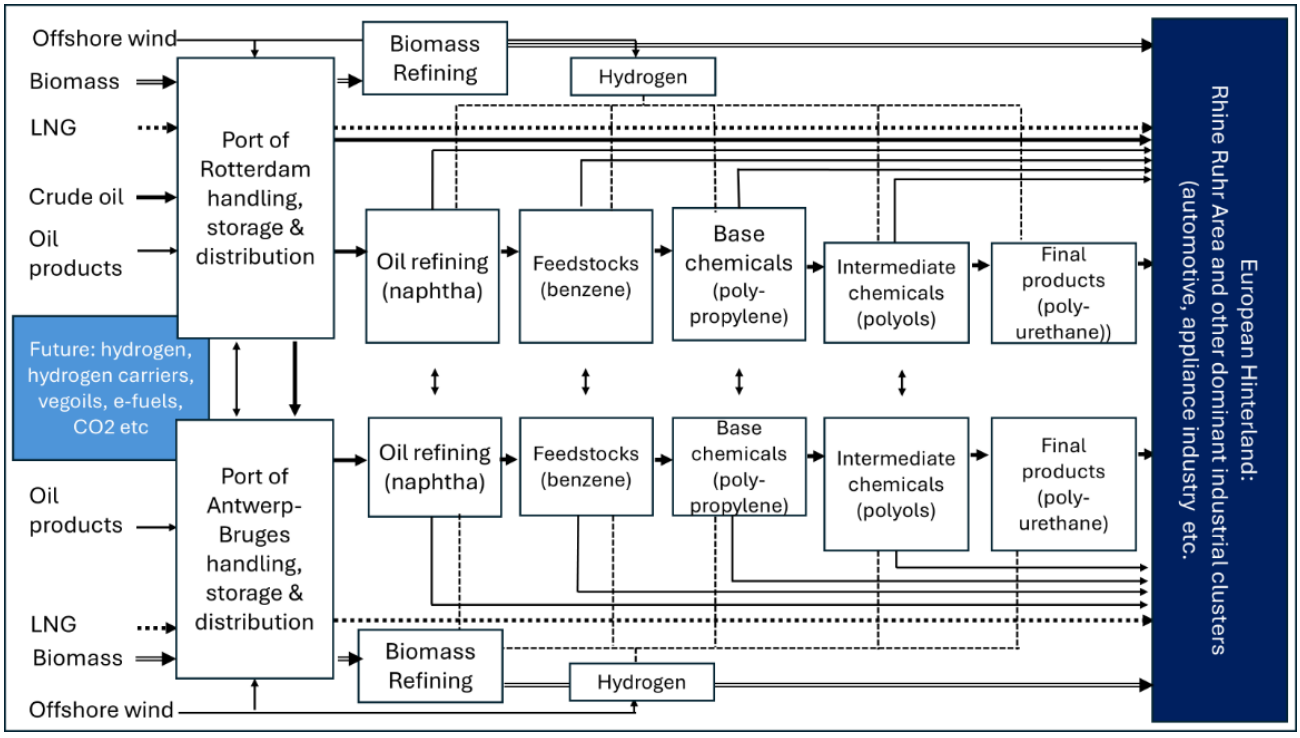
The strength and integrative aspect of the ports of Antwerp-Bruges and Rotterdam in the larger ARRRA-cluster lies in its scale, specialization & complementarity and connectivity.

Scale

Nowadays, most of the major international chemical and refinery companies have their European headquarters or a major plant in the ports of Antwerp-Bruges and Rotterdam and all the main West-European centres of industry and consumption lie within a radius of 1,000 km. Especially the large-scale presence of Bayer and BASF, with continued investments over the years, as well as the plants of Evonik and Covestro, are proof of a very tight connection of the port of Antwerp-Bruges with the German industry. Especially BASF is a good illustration with its second largest 'Verbund-site' located in Antwerp. These Verbund-sites—with Ludwigshafen as main location—are large integrated locations of BASF in which by-products of one process are used as starting materials for other processes resulting in energy and resource efficiency and higher product yields. Major investments from the past years include large-scale projects initiated by Borealis, BASF, Covestro, Evonik, INEOS, TotalEnergies, Kaneka and Nippon Shokubai. The port area in Antwerp-Bruges includes 500 chemical firms on over 2,500 ha of industrial land, 2 refineries (Total and ExxonMobil), 3 steam crackers, and production and storage sites of more than 300 different chemicals. (https://invest.flandersinvestmentandtrade.com/en/sectors/chemicals, 2024).

The petrochemical use of the port area in Rotterdam is over 2,800 ha and includes 60 chemical, circular and biobased firms and 5 oil refineries, of which Shell Pernis and ExxonMobil are the two most complex refineries. Also, in the port of Rotterdam, large scale investment is under way by firms such as Neste, Shell, Porthos (CCS), Gate-terminal and Air Products. Shell is building Europe's largest green hydrogen plant (Holland Hydrogen I), expected to be operational in 2025. In addition, Neste's investment of EUR 1.9 billion is renewable production capacity in worth noting.

Figure 6: Simplified chemical & energy map port of Antwerp-Bruges and Rotterdam industrial system: orientation towards European hinterland



Note: size of the blocks indicates specialization, products named: example

Specialization & complementarity

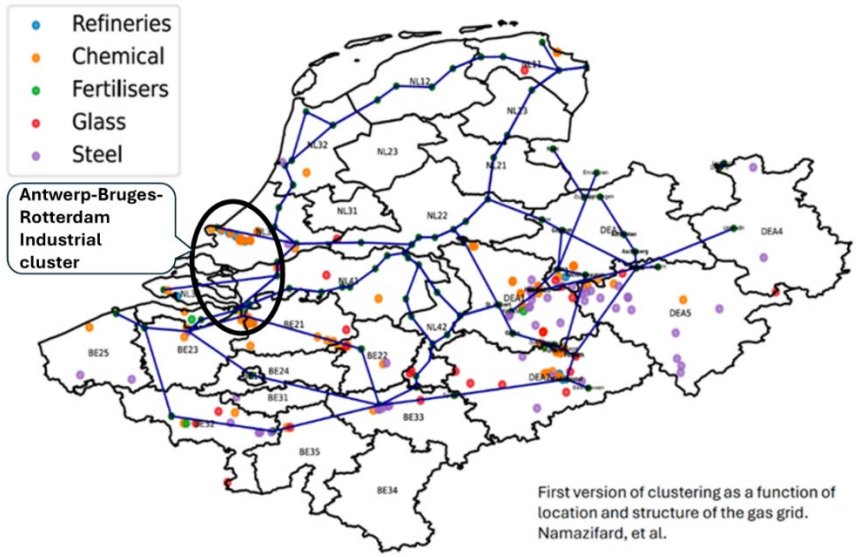
The industrial ecosystems of the ports of Antwerp-Bruges and Rotterdam have their specializations. In addition to the dominant oil refining capacity in the port of Rotterdam, the chemical industry in both ports has a complementary character: a high share of specialty/fine and intermediate chemicals produced in the port of Antwerp-Bruges (see figure above) and the production of mostly primary chemicals in the port of Rotterdam. The port of Rotterdam, with its large scale, deepsea transshipment facilities, provides for massive import volumes and throughput flows of basic inputs for the industries in the Rhine-Ruhr area: liquid energy flows (crude oil, oil products, LNG (GATE-terminal Rotterdam), chemical products and iron ore and scrap. Antwerp-Bruges has - besides a strong position in LNG (Zeebrugge, 15% of Europe's demand) - a strong portfolio of fine and intermediate (performance) chemicals. Antwerp is the polymer hub for Northwestern Europe, including specific logistics service providers present in the port area with large scale storage capacity and specific handling capabilities for polymers. In the section above we referred in detail to the links between the port of Antwerp-Bruges and BASF and Bayer. The various refinery and chemical companies in the cluster provide each other with feedstocks (supported by an integrated pipeline network). This shows its true integration and providing for agglomeration and spill-over effects.

Connectivity

One of the reasons for the ports of Antwerp-Bruges' and Rotterdam's success is its connectivity with overseas destinations and the European hinterland. Both ports are often the 'first port of call' in Northwest European container liner schedules. The ports have direct services to 1,300 ports in Asia, North America, South America, and West Africa and the cluster is close to the main European production and consumption centres. Especially extensive pipeline and intermodal connections by inland waterway and rail towards the hinterland

is a strength. For the integration of both ports in the ARRRA-regio this infrastructure has been of critical importance (see Figure 7).

Figure 7 Energy and feedstock infrastructure in the Trilateral Chemical Region in function of demand and supply centres (Source: 3C-VaCS, 2024 based on Namazifard, et.al. (2023))



2.3.3 Outlook for port-related energy intensive industries

The performance of the energy-intensive industry, of which the port-based process industry as presented above is a dominant example, is clearly analysed in the groundbreaking report by Mario Draghi on 'The future of European competitiveness', which he presented in September 2024 to European Commission President, Ursula von der Leyen. In the chapter on energy-intensive industries, the contribution to the EU economy is clarified. As written above, energy-intensive industries account for a relevant share of production and employment, create value for downstream industries, are crucial to avoid strategic dependencies in critical industries in Europe, are an important emitter of greenhouse gases and are traditionally a frontrunner in quality, innovation and green technologies, and their deployment. The Draghi Report is very clear in the eroding competitiveness of the EU energy-intensive industries, reflecting in output losses and an increased reliance on imports. The root causes are related to high energy prices and high emission costs related to global competitors, in addition there is a need for high investment for decarbonisation, there is an unlevel playing field and complex regulation and an untapped potential from circularity. Two clear priorities are stated in the report: enable the different energy-intensive industries in their path to decarbonisation and level the playing field with international competition. The report proposes eleven clear proposals towards these priorities, ranging from the improvement of harmonizing subsidy allocation mechanisms to improvement of the circularity of raw materials or stimulating demand for green products.

In the beginning of 2024, business leaders of 17 industrial sectors presented the 'The Antwerp Declaration' to Commission President, Ursula von der Leyen and Belgian Prime Minister, Alexander De Croo. The Antwerp Declaration calls for a European Industrial Deal to complement the EU Green Deal and safeguard quality jobs in Europe. The analyses in the Antwerp Declaration and the Draghi Report are consistent with each other. Europe's industries are facing the worst economic downturn in a decade at a period when investments are needed to achieve Europe's transition to climate neutrality. Urgent action is needed to restore the business case for investments in Europe. Europe's electricity production will need to multiply, and industry investments will need to be a factor six higher than the previous decade. The Antwerp Declaration proposes ten clear policy proposals to keep industry in Europa because the industry will deliver climate solutions Europe needs.

The Draghi Report and Antwerp Declaration are very relevant for the chemical and oil industry located in the ports of Antwerp-Bruges and Rotterdam. The chemical sector in Europe has gone through a challenging period marked by a decline of production by 7.6% in 2023 and 6.3% decrease in 2022. Also, circular production initiatives faced a tough period in which in the last year, six circular firms recycling plastics went bankrupt in the Netherlands due to the much lower costs of imported virgin plastics. However, the European Chemical Industry Council (Cefic) carefully projects a possible 1.0% growth in EU27 chemical output for 2024 (Cefic, 2024). The decline in European chemical production over the past years – especially where petrochemicals, polymers in primary forms, and basic inorganics are concerned – can be attributed to the issues also presented in the Draghi Report and Antwerp Declaration: a strong increase in energy prices and a significant decrease in the demand of goods in the aftermath of the Covid pandemic. Besides the automotive sector, other domestic customer industries in the EU also experienced a slowdown in 2023. Inflation, decreasing purchasing power, along with a complex and costly regulatory agenda in Europe were additional contributing factors, and also cheap imports of chemical products from Asia are problematic for the European chemical industry.

Despite this temporary slowdown, greener and futureproof investments continue in the chemical cluster. A recent evaluation by the Renewable Carbon Initiative (RCI) sheds light on the progress, challenges, and potential pathways for a net-zero chemical industry by 2050. The report highlights the critical role of renewable feedstocks, recycling innovations, and technological breakthroughs. By 2050, the global production of chemicals and plastics is expected to nearly triple compared to 2020 levels. The journey to net-zero emissions requires a dramatic reduction in fossil carbon dependency, with a focus on alternative sources like biomass, carbon capture and utilization (CCU), recycling and green/bleu alternative energy sources like hydrogen carriers (methanol, ammonia et cetera). The RCI's evaluation provides information on a steady decline in fossil feedstock reliance, replaced by a mix of biomass, CCU, and recycled materials. These trends underline the industry's collective commitment to a sustainable future, even as individual scenarios vary in their assumptions and projections (Harrandt, J., Carus, M., vom Berg, C., 2024: Evaluation of Recent Reports on the Future of a Net-Zero Chemical Industry in 2050).

3 Contribution to important (more recent) strategic challenges/goals for Europe

The climate crisis but also the disturbance of the geopolitical order in the world have a strong impact in the European society and its ports. The climate crisis asks for a transition towards clean, zero emission energy in which ports play a crucial role. Geopolitical forces, causing pressure on Europe's strategic and economic position requires strong attention. It leads to a plea for more strategic autonomy and safeguarding critical industries. And also here the ports of Antwerp-Bruges and Rotterdam are quite instrumental. Building upon their location, their scale, their strong European connectivity and the large scale industrial ARRRA cluster, they are important enablers for Europe's energy transitions, its transition towards circularity and also its strategic autonomy. In following section, we provide a more in-depth insight in the specific ways in which the ports of Rotterdam and Antwerp-Bruges jointly (potentially) create value for the energy and resource transition and circularity and for Europe's strategic autonomy.

3.1 Energy transition

The ports of Rotterdam and Antwerp- Bruges are for multiple reasons strong enablers for the energy transition that Europe must realize and has stated in the Fit-For-55 package. First, their location enables the large-scale import of clean energy. This is both green electricity from the large scale windparks in the North Sea as green fuels and energy carriers that are imported by maritime transport. And second, with their widespread connectivity and their existing integrated industrial clusters they build upon assets, infrastructures and competencies enabling an efficient and effective transition, not only within the borders of their ports but in the wider hinterland. These existing industrial clusters can provide clean chemical and clean fuels like hydrogen, ammonium, biofuels, and e-fuels. Their centrality to networks of pipelines (but also barge and rail connections) enables the distribution of the green fuels and energy carriers to their destinations: consumers and industries in the European hinterland. The ports are therewith key elements for the ambition that Europe has to reach net-zero in 2050 as is supported with the recent Net Zero Industry Act (NZIA). This act aims to enhance European manufacturing capacity for net-zero technologies and their key components, addressing barriers to scaling up production in Europe. The regulation will increase the competitiveness of the net-zero technology sector, attract investments, and improve market access for clean tech in the EU. By 2030, the act aims to create a Union market for CO2 storage services. It sets a Union-level goal and mandates an annual CO2 storage capacity of at least 50 million tonnes. The NZIA encompasses final products, components, and machinery necessary for manufacturing net-zero technologies, including:

- Solar photovoltaic and solar thermal technologies
- Onshore and offshore renewable technologies
- Battery/storage technologies
- Heat pumps and geothermal energy technologies
- Hydrogen technologies, including electrolysers and fuel cells
- Sustainable biogas/biomethane technologies
- Carbon capture and storage (CCS) technologies
- Grid technologies
- Nuclear fission energy technologies, including nuclear fuel cycle technologies
- Sustainable alternative fuels technologies
- Hydropower technologies
- Other renewable energy technologies
- Energy system-related energy efficiency technologies, including heat grid technologies

- Renewable fuels of non-biological origin technologies
- Biotech climate and energy solutions
- Other transformative industrial technologies for decarbonisation
- CO2 transport and utilisation technologies
- Wind propulsion and electric propulsion technologies for transport
- Other nuclear technologies

The act also covers manufacturers in energy-intensive industries like steel, chemicals, and cement that produce components used in net-zero technologies and invest in decarbonisation. (Draghi, 2024).

The ports of Rotterdam and Antwerp-Bruges have projects running or as initiative for almost of these listed net-zero technologies. Next sections go a bit deeper into wind at sea, hydrogen(carriers), biofuels and e-fuels.

3.1.1 Electricity from wind at sea

At European level there is quite an ambition for development of wind at sea. The nine North Sea Energy Cooperation countries (NSEC) amongst which the Netherlands and Belgium agreed to realize an installed capacity from 33GW now, to 120GW in 2030, to 300GW in 2050 (European Wind Power Action Plan). The NSEC supports and facilitates the development of an integrated offshore grid development. The seaports of Rotterdam and Antwerp-Bruges have a critical role in this. The seaports are the places where the electricity comes on shore, where it directly is or can be used in the industry or where it can be transformed into green energy carriers like hydrogen. The already existing potential demand within the integrated petrochemical cluster enhances the viability of investments needed. Both ports of have substantial existing and planned connections to the (planned) wind parks at the North Sea. Rotterdam aims to have 25GW connected in 2050, Antwerp-Bruges 8 GW.[5] Together this is about 11% of the NSEC's ambition.

Table 6: Joint planned electricity capacity from wind at sea (Source: Elia, 2024, Belgian Electricity System Blueprint for 2035-2050, PoR 2024, Haskoning, 2024)

Wind at sea (GW)	2023	2030	2050
Rotterdam	1,4	7,4	25
Antwerp-Bruges from Belgian domestic offshore	2,2	5,8	8
Joint	**3,6**	**13,2**	**33**
European ambition	*33*	*120*	*300*
Share in Europe of North Sea capacity	11%	11%	11%

The seaports are also the places from where the installation, service and maintenance of the windparks is facilitated. In the port of Rotterdam SIF is located at a site of 62 hectares, assembling monopiles and servicing the offshore installation of the windmill parks. Further expansion for marshalling but also for decommissioning and recycling is foreseen.

[5] At 45 km from the Belgian coastline, an artificial energy-island Princess Elisabeth is currently constructed by TM Edison. The island has a capacity of 3.5 GW renewable energy and is an important step for Belgium to achieve the European energy goals. It will transform the renewable energy produced by offshore wind farms, make connections to other national electricity grids, and monitor energy production. It will also function as a landing point for the interconnectors between Belgium and other European countries.

3.1.2 Provision of green fuels (clean hydrogen, bio-fuels, e-fuels)

Green Hydrogen and hydrogen carriers

Green hydrogen is one of the major alternative green energy carriers, especially for the industry, partly for transport. Hydrogen is already used in the industry, but this merely is grey hydrogen (produced with fossil fuels). Total existing hydrogen demands in Europe in 2023 has been estimated at 7.9Mt, a slight decrease compared to 2022 (-3%). The biggest share of hydrogen demand comes from refineries which were responsible for 57% of total hydrogen use, followed by the ammonia industry with 25% and 11% for methanol production and other uses in the chemical industry (European Hydrogen Observatory, 2024). The Hydrogen Council estimated in 2017 that the hydrogen demand could increase tenfold by 2050.

According to forecasts published by the German government, Germany alone will require at least 110 terawatt hours (Twh) of hydrogen by 2030 – and the needs estimated by the business world are actually much higher than this figure. Key hubs such as the port of Rotterdam and port of Antwerp-Bruges are already creating the necessary infrastructure to guarantee that the industry's energy supplies in Germany and Europe will be sustainable and reliable. Green hydrogen carriers as ammonia, methanol and LOHC, will partly replace existent fossil energy demand, especially for the industry and heavy (maritime) transport. There are substantial plans for import facilities in the ports of Rotterdam and Antwerp-Bruges for these green hydrogen carriers, that will be inputs for the integrated ARRRA petro-chemical cluster, the cluster around Chemelot and also the steel cluster in the Rhine Ruhr area. This is facilitated by planned pipeline infrastructures. And this goes together with:

1) planned electrolysers (a first 200 MW electrolyser is being built in Rotterdam with ambitions for extension with other plants into 2-2.5 GW in 2030) and ammonia crackers
2) storage facilities through transformation of existing liquid bulk storage facilities,
3) transformation of existing and building of new pipeline grids for the transport for these new energy carriers.

NB it is expected that around 10% of the hydrogen demand can be produced within the ports, 90% will need to be imported. One of the showcase projects related to the energy revolution is the former refinery site in the Antwerp port area, which is currently being transformed into a new hub for green energy. The Vopak Energy Park Antwerp site, which measures 105 hectares, will not only offer access to the sea, but also to various transport networks, including inland waterways, roads and rail services – and to pipeline links to north-west Europe, which will make it possible to supply hydrogen and hydrogen carriers to the important business centres there.

Bio- fuels

Also bio-fuels can be used as greener alternative to fossil fuels. Especially in the Port of Rotterdam already quite a number of large producers of bio- fuels that find their way to all kinds of industries, but also potentially the transport sector in Europe. (NB within Europe there already is an agreement for the use of at least 10% of bio-fuels in total fuel-use). There are concrete plans for new plants and expansions.[6]

E-fuels

E-fuels are potential alternatives for fossil fuels. European regulation states that where combustion engines still are allowed after 2035, they can only be fuelled by e-fuels. They are produced by using green hydrogen (produced with green electricity) and air-captured CO2. E-SAF (sustainable aviation fuel) is also an alternative

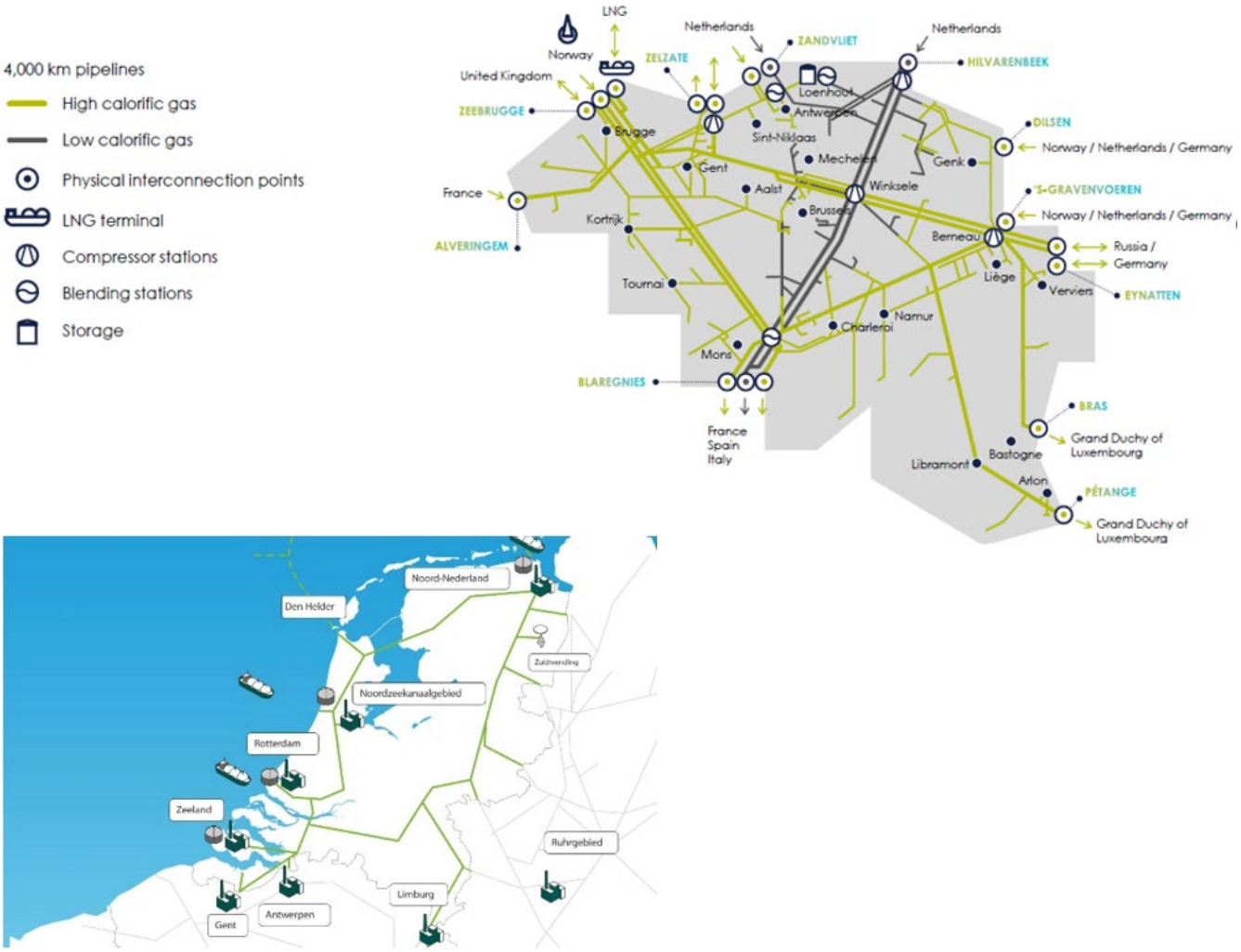
[6] Also in North Sea Port, which is not part of this study, but also a port industrial complex that lies in the same region, production of biofuels takes place.

fuel for the air transport sector. The ports of Rotterdam and Antwerp Bruges are places where such e-fuels can be produced because of availability of space, green hydrogen and CO2. Concrete initiatives are in the pipeline already, such as Hyofwind on the Zeebrugge platform of PoAB by 2026, and the Plug in Antwerp facility ready by 2027. Examples in Rotterdam are Power2X and Advario that develop an e-SAF Hub. The Port of Rotterdam accounts for 25% of the import and production aviation fuel for Europe, of which thus a small but increasing share is sustainable fuel (SAF). From 2025 a compulsory share of sustainable aviation fuel of 2% is valid, which will increase in future.

3.1.3 Existing assets, infrastructure and competencies

The ports of Rotterdam and Antwerp-Bruges have built up - with their long development history into large scale maritime transport nodes, energy hubs and industrial clusters – a set of assets, infrastructures and competencies that enables them to play a key role in the transition towards a green and strong Europe. Existing infrastructures and assets can be re-used, experience and existing knowledge enables a swift transformation. That applies to for example import, storage and transportation facilities, but also to (green) energy and feedstock production and distribution. And customer networks are already there. The two ports have extensive hydrogen and ammonia ecosystems, building on its own ports, pipelines, import infrastructure and large industrial users. They have already many players in hydrogen technology with strong hydrogen research centers. Such companies increasingly are using their expertise for developing large scale hydrogen import value chains internationally. Figure 9 shows an example of such a key transition asset: the transmission connected pipeline infrastructure in Belgium.

Figure 8: Illustrative pictures for key transition assets (source: Gasunie)



3.3 Circularity

Circularity is necessary to stay within planetary boundaries and is related to the need for 'de-fossilization'. The challenge will be to replace fossil inputs with non-carbon-based alternatives such as recycled plastics, biomass, captured carbon et cetera. Because of the still high-carbon intensity of the existing port-related industry, seaports are primarily focussed on this material transition towards decarbonization. Circularity is therefore directly related to the material and feedstock transition. In addition, the circular economy has gained importance due to the goal of 'strategic autonomy in Europe' (see next section). Critical raw materials can be recovered from many recyclable products. Seaports are ideally positioned to be an important engine of a European production and logistics transition towards the circular economy.

Circular production and consumption processes mean reverse flows, new collection and distribution patterns and new activities in which used products are collected and transformed into new (secondary) inputs and (intermediate) products. Ports provide this and are functioning as important enablers for the development of the circular economy in the larger European economy. Seaports are not only offering production capacities but also the logistics opportunities for an intra-European circular economy, as well as providing links to emerging global opportunities. At the moment, overseas imports of for instance wood and biomass already

are important building blocks for sustainable aviation fuels and building materials. So circular activities take place within supply chains of which ports are already part and which provide the necessary infrastructure and transport facilities.

At the same time, port-based circular activities have a large need for space. The Netherlands Environmental Assessment Agency (Rood & Evenhuis, 2023) expects that 40% additional space will be needed on industrial estates for the circular economy. The need for space also depends on the way the circular (and energy) transition will be executed. In a coherent transition, fossil chains are scaled down and a proportionate share is released in time for non-fossil activities such as the circular economy. In an incoherent transition, fossil and non-fossil operations exist side by side, which results in a much larger footprint (TNO, 2021). Space is also crucial because of the need to realize economies of scale in circular operations, resulting in low production costs and logistics advantages. These economies of scale will contribute to solving one of the most important barriers of recycling at the moment: bad business case. For example “while plastics recycling reduces fossil feedstock needs it has no strong business case at present. In particular, virgin material continues to be cheaper at current costs (including carbon prices), costs of landfill and waste incineration are still low, and it is difficult to earn a green premium for recycled plastics to compensate for higher costs, due also to the often limited quality of the secondary material” (Draghi, 2024). Circular activities are therefore a still risky business to invest in.

Because of the limited availability of space in seaports, existing installations must be converted into the processing of (chemical) recycling or other circular production techniques. The limited availability of space in seaports means that circular capacity also must be developed in the hinterland of seaports, for instance in the existing production clusters in Europe such as the Rhine-Ruhr area that also offer the large-scale recycling infrastructure that results in economies of scale.

An example of the use of existing industrial capacity for the production of synthetic materials/plastics is given by Bergsma et al (2020). The installed production capacity in the port of Rotterdam for synthetic materials/plastics without further internal use in the port, suitable for processing circular raw materials such as plastic, amounts to 6 million tonnes. Including the port of Antwerp, the existing circular capacity for synthetic materials/plastics will be much greater and will result in much more than a doubling of Rotterdam's capacity in the total Antwerp-Bruges-Rotterdam cluster, due to the specialised nature of the Antwerp cluster (see section 2.3.2). In addition, other materials will be processed in both ports, such as building materials, steel, wood or other types of biomasses.

3.3.1 Circular initiatives in the ports of Antwerp-Bruges and Rotterdam

The ports of Rotterdam and Antwerp-Bruges are already taking concrete initiative to develop circularity. Haezendonck and Van den Berghe (2020) found that the Flemish seaports, and ports in the lower countries and Europe more in general, show a high level of maturity in the circular transition, as compared to ports globally. This was also demonstrated in the number and quality of the longlisted and shortlisted European ports for the most recent ESPO award on circular economy and connecting communities, for which the port of Antwerp-Bruges was shortlisted. One recent activity is the Antwerp North Heat Network, called WAN, where Europe’s largest chemical and industrial companies located in the port together with Indaver, jointly use the residual heat of their activities to share with the company Boortmalt and surrounding communities via the Antwerp heat loop. In 2024, the port of Antwerp-Bruges distinguishes 30 different circular economy activities and besides demo plants and start-up initiatives outside the strict port area, they also have several promising circular economy projects ongoing. One more mature project is ECLUSE or the Waasland Port heating network where steam is sluiced from the Indaver and SLECO waste-to-energy plant to companies in the port.

The port of Antwerp-Bruges also dedicates 88ha of its land on the right bank specifically for CE activities and innovations, NextGen District. Today, seven core circular companies are already active on this site, and more are planned to scale up and find their way to these plots. Besides, knowledge and coordination centers such as Antwerp Coordination Centre (ACC), the Antwerp Maritime Campus (AMC), incubator facilities in and close by the port (for example NextGen demo and Blue Gate Antwerp) assure platforms for information exchange and innovation.

In addition, at the Zeebrugge platform of the port, land is reserved for circular activity development such as reuse of water and decommissioning of wind turbines from the North Sea. Besides land in the port areas themselves, both Antwerp and Zeebrugge actively searched for dedicated zones and space for circular activities that can either support or precede the circular activity in the port but can take place somehow remote but well connected to the circular economy sites in the port areas. Hence, sites along the Boudewijn Canal (for the Zeebrugge platform) and along the Albert Canal for the Antwerp platform are considered and researched to be valid options for, for example, pre-recycling activities. In fact, a study performed for the Flemish Agency for Innovation and Entrepreneurship VLAIO on the potential development of an industrial area along the Albert Canal at 25 km from the Antwerp port platform, indicated that the area was ideally situated for chemical pre-recycling activities, as it is a large economic and industrial development zone situated at the intersection of barge and pipeline connections (cf. "Leidingenstraat Antwerp-Ruhr area", ENA project, https://omgeving.vlaanderen.be/nl/ena-projecten, 2024). It could with these activities attract some chemical activities to feed the cluster activities within the sustainable transition, but without taking the scarce port space itself (VLAIO, 2022).

Likewise, the port of Rotterdam has a number of circular projects, such as the 'Circular Steam Project' by chemical firms LyondellBasell and Covestro (producers of propylene oxide and styrene monomer) in the Maasvlakte Area. Pryme, which operates a demonstration plant on the PlantOne site in Botlek that converts waste plastic into pyrolysis oil. Next, Shell Chemicals Park Moerdijk has started a new factory that allows plastic that is difficult or impossible to recycle to be reused. With the so-called Market Development Upgrader (MDU), the chemical complex can start using circular raw materials on a large scale. The waste-recycling company REKO processes 1.2 million tons of residual materials annually in a thermal cleaning installation. The electricity generated by the installation is used by 50,000 households and adjacent companies (Koole). International battery recycling company 'SK tes' is opening a new plant in the Port of Rotterdam. The plant will recycle lithium batteries, electric car batteries and battery production scrap to recover crucial raw materials. In addition, the energy company Neste is building a large biorefinery on the Maasvlakte - next to an existing factory located a short distance away. The raw material is used cooking oil intended for the production of sustainable aviation fuel.

In both ports, the circular economy is a priority in the port-innovation ecosystems and knowledge and coordination centres such as Antwerp Coordination Centre, the Antwerp Maritime Campus and other facilities mentioned above. In the port of Rotterdam an important part of the port innovation ecosystem is aimed at developing the circular economy. Initiatives are Bleu City, Plant One, RDM/Rotterdam Makers District and M4H, which is the circular 'delivery room' for the larger Rotterdam region.

3.4 Strategic autonomy

Recent geopolitical and geo-economic developments ask for increased strategic autonomy for Europe. One of the priorities as stated by Draghi's report is "to react to a world of less stable geopolitics, where dependencies are becoming vulnerabilities, and it can no longer rely on others for its security". The more recent deteriorating evolution in geopolitical risks demonstrates the effects on disruptions of trade and

security. With that, it is essential that Europe reacts with countermeasures that decrease the reliance for energy, base industrial inputs, critical raw materials but also enables catching up for its digital technology. Safeguarding the provision of base industrial inputs, development of processing facilities for important resources as lithium, strategic stockpiling and investment in circularity are such measures. The ports are logical places for that. They provide value for the strategic autonomy of Europe as energy providers and as facilitators of base industries that provide key inputs for Europe's industrial sectors, also the more technologically advanced. Their existing cluster and related facilities – including traders - make them potential locations for processing of critical resources, e.g. lithium. They are already strategic nodes for strategic oil(products) reserves and have the space, assets, routines, required certification and competencies to play an extended role for further and future strategic stockpiling. Circularity will – besides supporting decarbonization - help reducing the need for non-domestic critical resources.

3.4.1 Energy provision, facilitation of Europe's base industries for Europe's transition and innovation, critical raw materials

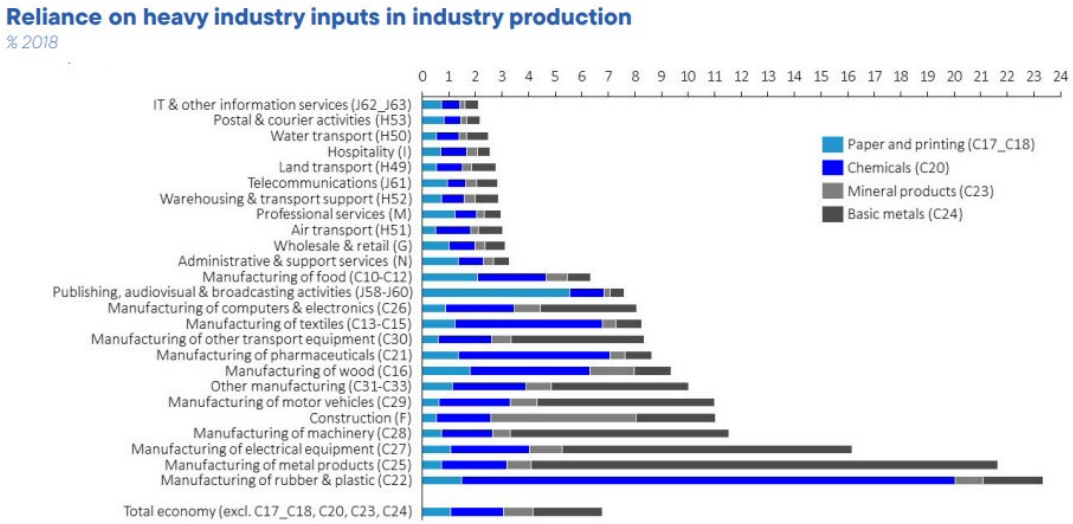
The ports of Rotterdam and Antwerp are *energy providers* and *facilitators of base industries*. And this is also important from a strategic autonomy perspective. "The current energy system in the Netherlands and the European Union (EU) is based on fossil fuels for approximately 80%, most of which are imported. The EU itself produces around 5% of the oil and 10% of the gas used within the EU. This makes our energy system vulnerable—much more so than is the case for the United States (US) or China."

Both Rotterdam and Antwerp-Bruges are significant energy ports. About 13% of European energy consumption passes through the port of Rotterdam. Within the port of Antwerp-Bruges, the port of Zeebrugge serves as an important natural gas import hub for Europe: Zeebrugge imports 15% of EU gas (this does not only include LNG, but also gas entering Zeebrugge through pipelines from Norway, UK, and France), and is a large supplier for the German market. Future expansions plans for natural gas within the port of Antwerp-Bruges include throughput capacity enlargement and future energy carriers.

Collectively, leveraging their unique strategic locations, their integration within key industries such as steel, chemical, food, their role as pivotal transport nodes in both domestic and international supply chains, and their capacity to function as catalysts for knowledge development, the ports of Antwerp-Bruges and Rotterdam (potentially) play a role in enabling the efficient import, processing, and distribution of raw material and heavy industry inputs. These activities are essential for supporting its resilience in various supply chains (see Figure 9) but also for defence and for advancing Europe's green and digital transitions. Besides it adds to the acceleration of knowledge regarding European critical raw material resources.

"According to the European Commission's methodology, out of 204 products with strategic dependencies 43% belong to chemical industries, 12% to basic metals, and 11% to mineral products. Strategic dependencies are input dependencies in critical industries or ecosystems, namely security and safety, health, and the green and digital transitions" (Draghi, 2024).

Figure 9: Europe's industrial sectors' reliance on base industrial inputs (Draghi, 2024)



Note: The graph displays each industry's use (direct and indirect) of paper and printing (C17_18), chemicals (C20), non-metal minerals (C23), and basic metals (C24) as inputs relative to total production in the respective industries. C17, C18, C20, C23, and C24 are omitted from the figure as intra-industry exposure is generally strong.

Source: European Commission, 2024. Based on OECD, 2021.

The European Critical Raw Materials Act aims to secure a sustainable supply of critical rand strategic raw materials, given the projected increased demand of critical raw materials (such as lithium, cobalt, nickel and rare earth elements) for the coming years and decades, combined with the current dependency on other economies such as China (e.g. magnesium), South Africa (e.g. platinum) and Turky (e.g. borate). Strengthening European resilience will be accomplished through the monitoring of strategic raw materials supply chains, coordinating the development of national strategic stocks (see also section 3.3.1), and expanding collaboration with other countries e.g. through Free Trade Agreements and Sustainable Investment Facilitation Agreements.

3.4.2 Strategic stockpiling for reducing political dependence

In the actual situation the two ports are already places for *strategic stockpiling* mainly for energy in the form of oil, gasoil/diesel, gasoline and kerosine. While it is not exactly known where these strategic reserves are, some facts can be given.

Both Belgium and the Netherlands have agreements with the International Energy Agency (IEA) and the EU for keeping 90 days of reserve of oil and oil products (this is around 4.8 million tons for the Netherlands, 75% crude, 25% products and approximately 3.92 million tons for Belgium, 53.7% crude oil and 46,3% finished products[7]). Both COVA and commercial companies keep these reserves (COVA 70%, companies 30%)

Both the port of Rotterdam and the port of Antwerp Bruges are critical actors if these strategic reserves would need to be activated. For the Netherlands, the largest part of this reserve is physically stored in the port of Rotterdam, on the Maasvlakte Oil Terminal (MOT). In Belgium, the port of Antwerp Bruges' role is more indirect, as little of this strategic reserve is stored within the port, albeit that the Port of Antwerp Bruges is still vital from a strategic autonomy perspective: in case of crisis, the finished products serve as a first line of defence, and need to be imported from one, or multiple, local or international storage facilities via inland waterway or pipeline to the Port of Antwerp Bruges, given the large quantities. Having multiple storage locations mitigates

[7] Finished products are products such as diesel, heating oil, jet fuel, and eBOB (the non-biocomponent of gasoline).

associated risks, and so the stock of finished products is distributed across several storage points, strategically located in facilities ranging from Hamburg to Le Havre. In case of an extreme crisis, i.e. if the crude oil reserves would have to be imported (as this is 100% stocked abroad), this reserve would need to be imported either via the pipeline network or via sea, to the 2 refineries (of Belgium) present in the Port of Antwerp Bruges.

Seeing actual geopolitical developments and the following political discussions at national and European level, we may argue that strategic stockpiling remains important and may even increase. Keeping energy reserves, also in alternative form to oil and oil products, for example hydrogen or ammonia, seems logical. But beyond that, managing stockpiles for critical raw materials that are relevant for the generation (solar panels, windmills) and storage (lithium batteries) of clean energy (solar, wind, batteries) will get more attention. While it is quite uncertain what this exactly will be, and what volumes it will concern, at the moment trading and storing such materials is the domain of certified commodity traders that have their assets in ports (Steinweg in Rotterdam is an example).

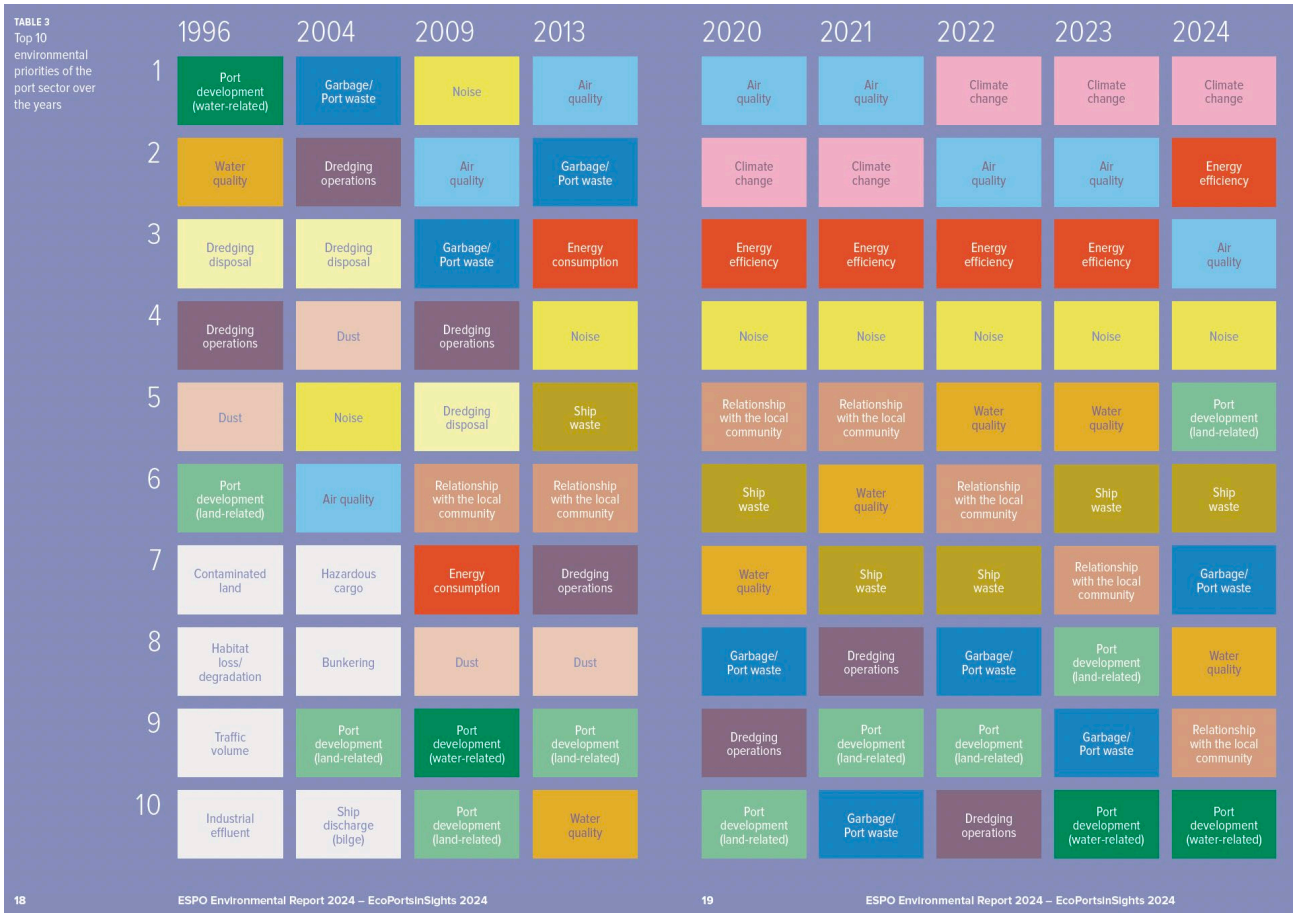
3.4.3 Circularity as key element in strategic autonomy

A key effective way in developing strategic autonomy is to reduce the need for critical raw materials that Europe lacks or can - only in the longer term and at relatively high costs -source domestically. Circularity is the answer to that. And as is highlighted in the specific section on circularity the ports of Rotterdam and Antwerp-Bruges position well for circularity with already quite some projects established and underway.

4 Impacting the living environment

Ports and its activities have an impact on the living environment The industrial and transport activities generate externalities. Emissions of greenhouse gasses, air- or water quality, noise or biodiversity are relevant examples of elements upon which ports have an impact. These impacts are merely perceived as negative. The most important are the ones impacting the climate and health of persons living around the ports. The annual ESPO report on the environmental priorities of ports, shows the top 10 of these priorities since the 1990s.

Figure 10: Top 10 environmental priorities of European (source: ESPO / Ecoports, 2024)



The impact on the living environment is mainly relatively local in the geographical area of the ports. Especially in the areas where different functions (economy, housing, nature) are located closely to each other, there is an impact. The industrial and transport activities are influencing these other functions, as said, often perceived as negative. Ports should therefore work on reducing the negative impact on the living environment, which is something the industry has been strongly focusing on since the 1990s. In this section we first indicate CO_2 emissions, followed by measures taken by port managing bodies to reduce negative impacts. CO_2 emissions are chosen because this one of the most dominant elements of the impact on the living environment in the energy/sustainability transition.

4.1 Emissions of CO_2

We focus in this elaboration on the emissions of CO_2. We specifically focus on the emissions by the industry. Shipping that comes to and goes from the port generates significant emissions as well, but this is less easy to attribute to the port.

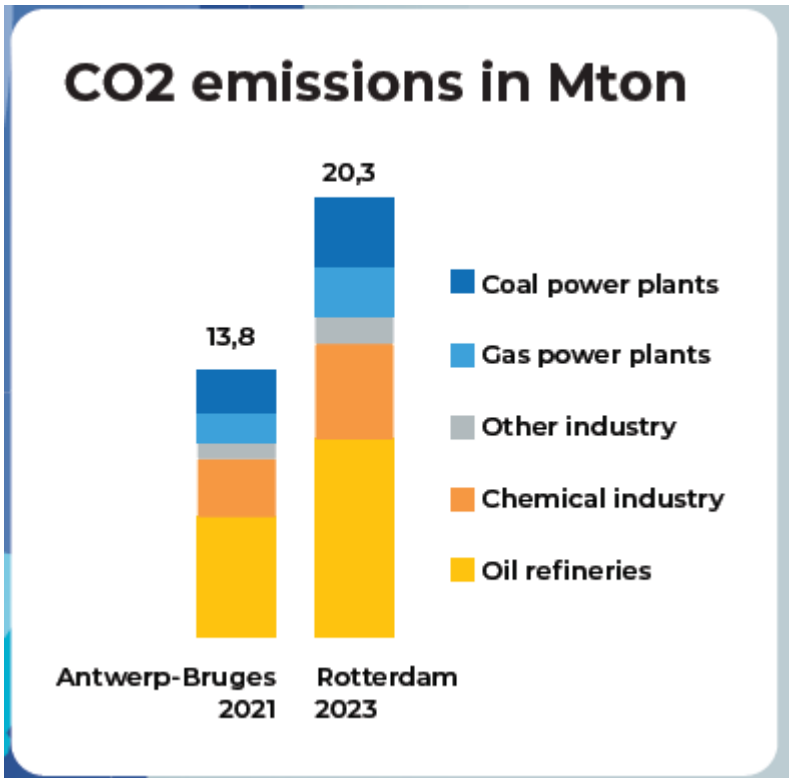


Figure 11: CO_2-emissions energy & industry Port of Rotterdam and Antwerp-Bruges

Figure 11 provides an overview of the CO_2 emissions from energy and industry in the port of Rotterdam and the port of Antwerp-Bruges for the last available year of the data. This is still a substantial share in the total emissions of both countries (between 16-20%). However relevant measures are taken or are planned to be taken with the expectation to have serious positive impact on future CO2 emission figures, going into the direction of targets stated for 2030 and beyond.

4.1.1 Examples of measures to reduce negative impact

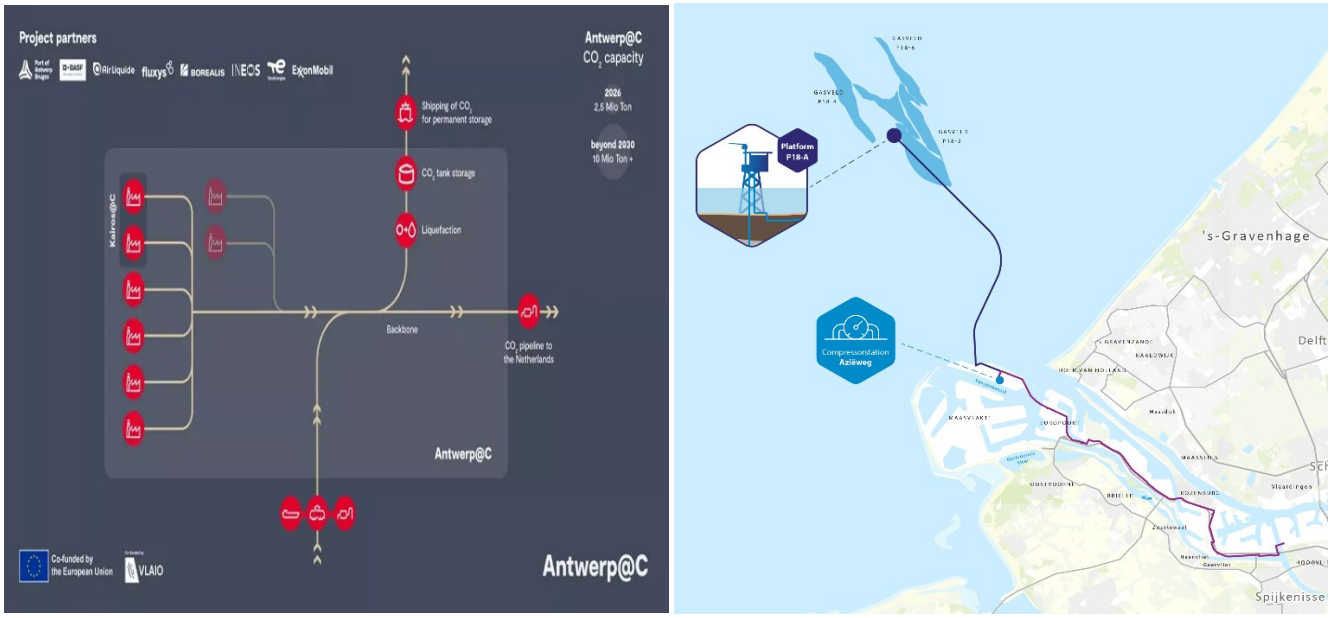
Both ports are actively working on reducing the negative externalities and impact on the living environment that they create with their activities. This includes, but is not limited to, actions with regards to emissions such as Carbon Capture and Storage/Usage (CCS/CCU), shore-power, electrification of terminals, transport and where possible of the industry in combination with the use of alternative fuels. Also facilitating and enhancing modal shift can be seen as a measure to reduces emissions.

CCS/CCU

Both ports are working on the introduction of major infrastructure projects for CCS. Porthos, Aramis and Antwerp@C are both projects in which the port authorities, together with private companies invest to store CO_2 emissions. Porthos is developing a project in which CO_2 from industry in the Port of Rotterdam will be transported and stored in depleted gas fields under the North Sea. The CO_2 transported and stored by Porthos will be captured by several companies. Porthos will store about 37 Mtonnes of CO_2, which is about 2.5 Mtonnes

of CO_2 per year for 15 years. This 2,5Mtonnes is about 10% of the total emissions in the Port of Rotterdam. In the Port of Antwerp-Bruges Fluxys and Equinor plan to develop a major infrastructure project for CCS, transporting captured CO_2 from emitters to safe storage sites in the North Sea, connecting Belgium to Norway. The investment decision is expected for 2025, and the goal is to be fully operational before 2030. The Port of Antwerp-Bruges provides value to Europe by enabling liquefied CO_2 from nearby hubs to connect to the Zeebrugge facility, extending the project's geographical reach beyond borders. In a more expanded collaboration within the energy and chemical cluster to create a common backbone, comprising seven leading companies (Air Liquide, BASF, Borealis, ExxonMobil, INEOS, Fluxys and Total Energies), the Antwerp@C project - next to the connection to Norway / gas fields in the North Sea through liquefaction in the first phase - also foresees a potential CO_2 pipeline to the Netherlands. The establishment of both cross-border CO_2 transport infrastructures could potentially halve the CO_2 emissions of the cluster by 2030.(see Figure 12)

Figure 12: CCS projects Antwerp@C and Porthos



Source: POAB, 2024 - https://www.portofantwerpbruges.com/en/our-port/climate-and-energy-transition/antwerpc,
Port of Rotterdam, 2024 : https://www.porthosco2.nl/project/

Electrification/use of alternative fuels

Second example of a major step in the reduction of the impact on the living environment is the electrification of transport and the industry or use of other types of sustainable energy sources, such as hydrogen for transport and industrial production. The presence of large amounts of green electricity from offshore wind is something that helps this transition. This is something that has been described in this report earlier in the section about energy transition and in both ports various companies have plans to do so.

Shore power

Both ports are actively investing in shore power to reduce the negative impact of shipping on the living environment. This is in line with the AFIR regulation, even going beyond it. When in ports, ships can use the shore power to power the equipment on board, rather than using a (diesel powered) auxiliary engine or generator. On some quays and for some activities there are already shore power connections in both ports, both for inland vessels as well as seagoing vessels. Already in June 2021 both ports, together with the ports of Bremen, Hamburg and Haropa signed a MoU on the establishment of a framework on the deployment of

onshore power supply. Both ports have the ambition to have shore power for the largest container vessels from 2028.

Enhancing modal shift

Both ports are important transport nodes in various flows of goods. Large volumes are transferred via the ports to and from the hinterland. By doing so, the ports facilitate industrial production, logistics and other activities in the rest of Europe. In the context of the impact on the living environment, the distribution over the different modes is important. Different modalities have different impact on the living environment. A modal shift to modalities with a smaller impact on the living environment helps to reduce the negative impact on the living environment that ports have. The large amounts of goods that seaports handle provide the opportunity to consolidate flows and to transport them in a more efficient and environmentally friendly way. Besides the amounts, the good intermodal connections that the ports have, provide opportunities to enhance the modal split towards modalities with a lower impact on the living environment.

Figures about the modal split for all transport of goods to and from the hinterland through the port of Rotterdam provide insights about the modal split. About 48% of the volume is transported by barge, about 26% by truck, about 17% by pipeline and about 9% by rail. Despite the efforts by the port of Rotterdam and other stakeholders to diminish the share of road transport, the modal split remains relatively similar over time.

If we focus on only the import to the hinterland, then this is for the largest part done by barge (about 50% of the volume) and pipeline (31% of the volume), while for the export flows from the hinterland, barge and truck are about the same. For containerised volumes, truck is for both directions (to and from the port) the largest mode of transport (about 40-45%), closely followed by barge. The Port of Antwerp-Bruges' modal split towards the hinterland (incl. industry) shows a relatively comparable modal split. The share of barge transport is about the same, road slightly higher, pipelines and rail slightly lower. In general, one can see that both ports transport the goods to and from the hinterland by means of different modes and try to stimulate the modal shift to more environmentally friendly modes.

5 Synergy

The challenging situation that Europe's port related industries face, together with the need for their transformation into a - at the same time – globally competitive and sustainable industry requires searching for synergies as to enhance both efficiency and innovation. The ports of Antwerp-Bruges and Rotterdam can (potentially) create such synergy: in their combined scale co positive cluster effects. Such synergetic effects arise by the different values that the ports create. In next sections we go deeper into these synergies and how they increase the values that are generated by the two individual port clusrters.

5.1 Synergy through the combined scale

In terms of scale the two ports of Rotterdam and Antwerp-Bruges combined provide for a quite unique port region in Europe. They are the number one and two port clusters in size within Europe with direct deep-sea facilities; they are located only a hundred km from each other; they have extensive direct transport and pipeline connections between them; and they have an overlapping hinterland network. There are not only strong ties between the two ports but also overlapping relations with strategic hubs in the hinterland. And, most importantly, they form an integrated industrial cluster that - combined with the connected Rhine Ruhr area – is a key global player. Taken together they outweigh all other ports and port regions in Europe.

5.2 Synergy trough positive cluster effects

The proximity of the port of Antwerp-Bruges and the port of Rotterdam fosters cluster synergies. This goes in several significant ways: through internal competition, agglomeration effects, specialization and complementarity and collaboration. The cluster effects are further strengthened by including the hinterland in the cluster perspective. In the following sections we elaborate on these cluster effects.

5.2.1 Internal competition

First, the *competition* in specific cargo related business segments, such as containers and breakbulk, drives market discipline, which in turn promotes innovation, competitive pricing, and operational efficiency. These competitive dynamics drive both ports to strategically manage resources and invest in infrastructure and services, ensuring their global competitiveness or further improving them. Also, within the industrial cluster competition benefits emerge. In the Antwerp-Rotterdam-Rhine-Ruhr industrial cluster several important global players such as TotalEnergies, ExxonMobil, Shell, BP, Vitol, BASF and Bayer have operations servicing same supply chains. This means that intra-firm cooperation is strong, resulting in efficiency and drivers for innovation.

5.2.2 Agglomeration advantages

The available cluster forces and *agglomeration advantages* are a very powerful characteristic of the industrial clusters of the ports of Antwerp-Bruges and Rotterdam. These advantages occur in areas such as industrial integration, logistical infrastructures, supply networks, available innovation and knowledge infrastructure, a high-quality labour market, proximity to the North Sea (offshore wind) and quality of regulations and governance. Both ports together could raise these advantages further, because the size of the cluster formation is an important condition for the level of agglomeration advantages. Strengthening existing cluster and agglomeration advantages therefore is a very promising option for the future of both ports (Kuipers & Van Son, 2024) and a guarantee for supplying the European hinterland of both ports. In view of this, the Trilateral Chemical Region, an initiative of (regional) governments in Germany, The Netherlands and Flanders have developed a joint vision. It fits entirely with strengthening cluster forces within the larger European industrial

clusters (such as ARRRA), a precondition for being able to realize the important actions formulated in the Draghi Report and the Antwerp Declaration.

5.2.3 Specialization and complementarity (integrated diverse local production systems)

With respect to the chemical and industrial business and flows, both port clusters are very complementary to each other. Within the trilateral region, the basic chemicals industry is the largest, and relatively more important for the Port of Rotterdam. The basic chemicals industry within ARRRA profits in particular from its highly integrated production structure (also called the "Verbund" structure) with clients and suppliers very close and with a tight physical infrastructure network. For specialty chemicals and pharmaceuticals, the Port of Antwerp-Bruges is a more important angle in the ARRRA triangle, and for plastics the Ruhr area is leading. Every partner in the trilateral region has its role to play and can only form together this strong European cluster.

Also for CE, complementarity is an important feature of both port clusters. One of the most important conditions for enabling a circular economy is available space for circular operations. Specialization in the different industrial clusters is very important for realizing this opportunity. This means the right circular operation at the right location and within the right industrial infrastructure where the re-use of existing installations for circular processes is possible. In having a number of large, very well-connected industrial sites within the ports and the larger hinterland, such specialization can benefit the cluster as a whole. The ports of Antwerp-Bruges and Rotterdam both focus on CE for de-fossilising their industry and thus supporting the necessary transition of their industry through facilitating the replacement of fossil inputs and attracting (recycled) secondary materials from all over Europe and beyond.

5.2.4 Collaboration

Collaboration brings advantage: 1) where less pressure from competitive forces is at play, because there is complementarity; 2) where markets are not yet mature and they can both enhance each other's growth; 3) where external forces are that high, that a going alone strategy will not work out positively.

The collaboration that the ports of Rotterdam and Antwerp-Bruges engage in and plan to develop further for the development of their industrial cluster and especially its transitions towards zero-emission and circularity fits these criteria. First, the actual industrial cluster specialization already reduces the level of competition, allowing for further collaboration. Second, the challenge of the energy and resources transition in the context of a challenging geopolitical environment are external forces that require joint forces. And third, the new markets that need to be developed related to the energy transition and circularity are far from mature. This all makes collaboration a logical, and even necessary action. And this is clearly taken up by the two port managing bodies of Rotterdam and Antwerp-Bruges. Where in the past a joint investment was made in a connecting pipeline system, but later collaboration was not always that evident, we now see increasing collaboration between the two ports in their acting and joint efforts, especially for the energy transition.

5.3 Synergy for managing externalities

Both ports are working on reducing the negative externalities and impact on the living environment that they generate with their activities. This includes, but is not limited to, actions about emissions, air quality, water quality, biodiversity. In the reduction of the negative impact on the living environment, there is potential synergy to be realised. Systems such as CCU/S (Carbon Capture Utilization and Storage) could be combined and jointly invested in. At the moment, Port of Rotterdam, with Porthos and Port of Antwerp-Bruges, with Antwerp@C, have developed their own CCS system. Both ports can also learn from each other and exchange best practices when it comes to reducing the impact on the living environment.

6 Highlights/take-aways

The way in which European policymakers look at the value that the ports of Rotterdam and Antwerp-Bruges generate, needs careful consideration. On one hand their industries' competitive position is under pressure and so is their licence to operate, as they are still heavily fossil fuel based. But at the same time, they are surely part of the solution, providing valuable assets, space, connections and competencies needed for Europe's industries' competitive position, its energy and resource transition and its strategic autonomy.

The ports of Antwerp-Bruges and Rotterdam generate values that are both economic, societal and strategic. With their strong connectivity and integrated industrial clusters, they clearly facilitate a value creation in the wider European region. The ports together form a logistical and industrial complex with a for Europe unique combination of scale, deep-sea location, space, large overlapping hinterland network, existing integrated industrial cluster with a global scale, large inflow of green electricity and import of green energy carriers, that forms a basis for the energy transition and for circularity, that is so hard needed for Europe's competitive and sustainable future.

The trade-offs that are made for investments in ports – both at national and European level – are important for Europe's ambitions and must take an integrated perspective, taking all relevant values that the ports bring into account. This is not an easy job because the values that ports generate - and that gain in importance - are the more societal and the more strategic ones and lie beyond the borders of the individual port regions. That makes it hard to measure and quantify. Still, they cannot be neglected.

And while now, the ports' industries add to the climate crisis, impacting their licence to operate, and while its competitive position is under pressure, the future path is clearly stated, amongst others in the report of Draghi: accelerate decarbonization, focus on circularity and create a level the playing field with international competition - especially those that are based upon different market models (like China): by investing in infrastructure and in innovation, and by streamlining the regulatory framework. The values that the ports and its industrial clusters can bring for Europe - also for its future - have been made clear in this short study.

This short study also shows that there are benefits to be gained by applying an integrative perspective on the ports of Antwerp-Bruges and Rotterdam in particular. The synergy realized by their combined scale, overlapping networks, interconnections, complementarity and specialization makes that 'their whole is greater than the sum of their parts'. Strengthening their increasing collaboration could raise these advantages further.

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