Sustainable Logistics for Europe
The Role of Ports
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Executive summary

Sustainability and the role of ports
Sustainability is becoming an increasingly important objective for the entire production chain, including transport, a sector in which there are still substantial gains to be realised in reducing environmental impacts. In this 2016 study, Panteia were commissioned by the Port of Rotterdam Authority and Deltalings (Rotterdam Port and Industry association) to carry out an independent investigation into the role that can be played by seaports in stimulating higher levels of environmental efficiency. The study involved an interview programme with key players in the market, and a modelling exercise to analyse the environmental impacts of container transport between the Far East and Europe.

Commercial Factors are still decisive in transport
Transport is traditionally a sector in which commercial factors are decisive, but consumers increasingly value sustainability, and increasing pressure is being placed on consumer goods manufacturers to produce in a more sustainable way. From the interviews it emerged that measures to reduce CO₂ emissions are considered the most important. However, transport services are still chosen largely on the basis of costs and service quality. Therefore the most successful initiatives are likely to be those fostering lower costs and, simultaneously, lower emissions. Key drivers for achieving lower rates of emissions through fuel efficiency include:

- Mode substitution
- Scale of transport
- Reduction of empty running and overcapacity
- Fleet modernisation

Maritime transport is a green mode of transport, but more can be done
Numerous studies agree that rates of greenhouse gas emissions per tonne-kilometre are substantially lower for maritime transport than for land transport. Our models show that CO₂ emissions in 2016 for a large container vessel on the Europe-Far East trade lane are around ten times lower per tonne-km than road transport. In recent years this gap has increased due to the use of larger ships with more modern engines. However, the rate of increase in CO₂ efficiency is slowing down, and gains are being eroded by overcapacity in the maritime sector. So, while maritime transport remains the greenest transport mode, more can be done to reduce the high absolute levels of emissions arising from intercontinental transport.

Levels of emissions on Europe-Far East services vary significantly
By analysing ship deployment across a range of Far East - Europe container services it is possible to see that levels of emissions (kg of CO₂ per TEU per day) differ greatly depending upon the size and age of the vessel. The figure below shows how the use of larger vessels with more modern engines reduces average rates of CO₂ emission.
The most efficient vessels may achieve levels of CO$_2$ emission close to 30 kg per TEU per day given high load factors, whereas at the other end of the scale, levels of over 120 kg per TEU per day are found. For a 30 day voyage, these differences result in substantially differing levels of environmental impact per unit shipped. It is noticeable that the majority of European gateway ports can now receive vessels capable of achieving levels of emissions close to the best standards available. Severe commercial pressures to reduce fuel costs through economies of scale have stimulated rapid progress in this area. For a number of large seaports in Europe the level of CO$_2$ emission for ships calling is shown in the figure below.
These figures depend upon the shipping lines achieving high load factors, so smaller vessels, with higher rates of CO₂ emissions per TEU per day, may still be optimal for specific trades.

**Sustainability needs to be tackled by analysing whole transport chains.**

Maritime and inland transport are often regarded as completely separate distribution systems, but to be able to manage environmental impacts effectively it is necessary to analyse whole transport chains. Port choices made by shipping lines dictate the entry and exit points into the hinterland networks. Often these choices are linked to agreements and relationships between shipping lines and container terminals, and they are not necessarily optimised to minimise overall transport distances. The model analysis shows that a typical TEU imported from the Far East to Central Europe on a modern, large containership will generate 800-1 000 kg of CO₂ emissions on the maritime leg, around 25 kg in the port itself, and up to 700 kg in the hinterland, depending on the inland distance and the choice of inland mode. Some margin of savings are possible at the European end of the maritime leg, but the hinterland portion can be reduced substantially by landing the container close to point of final consumption at a port with short-sea, rail and/or inland waterway connections. Port choice is therefore the crucial factor in optimising transport chains.

**Ports are the link between maritime and inland transport legs**

Emissions of greenhouse gases arising from port activity are minimal in comparison with those arising from transport operations (around 1-3% for Europe- Fareast container transport). However, interviewees identified a key role for ports as facilitators and stimulators for initiatives which have broader environmental impacts. Such initiatives include providing multimodal connections, application of ICT, platooning, and developing pilot projects for sustainable fuels. By playing a pro-active role, ports can bring cargo owners, transport companies, and other service providers together to develop innovative solutions.

**Optimised Transport Chains – Far East – Europe**

A model was constructed to analyse the routing of containers on the Far East Europe trade lane from the perspective of internal and external costs, including CO₂, SO₂, NOₓ, and particulate matter (PM). This trade lane was selected because it accounts for 54% of total laden containers imported to or exported from Europe. The aim was to use the model to select routes which minimise internal and external costs for all European NUTS3 regions. Thus, it selects a maritime service, a main port, a feeder port (if required) and a sequence of inland modes in optimal combination. The analysis was based upon current ship deployment and current inland freight services (short-sea, road, rail, and inland waterway) available at specific European seaports.

**Hinterland versus maritime costs**

A typical container from China to central Europe travels around 15 000 to 18 000 km by sea and up to 900 km by land, a ratio of approximately 20 to 1. However, because of the efficiency of modern container vessels, the ratio of maritime to inland external costs is approximately 70 to 30%. Examples of these ratios for a selection of routeings involving different port choices, across a range of different emissions is shown below.

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1 For more detailed information on the geographical NUTS-2013 regions, see: http://ec.europa.eu/eurostat/web/nuts/overview. This nomenclature of territorial units comprises 1342 regions on a European level.
Port choice determines:

- The maximum size of intercontinental vessel that can be used for the Asia to Europe leg, and therefore the rate of emissions at sea.
- The distance to the hinterland, and the range and attractiveness of inland modes which can be used for the hinterland leg.

The model calculates the most efficient route, using (1) internal costs only, and (2) a combination of internal and external costs. The shaded areas in the maps below show the effect of internalising external costs in terms of hinterland that is lost and won by the various port clusters.

Hinterland lost by port clusters as a result of internalisation of external costs
Hinterland won by port clusters as a result of internalisation of external costs

The maps show that internalising external costs across the whole chain makes relatively little difference to port choice. In general the optimal route choice is the one which lands the containers close to their final point of consumption, for all European regions. This is explained by the fact that the high volumes, the deployment of large vessels and the presence of sulphur emission control areas help to compensate the routes involving more distant ports (e.g. North Sea and Baltic) for the extra few days sailing around the coastline. Therefore the hinterland costs which are significantly higher per unit per kilometre than maritime costs are still the decisive factor, for determining the optimum port choice for each region.

**CO₂ and SO₂ emissions**
The maps below indicate the sum of maritime and hinterland emissions (CO₂ and SO₂) for a container imported from China to every EU NUTS3 region, based on optimised routeings.
CO₂ emission of the entire transport chain, mapped onto destination-regions

SO₂ emission of the entire transport chain, mapped onto destination-regions

Lowest emissions are generally found in regions close to the ports where the most fuel efficient vessels are calling. Greece, southern Italy, southern Spain, southeast England and the northern coastline of continental Europe are good examples. Where there are dense networks of inland waterway and rail services attached to the gateway ports e.g. Belgium, Netherlands and Germany, the emission levels for inland
regions may also be below average. Highest emission levels are found for shipments to land-locked regions or otherwise less accessible regions such as Hungary, the Baltic States, northern Spain and Scotland. An optimal routeing to Hungary would involve the use of an Adriatic service and inland transport by road. The challenges faced differ by geographical region. In southeast Europe, large gains can be realised within the maritime leg of the chain, and by developing intermodal inland transport to a greater extent. Regions like Scotland, northern Spain, Ireland and the Baltic States which are more distant from the main intercontinental hubs can benefit by the use of greener short-sea services to avoid long overland hauls. Regions such as Benelux, northern France and northern Germany, which already enjoy access to efficient maritime services and multimodal inland connections, can benefit most from elimination of empty running, greater operational efficiency through digitalisation, and measures to introduce cleaner fuels.

Conclusions
Interviewees indicated that they face renewed pressure to improve the sustainability of their operations. Profitability demands sustainability. It is apparent that by 2016, many quick-wins have been deployed, so in future it will be necessary for industry to tackle more complex areas, including logistics, where cargo-owners have less direct control and where end-consumers and policy-makers have less market or regulatory leverage. Complexity arises due to the need to optimise the performance of long-distance multimodal chains, and because open, global markets, such as inter-continental shipping, operate according to commercial logic. Ports have a key role to play as facilitators through the provision of infrastructure to enable the operation of efficient deep-sea, short-sea and hinterland transport services. Now, this role also extends to the deployment of ICT, alternative fuels such as LNG and biofuels, and other forms of technical innovation.
1 Background

The Port of Rotterdam Authority and Deltalinx (Rotterdam Port and Industry association) have commissioned policy research company Panteia to carry out an independent investigation of the role of ports in sustainable logistics for freight transport via seaports.

In our approach, we first describe the transport chain, market developments and relevant environmental legislation. Next, the results are presented of a consultation of cargo owners and operators that were asked about their views on how sustainability can be improved and the possible role European seaports can play. A model was then used to determine if more sustainable transport will induce changes in the pattern of the supply chains. In particular freight flows may shift from one seaport to another and/or use different hinterland transport modalities. Finally, we conclude how the seaports' efforts could best be focused.

1.1 Introduction

Within the European Union (EU), including domestic transport, maritime transport accounts for around 20% of transported goods\(^2\). Five main markets can be distinguished: the container market, the ro-ro market, the market for conventional general cargo, the liquid bulk market, and the dry bulk market.

The EU is highly dependent on seaports for trade with the rest of the world and within its internal market. The EU coastline extends to 66,000 km\(^3\), bordering the Atlantic Ocean, Mediterranean Sea, Black Sea and Baltic Sea. Measured in tonnes, 74% of goods are imported from and exported to the rest of the world and 37% of the intra-EU trade transit is through seaports\(^4\). Ports guarantee territorial continuity of the EU by servicing regional and local maritime traffic to link peripheral and island areas. They are the nodes that facilitate multimodal logistic flows of the trans-European network, using short-sea shipping, rail, roads and inland waterways links.

An important sector is the Asia-Europe container market, which has grown to become the dominant European trade relation as a result of a specific form of globalisation, in which a high proportion of new manufacturing investment has shifted to China since the early nineties. All Asia - Europe-related freight traffic is directed via the Suez Canal\(^5\).

The challenge here is to let the freight transport take place with minimal impact on the environment and beneficial to a sustainable economic growth.

Paris climate conference

Currently, there is a growing worldwide concern for the environment and a crucial event was the Paris Climate Conference in December 2015, where 195 countries adopted the first-ever universal, legally binding global climate deal. The agreement sets out a global action plan to put the world on track to avoid dangerous climate

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\(^2\) Modal share of freight transport to and from EU ports. European parliament, 2015.
\(^3\) The World Factbook. CIA, 2016.
\(^4\) Modal share of freight transport to and from EU ports. European parliament, 2015.
\(^5\) For the outbound services, all but one service take the route to Asia via the Suez Canal. The FAL 8 Europe of CMA CGM however is directed via Cape Good Hope, taking a detour of about 2,000 nautical miles. In order to re-attract vessels flows being redirected (mainly on the Asia - America services), the Suez Canal authority has lowered the canal dues by 30%.
change by limiting global warming to well below 2°C. World leaders acknowledged the urgency for decarbonising our energy supplies and to undertake a radical transformation of the global economy in order to reduce the emission of greenhouse gases (GHG) - the main cause of global warming. The agreement is due to enter into force in 2020.

Figure 1.1: EU28 greenhouse gas emissions by sector and mode of transport, 2012

Transportation is a major contributor to the Europe’s greenhouse gas emissions (see Figure 1.1). More sustainable logistic transport chains could be a part of the solution. However, although shipping and aviation were referred to in the world’s previous climate change deal, the Kyoto Protocol, the Paris agreement does not include these sectors. This means that the international bodies responsible for the sectors — the International Maritime Organisation (IMO) and the International Civil Aviation Organisation (ICAO) — are not obliged to develop emissions policies to meet the Paris targets.

Initiatives of market parties in the logistic transport chain

However, there are many market parties in the logistic transport chain that actively try to move to a higher level of sustainability. Within the context of this study, interviews have been performed with cargo owners and transport operators that put a high value on sustainability. This is also demonstrates by initiatives such as for instance the Clean Cargo Working Group (CCWG), Lean & Green and BICEPS. The Clean Cargo Working Group (CCWG) is a global, business-to-business initiative dedicated to improving the environmental performance of marine container transport. Lean and Green is a stimulation programme for every company or governmental body

6 See: http://www.bsr.org/en/collaboration/groups/clean-cargo-working-group
7 See: http://lean-green.nl/
8 BICEPS: Boosting Initiatives for Collaborative Emission-reduction with the Power of Shippers. See: http://www.purebirds.nl/..../biceps-network
with the intention to move to a higher level of sustainability, by optimizing their mobility processes. BICEPS is a network in which five major companies have joined forces to develop a common and concurrent approach to sustainability in their procurement of ocean freight and selection of carriers.

**World Ports Climate Initiative**

Due to their central role in the logistics chain, seaports are key to reducing the environmental footprint of freight transport in the port itself, but are also important on the maritime and hinterland leg of the logistics chain. The world’s key ports have committed themselves to reducing greenhouse gas (GHG) emissions through the World Ports Climate Initiative\(^9\) (WPCI). They do this through influencing the sustainability of supply chains, taking into account local circumstances and varying port management structures.

### 1.2 Sustainability: current legal context

Achieving energy efficiency and controlling and minimising greenhouse gas emissions are examples of IMO efforts to make international shipping sustainable. Another example is the Sulphur Emission Control Areas (SECAs) or Emission Control Areas (ECAs). These are sea areas in which stricter controls were established to minimise airborne emissions from ships that entered into effect in May 2005. It contains provisions for two sets of emission and fuel quality requirements: a global requirement and more stringent controls in special Emission Control Areas (ECA). By 2010 a revised stricter annex was enforced with significantly tightened emissions limits. As of 2011 there are four existing ECAs: the Baltic Sea, the North Sea, the North American ECA, including most of US and Canadian coast and the US Caribbean ECA. The stricter standards have not only helped to bring down sulphur emissions at sea but they also have sharply decreased in the port area of EU ports.

Further, IMO has introduced regulations on energy efficiency for ships to make the Energy Efficiency Design Index (EEDI), for new ships, and the Ship Energy Efficiency Management Plan (SEEMP) for all ships of 400 gross tonnage mandatory. The EEDI is a non-prescriptive, performance-based mechanism that leaves the choice of technologies to be used in a specific ship design to the industry, as long as the required energy-efficiency level is attained. The SEEMP establishes a mechanism for operators to improve the energy efficiency of ships.

The European Commission also aims to move transport further towards sustainability. The 2011 White Paper on Transport takes on the challenge of seeking a deep transformation of the transport system, promoting independence from oil, the creation of modern infrastructure and multimodal mobility assisted by smart management and information systems. It is put forward together with the provision of a roadmap towards a low-carbon economy by 2050. Directives that are relevant in this context, concern:

- Promotion of the use of energy from renewable sources\(^10\)
- Emissions from heavy duty vehicles\(^11\)
- The Non-Road Mobile Machinery Directive\(^12\)
- Deployment of alternative fuels recharging and refuelling infrastructure\(^13\)
- Port Reception Facilities\(^14\)

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\(^9\) For the 55 members of the WPCI, see: [http://wpci.iaphworldports.org/about-us/members.html](http://wpci.iaphworldports.org/about-us/members.html)

\(^10\) Directive 2009/28/EC

\(^11\) Regulation (EC) No 595/2009

\(^12\) Directive 97/68/EC

\(^13\) Directive 2014/94/EU

\(^14\) Directive 2014/94/EU
Also relevant is the EC announcement in the Energy Union strategy to come up with a revision of the Eurovignette directive on internalisation of external costs and with a communication on decarbonisation of transport\textsuperscript{15}.

The Directive on the deployment of alternative fuels recharging and refuelling infrastructure aims to facilitate the development of a single market for alternative fuels for transport in Europe. It requires Member States to develop national policy frameworks for the market development of alternative fuels such as Liquid Natural Gas (LNG) and their infrastructure. Common technical specifications for recharging and refuelling stations are foreseen. For developments that are relevant for the freight transport chain, the required coverage and the timing by which this coverage must be put in place is shown in Table 1.1:

Table 1.1: Coverage and the timing alternative fuels recharging and refuelling infrastructure

<table>
<thead>
<tr>
<th>Measures regarding alternative fuels</th>
<th>Coverage</th>
<th>Timing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity at shore-side</td>
<td>Ports of the TEN-T core network and other ports</td>
<td>2025</td>
</tr>
<tr>
<td>LNG at maritime ports</td>
<td>Ports of the TEN-T core network</td>
<td>2025</td>
</tr>
<tr>
<td>LNG at inland ports</td>
<td>Ports of the TEN-T core network</td>
<td>2030</td>
</tr>
<tr>
<td>LNG for heavy-duty vehicles</td>
<td>Appropriate number of points along the TEN-T core network</td>
<td>2025</td>
</tr>
</tbody>
</table>

Source: Directive 2014/94/EU

Further, the Regulation for the Trans-European Network for Transport\textsuperscript{16} (TEN-T) states that all the Member States of the European Union must contribute to the development of Trans-European Networks. The regulation divides the Trans-European network into two ‘layers’, a comprehensive network and a core network. Maritime ports on the core network must be connected with railways and roads and, where possible, the inland waterway transport infrastructure of the Trans-European transport network. According to the Regulation, this should be realised in 2030.

Last, the Regulation on the monitoring, reporting and verification of carbon dioxide emissions from maritime transport\textsuperscript{17} (MRV) creates a legal framework for the monitoring, reporting and verification of CO\textsubscript{2} emissions from maritime transport. It also helps the EU generate momentum for the best possible outcome in the international discussions. The Regulation requires large ships (over 5 000 gross tonnes) calling at EU ports starting from January 2018, to monitor and report CO\textsubscript{2} emitted on journeys to, from and between EU ports and also when in a EU port, as well as parameters, such as distance, time at sea and cargo carried, to determine the ships' average energy efficiency.

The MRV system is estimated to cut CO\textsubscript{2} emissions from the journeys covered by up to 2% compared with a ‘business as usual’ situation, according to the Commission’s impact assessment. In addition, the system would also reduce net costs to owners by up to €1.2 billion per year by 2030\textsuperscript{18}.

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\textsuperscript{14} Directive 2000/59/EC
\textsuperscript{15} See: http://eur-lex.europa.eu/updated roadmap for the energy union
\textsuperscript{16} Regulation (EU) 1315/2013
\textsuperscript{17} Regulation (EU) 2015/757
\textsuperscript{18} Impact Assessment MRV Regulation: http://ec.europa.eu/swd_2013_0237_en.pdf
1.3 Contents of this report

The contents of this report are as follows:

- Chapter 2 describes the scope of this study.
- Chapter 3 describes the macro-economic developments, as well as the global trade relations. In addition, the prices of oil products will be highlighted, as they have a strong influence on the transport market.
- Chapter 4 describes the transport and logistic chain itself. For the purpose of the analysis, we have split this chain into three parts: maritime transport, activities in the ports and hinterland transport. For hinterland transport, the following modalities have been taken into account: roads, rail, waterways and short sea shipping/feeders.
- Chapter 5 contains the results of an interview programme of cargo owners and operators. Various important drivers to combat climate change and air pollution have been identified, based on the opinion of the interviewees. Subsequently, suggestions for the role of seaports are provided.
- Chapter 6 presents a modelling exercise to determine the environmental effects along the logistics supply chain for transport via various seaports in the European hinterland.
- Chapter 7 presents the conclusions and recommendations where the seaports’ efforts could best be focused.
2 Scope of this study

2.1 Geographical scope, cargo sector and time horizon

In this study we look at container transport and more particularly, at the Asian trade lanes as these represent the EU’s dominant trade relation.

The analysis is focused on the medium-term; until 2025.

2.2 Focus on climate change and air pollution

In general, the concept of sustainability can be expressed in three aspects: people, planet and profit:

- ‘People’ pertains to fair and beneficial business practices towards labour and the community and region in which a corporation conducts its business;
- ‘Planet’ refers to sustainable environmental and climate related practices;
- ‘Profit’ is the economic value created by the organisation after deducting the cost of all inputs, including the cost of the capital tied up.

In this report, we will concentrate on the environmental (including GHGs) aspect of sustainability. In freight transport via seaports, there are many ways in which environmental sustainability can be affected:

- Climate change due to Greenhouse gases, such as carbon dioxide, help to trap heat in the Earth’s atmosphere as a part of the greenhouse effect. The main effect of atmospheric greenhouse gas concentrations is global warming. In turn, this may result in sea level rise and extreme weather.
- Air pollution due to emission of pollutants, such as sulphur dioxide (SO₂), nitrogen oxides (NOₓ) and particle matter (PM) makes asthma worse and exacerbates heart disease and respiratory illness. Therefore, addressing the emission levels is aimed at significantly reducing premature deaths caused by air pollution, whilst simultaneously resolving environmental impacts, such as acidification and associated losses in biodiversity.
- Water pollution on the maritime part of the logistic chain, on the hinterland part — when using inland waterways — and in the seaport itself. Water pollution may consist of solid wastes, sewage, sludge and oil spills.
- Species introduction by the discharge of ballast water that disrupt the marine ecosystem.
- Noise caused by ships at sea, activities in the ports and by hinterland transport.

This investigation focuses on greenhouse gases impacting climate change and air pollution.

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19 Environmental impacts of international shipping. OECD, 2011.
20 Greening of port operations. Swiftly Green, 2015.
3 External factors that influence the transport market

This chapter examines external factors that determine market trends in the international transport of containers between the Far East and Europe through seaports. The macro-economic environment and global trade relations are discussed first, followed by a concise analysis of fuel prices.

3.1 Macro-economic environment

Freight flows in the world depend strongly on international trade, which in turn depends on global economic activity. In 2015, global economic activity remained subdued. Growth in emerging markets and developing economies — while still accounting for over 70 percent of global growth — declined for the fifth consecutive year, while a modest recovery continued in advanced economies\(^2\).

The volume of world merchandise trade has grown at a slow, steady pace in recent years, but this consistency belies changes in the contributions of WTO geographic regions to trade volume growth over time (see Figure 3.1).

Figure 3.1: Contribution to world trade volume growth by region, 2011-2015, annual % change

![Graph showing contribution to world trade volume growth by region](image)

Source: WTO secretariat, 2016

Asia contributed more than any other region to the recovery of world trade after the financial crisis of 2008-2009. However, the region’s impact on world import volume growth declined last year as the Chinese and other Asian economies cooled. Asia contributed 1.6 percentage points to the 2.3% rise in the volume of world merchandise imports in 2013, or 73% of world import growth, but in 2015 the region contributed just 0.6 percentage points to the global increase of 2.6%, or 23% of world import growth.

In contrast, Europe has mostly weighed down world trade since the financial crisis, by actually reducing global import demand growth in 2012 (-0.7%) and 2013 (-0.1%). However, in 2015 Europe once again was making a large positive contribution,

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\(^2\) Trade statistics and outlook. WTO, 2016.
accounting for 1.5 percentage points of the 2.6% increase in world import volume, or 59% of the global trade growth. The gradual recovery of intra-EU trade in 2014 and 2015 was responsible for much of the rebound in Europe, as the drag exerted by the European sovereign debt crisis faded.

### 3.2 Global trade relations

Figure 3.2 shows the size of import and export flows of containers to and from Europe in relation to other trade areas in the world. Generally, it can be noted that the flows vary in size considerably. The following can be concluded that:

- The most important European trade relations are with the Far East. Annually, more than 15 million laden TEU are imported from the Far East (Japan, China, South Korea and Singapore). With 7 million TEU on a yearly basis, the export flows have a considerably smaller size.
- Second to the Far East is the trade relation with North America (Transatlantic market). The European export to North America is nearly 3 million TEU on a yearly basis. The export is nearly 4 million TEU.
- The trade relations with the Middle East are also considerable. The import flows are somewhat greater than 2 million TEU, while the export is close to 3 million TEU.
- The trade relations with Africa, Latin America and Australia (including New Zealand) are relatively limited. The export to Africa and Australia are larger than the imports. For Latin America the export and import are more in balance.
- In summary, Europe imported 22.8 million TEU on a yearly basis, against an export of 17.8 million TEU.

**Figure 3.2: Size of import and export flows (laden TEU) between Europe and other parts of the world.**

- **Far East:** Import > Export
- **Trans Atlantic:** Import > Export
- **Middle East:** Import > Export
- **Africa:** Import > Export
- **Latin America:** Import > Export
- **Australia:** Import < Export

*Source: Dynaliners Weekly 46/2014.*
3.3 Price of fuels

Oil prices have declined markedly since September 2015, reflecting expectations of sustained increases in production by the Organisation of the Petroleum Exporting Countries (OPEC) members, amidst continued global oil production in excess of oil consumption. Future markets suggest only modest increases in prices in 2016 and 2017.

Marine gasoil/diesel and fuel oil

In the marine bunker fuel market there are two dominant fuels: marine gasoil/diesel and fuel oil. Fuel oil is the cheapest and in most cases the preferred fuel for shipping companies. As a result, fuel oil has a larger market share than gasoil/diesel. However, in certain Emission Control Areas (ECA’s), in the North-Sea, Baltic Sea and the North-American coastline legislation has been imposed that limits use of fuel oil. Gasoil is less polluting than fuel oil and therefore these ECA shipping companies can switch over to this cleaner fuel. Starting from January 2015, new ECA legislation has come into effect which limits sulphur content in marine fuels to 0.1% in the ECA-zones. Prior to this date, using LSHFO with a sulphur content less than 1.0% was sufficient. This means that unless a vessel has a scrubber, it must switch to gasoil when passing through the ECA zone. Because the North-Sea and Baltic Sea are ECAs, this new legislation will influence consumption volumes of marine fuels.

Other than that, consumption volumes of marine fuels are related to international trade. Consumption volumes of marine fuels have been in a downward trend due to advances in fuel efficiency and slow steaming policies. Slow steaming policies adopted by shipping companies are practices to reduce cruise speed which reduces fuel consumption per distance travelled. This however, is at the expense of the duration of the voyage. In essence, this is a trade-off between reducing variable fuel costs at the expense of fixed capital costs. After the collapse of the oil price fuel costs are less significant in this trade-off and one might expect a recalibration of the slow steaming policy. This would support consumption rates. How large this effect would be is hard to determine, but the assumption of a stable outlook for consumption volumes implicitly adopts the view that the downward trend caused by advances in fuel efficiency is countered by the positive effect of recalibration of slow steaming policies.

Figure 3.3 shows the forecasted consumption volumes for marine gasoil/diesel (MGO), for the marine fuel segment. The effect of the introduced ECA legislation is estimated by looking at how consumption volumes have changed in 2015 compared to the same periods in 2014. This difference is taken as the initial effect of the introduction of ECA legislation. However, because gasoil is considerably more expensive than fuel, oil shipping companies have an incentive to invest in scrubbers that enable vessels to clean exhaust fumes while burning fuel oil and at the same time adhering to ECA legislation. So after some time it is likely that market share gains of gasoil will be reduced and fuel oil market share losses will also be reduced.

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22 A scrubber is a pollution control device that is used to remove unwanted pollutants, in this case SO₂ from an exhaust gas stream.
Figure 3.3: forecasted consumption volumes for marine gasoil/diesel (MGO), marine fuel segment

LNG
Alternatively, ships may also run on Liquefied Natural Gas (LNG), which is environmentally friendly, safe, and widely available. The feasibility of an LNG propelled vessel compared to traditional heavy oil fuels and marine fuel oil depends on a business case where the price of MGO/HFO on the one hand, and the price of LNG on the other, is a crucial input parameter for the financial assessment. Figure 5 shows the LNG and ship fuel prices. It must be remarked, however, that many new vessels are equipped with a dual fuel engine that may use natural gas and bunker fuel. Also, in that case there is space reserved for an LNG tank.

Figure 3.4: Historical fuel prices on marine fuels and natural gas

Source: Panteia and PJK, 2016
Source: Clarkson, Worldbank
Biofuel

Biofuel is a liquid or gaseous fuel used for transport and is produced from biomass. The EU is strongly dependent on fossil fuels for its energy consumption. To reduce this dependence, biofuels have become an important substitute for fossil fuels particularly the road transport markets. In addition to this economical and geopolitical aspect, biofuels have an environmental aspect and that is to reduce global greenhouse gas emissions if the production of the refined biomass is subject to stringent sustainability criteria.

The biofuel industry has shown significant growth in production, consumption and trade during the last decade. In a short period of time the industry turned global with production and consumption markets all over the world. Ports are excellent locations for biofuel refineries and as such spurring the transition toward a bio based economy.

Still, the application of biofuels is more expensive than fossil fuels. With current prices, there is no incentive to apply biofuels. Legislation may help here. The Renewable Energy Directive\textsuperscript{23} requires that in all EU countries at least 10% of their fuels for inland road, rail and waterway transport come from renewable sources by 2020.

\textsuperscript{23} Directive 2009/28/EC about the Promotion of the use of energy from renewable sources.
4 The logistics chain

This chapter describes the elements of the logistics chain between Asian seaports and the European hinterland. The total chain is split into three parts:

- the maritime leg,
- the activities in the seaports and
- the hinterland leg.

Figure 4.1 gives an impression of the importance of these three parts as far as their share in the emissions of CO₂ is concerned.

figure 4.1: Indicative share of CO₂ emissions in the transport chain from Asia to Central Europe.

Source: Panteia (2016)

These will be discussed hereafter.

4.1 Maritime transport

Developments in the maritime part of the container transport chain can be characterised by:

- a gradual increase in the scale of the container ships, to a different extent in different parts of the world and
- a situation of overcapacity, with slow steaming as an initial answer to overcapacity and technological developments that save fuel and costs.

These characteristics are further treated below. Port characteristics and ranking in the rotation scheme of container liners need to be taken into account in order to determine the environmental performance of a ship.

Scale increase

Figure 4.2 shows the composition of the newly built container vessels from 2016 to 2020 in terms of size. It can be seen that the largest growth occurs in the range where the ships have the biggest size. In fact, this process will be ongoing for a number of years, which will lead to an overall growth of the average vessel size.
Figure 4.2: Overview of container vessel fleet from 2016 to 2020, newly built ships

Source: Alphaliner, fleet forecast as of 1st of January 2016.

Figure 4.3 shows that on the most important trade routes from the Far East to the rest of the world, the average size of ships has steadily increased. The slowest growth can be seen on the route to the East Coast of the United States. This is caused by the restrictions of the Panama canal. The fastest growth can be seen on the routes to the Mediterranean and to Northern Europe, of which the route to Northern Europe increased the fastest.

Figure 4.3: Average size of ships deployed on mail East-West routes: 2005-2015.

Source: Alphaliner
Figure 4.4 shows the number of calls per vessel size class for Mediterranean ports and Hamburg – Le Havre range ports in more detail. It can be seen that on average, the call size is smaller for the Mediterranean ports and the distribution is less peaked.

Figure 4.4: Number of calls per vessel size class for Mediterranean ports and Hamburg – Le Havre range ports.

Overcapacity and slow steaming
However, despite the growth in size of the vessels, international trade is growing slower than the deadweight tonnage capacity, in particular, since the pre-crisis year 2007. This resulted in oversupply of capacity and consequently, in lower utilisation of individual ships on average.

Fuel consumption and, consequently, bunker costs depend mainly on a ship’s speed, but, for instance, also on a ship’s design and hull condition, bunker fuel grade and weather conditions. However, bunker costs significantly depend also on bunker prices, which are an external factor and therefore out of the control of ship operators. Slow steaming is mainly applied in container shipping and indicates a reduction of the operating speed of long-distance liner ships. Slow steaming can help the economic performance of shipping carriers in two ways: it can artificially decrease the supply in maritime transportation, so shipping carriers can benefit from lower fuel consumption, as well as from higher freight rates, due to a better relation between supply and demand.

Fuel consumption is closely related to the emission of greenhouse gases and air pollutants. Although maritime transportation is a relatively clean and energy-efficient mode of transport, emissions from the growing maritime transport sector represent a significant and increasing source of air pollution (see Figure 4.5).
From the economic point of view of a shipping carrier, it is therefore, necessary to find an optimal speed in order to reduce costs. However, it may be that as the economy and markets pick up and excess capacity is brought back into service, speeds will once again increase to meet the growing demand.

There are other entities besides shipping carriers involved in the supply chain. For example, longer transit times can actually increase shippers’ costs because they need more inventory to feed this longer supply chain. Longer ocean transit times can also impact shippers’ cash flow, as the time from production to sale is extended. However, for many manufacturers, retailers, importers and exporters, supply chain reliability is more important than transit time or rates, and slow steaming gives better time flexibility than regular steaming, as there is still room for speed increase if the ship is delayed. The use of new ICT-based and internet technologies can provide a higher service level toward ship and cargo planning.

Figure 4.6 shows that over time, there is a decrease in CO₂ emissions per TEU per day of transport time. The declining lines show the relation with ship size. The shift between both lines indicates the effect of technological development and slow steaming.

The use of larger vessels with more modern engines has decreased and will decrease the CO₂ emissions emitted per container per day. For example, a 10 000 TEU vessel built in 2015 still emits almost twice as much CO₂ per TEU per day as a 20 000 TEU unit of the same building year. The difference in CO₂ emissions between bigger and smaller vessels is, however, diminishing.
Figure 4.6: Scatter plot of CO₂ emission per TEU per day for vessels according to size and year of built.

Figure 4.7 shows the relation between CO₂ emission per TEU per day and the vessel size class for all vessels calling at the seaports of Rotterdam, Genova and Koper. It can be seen that: for Rotterdam, the CO₂ emissions per TEU per day are lower because of the larger size of the ships travelling to that region.

Source: Panteia, 2016. Based upon ALPHALINER data.
Figure 4.8 shows a boxplot for all large seaports in Europa. Also indicated is the number of weekly loops of the Far East – Europe services.

Figure 4.8: Boxplot of kg CO₂ per TEU per day for all large seaports in Europa

Source: Panteia, 2016. Based upon ALPHALINER data.

Figure 4.8 indicates the range of CO₂ emissions per TEU per day for containers brought by deep-sea vessel. The figure does not necessarily reflect the sustainability of a port, but it provides an overview of the carbon-intensity of the vessels that call at these ports.

The figure illustrates the fact that a port that is able to attract low carbon intense vessels will decrease the CO₂ emission in the supply chain that is running through its port. This indicates the importance of incentives or other measures that seaports can offer to ship-owners, in order to decrease the carbon-intensity of vessels calling in these ports.

4.2 Activities in the ports

Figure 4.9 shows the size of EU-based ports and their growth. The base ports form the most important entrance and exit points to Europe from overseas.
In order to connect the maritime leg and the hinterland leg of the transport chain adequately, the capacity of the seaports on the waterside has to match the capacity on the landside. This concerns the port entrance channel, berthing places and terminal handling capacity on the waterside. On the landside, this also concerns terminal capacity, as well as access infrastructure. Not all seaports feature all modalities for hinterland transport. In fact, only a limited amount of seaports, possess a connection to the hinterland via inland waterways. Investments in transport infrastructure, in particular rail, create sustainable connections with the hinterland. In that respect, and partly within the context of the TEN-T corridor development, many European ports have benefitted greatly from investments in their hinterland infrastructure or will do so in the near future. Examples in this respect are the Port of Antwerp (railway line between Brussels and Luxemburg), and Hamburg and Bremen (electrification of the line Hof-Regensburg in order to relieve the main North-South rail axis). Connecting rail infrastructure for ports in the Liguria and Adriatic part of the Mediterranean Sea will also provide a better link to the hinterland.

Source: Eurostat

Footnotes:
24 Investeringen in TEN-T Corridors (Investments in TEN-T Corridors), Panteia 2015.
25 Part of the improved infrastructure are also the base tunnels under the Alps.
The following transport related activities in the seaports cause air pollution and release of GHGs:

- Ships manoeuvring and at berth,
- Unloading, loading and storage of containers at terminals,
- Loading and unloading of containers on hinterland transport units and
- Port related services other than loading and unloading.

**Ships at berth**

Although a ship at berth does not move, it uses energy to remain operational. Electricity that is needed for this can be generated by the ship’s own aggregates that are connected to the ship’s engines. The pollution that is caused by this, can be avoided by making use of shore power, that connects the ship to the grid or a mobile device. Local pollution can be avoided by this. Reefers consume additional energy needed for cooling. Onshore power supply (OPS) provides sustainability benefits as opposed to the use of on-board diesel aggregates. However, the operational costs may be higher, especially in the case of ships that need additional investments in order to be able to use shore-side electricity. See Figure 4.10 for a comparison based on a calculation tool by CE Delft (2015). It must be remarked that nowadays, for some new ships the on-board equipment for OPS is already built-in, so that for new ships this is not relevant anymore in comparison with on-board diesel aggregates.

Figure 4.10: Annual costs for a container ship (6 500 TEU, 500 reefers) of onshore power supply versus diesel (including external costs)

![Graph showing annual costs for a container ship](image)

Source: CE Delft, 2016

**Unloading ships, loading ships and storage of containers at terminals**

Port equipment that is needed for loading and unloading ships requires substantial energy to lift containers. For electric equipment however, as soon as the hoisting is slowed down or the container is lowered, the hoisting motor factually changes into a generator which then produces energy. This can then be used for the other engines on the crane or fed back into the electricity grid. This may decrease energy consumption at the terminals by more than a factor of two. Alternatively, container handling equipment may be sustainably powered by climate-neutral wind-generated electricity, which also eliminates the noise and harmful emissions associated with conventional diesel engine-powered operations. For horizontal transport over the terminal area, yard trucks or AGV’s may be powered by a hybrid or a fully electric drive system.

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26 Cost benefit calculation tool onshore power supply. Methodological note. CE Delft, 2016
27 According to the vessel register of Der Norse Veritas, it comprises the 13 latest new-built vessels from UASC. This number may however be higher, as shipping lines are not obliged to register at DNV GL but can also use other vessel registers.
Loading and unloading of hinterland transport units

Efficient loading and unloading of hinterland transport units provide benefits in terms of operations, but there are also environmental benefits, as it may incur energy savings as well. Here, adequate information systems may help in minimising waiting time and in particular, for rail transport and inland navigation, the number of stops in the port.

Time and energy may also be saved by avoiding congestion at the terminals in the seaports by moving containers out of the port as soon as possible when they are unloaded from maritime vessels. They can be transported to an ‘extended terminal gate’ in selected hinterland locations. This allows for the movement of containers into those locations without prior involvement of the shipping company or the shipper/receiver. Extended gates extend the delivery point from the perspective of the shipper/receiver from seaport terminal along a corridor to an inland multimodal terminal. Transportation to and from the extended gate can mostly be done by intermodal transportation. Essentially, the gate of the sea terminal is now placed at the inland terminal.

Port related services other than loading and unloading

Port authorities manage, operate, inspect, maintain and develop ports. They are responsible for a safe and smooth handling of all shipping. Other services provided by port authorities or private port operators may comprise waste management, pilotage, towage and mooring services. In order to perform these tasks sustainable procurement of equipment, vessels, (lease)cars, alternative fuels and energy consumed can limit the production of greenhouse gases and air pollutants.

4.3 Hinterland transport

The assumed definition of a port’s ‘hinterland’ is the area inland from the port to which imports are distributed and from which exports are collected. Hinterland transport may take place via:
- Short-sea shipping
- Road transport
- Rail transport
- Inland waterways transport
- Pipelines
- Or a combination thereof.

As this study focuses on containers, we will leave out pipelines as a hinterland transport modality. In the following sections, the other transport modes will be briefly discussed.

4.3.1 Short-sea shipping

Deep sea shipping (DSS) refers to the maritime transport of goods on intercontinental routes, crossing oceans. By contrast, short-sea shipping (SSS) involves relatively short distances, for instance, within the EU. Intercontinental sea trade of containers is the most concentrated sector characterised by transhipment according to a hub and spoke pattern. SSS can be seen as a way of transport to the hinterland for ports with a hub function where cargo is allocated to other ports via feederings. In this case, ports have an indirect connection with the European hinterland. Examples are Marsaxlokk, Gioa Tauro, etc. Figure 15 presents the respective share of DSS and SSS for the most important ports for containers.
4.3.2 Inland transport
The inland connections of ports vary greatly, depending on the characteristics of the port in question and in particular on the port activities (type and quantity of goods handled).

- Overall, roads are the most frequently used mode of transport for moving goods from port to inland destinations. However, as better highlighted in the following sections, other modes are also shown to frequently be used.
- The extent to which different countries in the EU use rail to transport freight is very mixed. The reasons for this are, amongst other things:
  - geographical: island countries generally use rail to a lesser extent; landlocked countries in the centre of Europe, which are used as transit countries to the major ports, use rail to a greater extent;
  - economical/political: countries whose development has included heavy industries generally use rail to a greater extent;
  - environmental: countries with a long-term policy on the environment generally use rail to a greater extent. For sustainability reasons, a modal switch to rail is viewed as beneficial; in EU Member States, particularly in Austria and Belgium, rail has increased its modal share thanks to stronger incentivising policies.

Source: Eurostat
With respect to rail and taking the dimension of total port throughput into consideration, the best rail performance is found in Hamburg. The developments with regards to rail transport infrastructure and TEN-T requirements are important, in particular electrification, sidings and platforms that enable 750 meter long trains and ERTMS.

Inland waterways are largely used for the transport of containers by the ports of Rotterdam and Antwerp and to a much lesser extent in other ports of the Hamburg-Le Havre range. All are located on the estuary of navigable rivers. Also, the port of Marseille/Fos offers IWT connections via the Rhône – Saône river basin. So is the port of Constanta. However, the Danube variabilities in water level prevents the operation of reliable liner services. For bulk cargo, the modal split of inland navigation is 22% though and major investments in the navigability of the Danube river as well as investment in port infrastructure might start up container barging again.

The tendency for scale enlargement in inland navigation has come to a halt. Slow steaming is only an option in the case of careful planning of lock and bridge passages. Inland navigation is also often used for repositioning of empty containers and feeder transport within ports between deep sea terminals and rail terminals.

Figure 4.12 shows the modal share data for containers in selected ports.

Figure 4.12: Modal share data (2013) for containers in selected ports

![Modal share data](image)

Source: European Parliament, 2015

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28 Modal share of freight transport to and from EU ports. European parliament, 2015.
5 Perspective of market parties

In this chapter, the results are presented of a consultation of cargo owners and operators who were asked about their views on how sustainability in the transport chain can be improved and the possible role European seaports can play. First, general observations from the interviews are dealt with. Subsequently, potential steps for greening each part of the transport chain are identified, along with the envisaged role of the seaports.

5.1 Characteristics of cargo owners and operators consulted

The cargo owners and operators were evenly spread over the various cargo types: (petro)chemistry, food and beverage, furniture and electrical and electronic devices. Generally, the cargo owners interviewed were large organisations who together ship hundreds of millions of tonnes on a yearly basis. The operators interviewed cover all modalities and belong to the largest within Europe.

Without exception, sustainability plays a role in the strategy of these organisations. Sustainability is basically approached in two different ways. First, as a win-win, attempting to optimise the payload so that sustainability and cost reduction go hand in hand and the statement ‘profitability requires sustainability’ is subscribed. Second, by taking measures for which an investment is needed and that actually cost money. Remarks were made that many of the win-win situations have now partly been utilised and that gradually higher investments are needed to bring emissions down.

Although the parties interviewed place a high value on being sustainable, it is not yet the decisive factor in logistics. Interviewees indicate that price and competitiveness still rank on top, followed by service and performance (reliability). It is acceptable if prices for more sustainable solutions are slightly higher than a less sustainable alternative, but the difference should be no more than about 5%.

Strategies concerning sustainability seem primarily focused on climate change, although, in the case of reduction of fuel consumption, this goes hand in hand with a decrease in air pollution.

Many of the cargo owners are keen on all developments with regards to alternative and clean fuels although they are often not involved in the transport activities themselves as these are commissioned to a service provider. There are several pilots running for instance, with LNG, biofuels and hydrogen. LNG is an important alternative fuel, with a strong positive impact on reducing air pollution. The ability to reduce climate change is relatively limited, but interviewees also mentioned that LNG must be seen as a transition fuel towards the use of bio-LNG, which is more climate neutral. Hydrogen was also mentioned several times as an important fuel for the future. However, the ability to fuel hydrogen along the hinterland routes, is considered a prerequisite for a successful roll-out.

Most of the organisations interviewed report on their achievements in the area of sustainability annually and have clear views for the future. In a number of cases, they also require suppliers to complete an annual environmental performance survey (which scores their sustainability performance). Some cargo owners have developed their own sustainability code with which their service providers are obliged to comply.
5.2 Market parties’ view on reduction of climate change and air pollution in the transport chain

The interviewees were asked how sustainability can be improved and what they envisage as a role for the seaports. This is described below for each part of the transport chain. However, the emphasis of the feedback lies on the hinterland part of the transport chain.

5.2.1 Maritime leg of the transport chain

Most sustainability strategies of the cargo owners are aimed at making hinterland transport more sustainable, but some also look at the maritime part of the chain. This is difficult to steer for the parties interviewed, although it has been acknowledged that this also contributes to the total sustainability of the logistics chain. Contracts with maritime transporters are relatively short, often one year. This makes it difficult to cooperate on the area of sustainability and make joint investments.

Scale enlargement in maritime transport creates efficiency benefits in terms of fuel consumption and thus reduces the emission of CO\textsubscript{2} and air pollutants. However, the interviewees remark that seaports must be sufficiently deep and also quays and transhipment loading/unloading equipment must be large enough to cope with these ships.

Visiting a seaport with a seagoing vessel or an inland vessel incurs port dues and waste disposal contributions. The interviewees are pleased to see that some port authorities are using port dues to reward sustainable ships\(^{29}\), in particular, the extra discount that is awarded when vessels have low NO\textsubscript{x} emissions. This is favorable for ships that use LNG as a fuel\(^{30}\). In case of LNG, ship-ship bunkering facilities are needed for maritime ships. Further, onshore power supply is needed for maritime ships.

Interviewees pointed out that reductions of CO\textsubscript{2} and air pollution can take place in the maritime part of the logistic chain as indicated in Table 5.1\(^{31}\):

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Less CO\textsubscript{2}</th>
<th>Less air pollutants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scale enlargement, slow steaming and technological development</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Use of LNG as a fuel</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Use of low sulphur marine gas oil in SECA</td>
<td>0</td>
<td>+</td>
</tr>
<tr>
<td>Onshore Power Supply</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

Source: Panteia, 2016

\(^{29}\) For vessels that score high on the Environmental Ship Index (ESI). The ESI is an international benchmark for emissions from seagoing vessels. Also vessels that have a Green Award certificate are rewarded with discounts on the port dues.

\(^{30}\) Or a catalyst.

\(^{31}\) After treatment systems, such as scrubbers, were not mentioned during the interviews.
Suggested roles for the seaports
To stimulate sustainability, seaports may pursue the following roles:

- To benefit from scale enlargement, sufficiently deep seaports can take care of a well-maintained access channel and the ability to service larger vessel sizes in terms of available quay length and size of transhipment equipment.
- Seaports can provide an incentive for the use of alternative fuels by a reduction on port dues for clean vessels.
- Seaports can provide facilities for maritime vessels to enable ship-ship bunkering of LNG or bunkering facilities for clean fuels.
- Seaports can provide onshore power supply for maritime vessels.

5.2.2 Activities in the port
Interviewees stress that more transparency in the ports is needed in order to gear the different parts of the transport chain to one another. In some cases, cooperation proves beneficial for all taking part. An example is the cleaning of containers or management of empty containers. Profits are shared between partners. Thus, a win-win situation is created. Another example is the management of empty containers, so that they can be exchanged and used where needed. Of course, this depends on shipping companies agreeing on empty depots for common use. Adequate ICT systems are essential here. Interviewees would like to see the seaports taking the lead in creating more transparency in the transport chain. This requires bringing parties together and enabling the development of the systems that are needed. Interviewees indicate that seaports can try to steer towards such cooperation and take a leading role in case organising capacity is lacking. Also seaports can help to coordinate an information system that shows where empty containers become available. There may be a huge potential for greening with Small and Medium Sized Enterprises (SMEs). Sometimes the initiatives in themselves contribute little to sustainability, but the sheer number may add up to a significant impact. As SMEs themselves often do not have the organising capacity, seaports can help by means of a coordinating role.

Congestion in the port must be avoided. An optimal use of available space in the port may enable infrastructure and equipment with sufficient capacity, which in turn will reduce waiting times. Further, extended gates may improve the accessibility from the land side.

Interviewees pointed out the necessity for facilities in the port for shore power and bunkering for inland as well as sea-faring ships. In regards to alternative fuels, there must also be a possibility to bunker or tank in the hinterland. A fuelling network should therefore be rolled out.

Interviewees remarked that it is difficult for them to verify if a port is really green, because there is no independent verifier. A green certificate for ports would be useful. For transporters, for example, various green labels exist. However, in only a few cases cargo owners can choose the ports their goods pass through based on sustainability as the main argument. Transportation takes place with many transport service providers from specific starting locations to specific end destinations, and as a consequence, in the vast majority of cases the choice of port is made by the shipping companies. Only in cases where cost, service and overall CO₂ footprint (including pre- and on-carriage) are exactly the same for two ports, could cargo owners theoretically consider choosing a port on the basis of their green record.

32 A small and medium sized enterprise is defined as a company with a headcount < 250 and a turnover ≤ € 50 m or a balance sheet total ≤ € 43 m
Reductions of CO₂ and air pollution can take place in the port itself as indicated in Table 5.2.

Table 5.2: Reductions of CO₂ and air pollution in the seaports

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Less CO₂</th>
<th>Less air pollutants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy recovery of transhipment equipment</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Port services using biofuels</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>Port services using LNG</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Reduction of congestion in the port</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Reduction of waiting times in the port</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Extended gates / empty depots for containers</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Use of shore power at berth</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

Source: Panteia, 2016

Suggested roles for seaports
To stimulate sustainability, seaports may pursue the following roles:
- Seaports authorities can show exemplary behaviour, by using energy efficient equipment and/or equipment that uses biofuels, LNG and/or electricity for their own operations.
- Seaports can stimulate and facilitate initiatives regarding green operation from terminal operators, transport companies or shippers.
- Seaports can provide financial incentives (discount) for sustainable behaviour.
- Seaports can set minimum requirements for access to the port.
- Seaports can provide onshore power supply for inland as well as maritime ships.
- Seaports can take the lead in creating more transparency between the various parts of the transport chain. Part of this means bringing parties together and the development ICT.
- Seaports can play a catalyst role in the rollout of alternative fuel networks in the hinterland.
- Seaports can develop a green label for ports among themselves, for instance under the auspices of IMO or IAPH.

5.2.3 Hinterland part of the logistics chain
There are basically two possibilities with which transport can become more sustainable: by reducing the number of kilometres travelled or by greener transport.
- Less kilometres can be achieved by logistics network optimisation of vehicle fill optimisation (higher load factor).
- More green kilometres can be achieved by intermodal solutions, alternative fuels or technological development. Part of this is also the provision of better information and more transparency between actors within the logistic chain.

Interviewees welcome that good behaviour is rewarded, for instance by offering a discount on the port dues in the case of clean inland vessels that have a green certificate. NOₓ emissions affect public health and therefore have a high impact on port surroundings and particularly in the case where the seaport is situated in a densely populated area. Some interviewees add that ports must be strict to polluting vessels and not grant them access. Also reefers older than 15 years should not be allowed. The point is raised that the external costs that are incurred by less sustainable transport should be internalised more. Some of the interviewees suggest more legislation might be a necessary condition to stimulate polluter pays or to embrace a more sustainable way of working.
Interviewees have a preference for transport via more sustainable modes. Rail, but also inland waterways — when present — are considered more sustainable modes than road transport, despite that it is acknowledged that road freight transport has made great achievements in bringing down emissions and continues to do so.

Interviewees expect from seaports a pro-active strategy to support intermodal transport. This goes as far as taking the lead by supplying information on the container flows and where empty containers can be collected. Moreover, investments from seaports in inland terminals can increase cooperation in the transport chain.

Transporters who were interviewed said to generally point their customers towards sustainable solutions. To a limited degree and with a proper explanation, additional costs as a result of working more sustainably can be passed on. As an example, one transporter mentioned that in this way clients were willing to pay the low sulphur surcharge. There is also pressure from clients who in their tenders request a mention of sustainability as a criterion for selection.

Many operators advise their clients on the best transport solutions that are available at any given moment, irrespective of the mode of transport that it might concern. However, not all cargo owners have the freedom to choose the best modality at the best moment. In case of transport of dangerous goods, the cargo owner wants to be in control of the transport chain. Waterways and rail are considered safer modes and are therefore in favour for the transport of dangerous goods.

Interviewees describe sustainability as a dealmaker, not a dealbreaker. Clients are willing to absorb additional costs of up to 5% more, for a more sustainable option. In case of higher additional costs, clients are likely to move to another provider.

As indicated for the activities in the port, also for the hinterland ICT applications are considered of paramount importance. Port community systems are considered very useful in terms of the exchange of information between everyone in the logistics chain. However, interviewees indicate that these systems should be extended into the hinterland. Port community systems also must be better equipped as an instrument, for instance, to reduce CO₂.

Road transport
Despite technological developments such as Euro 6, road transport is currently considered to be a less sustainable mode than rail transport and inland shipping. However, as one of the interviewees indicated, a more flexible supply chain than transport with a truck does not exist. The expectations with regards to alternative fuels, such as LNG and hydrogen are high. Hydrogen can be completely climate neutral and non-polluting. Some interviewees are confident that 2017 is the year of the breakthrough of LNG. Strong parties are now involved in the development and rollout of an alternative fuel network and the so-called ‘chicken and egg’ problem regarding the construction of bunker/tank facilities and their users, is basically over. Still, the provision of bunker and tank stations is considered a topic where ports should take on a catalyst role, also where it concerns the more inland locations. Interviewees indicate that it also must be possible to tank alternative fuels more inland at the end of the inland leg of the transport chain.

In road transport there are two developments that increase efficiency and therefore, reduce the emission of greenhouse gases and air pollutants:
Long and heavy vehicles (LHV’s) move more freight per unit, which reduces the air resistance and may lead to a reduction of fuel consumption of up to 30%.

Grouping trucks into platoons is a method of increasing the capacity of roads and to reduce congestion. Platoons decrease the distances between trucks. Electronic coupling allows for a closer headway between vehicles. Because of a reduction in air resistance, fuel consumption can be lowered by 10-15%.

Platooning and LHV’s are considered very promising developments that will outgrow the experimental phase in the coming few years. Platooning can be operational by 2025. Seaports must ensure that these concepts can be allowed, particularly in the port area once operational.

Measures regarding minimum access requirements are mentioned for trucks, as well as prohibiting polluting ships from entering the port. Some cargo owners have set similar requirements. For instance, trucks must be less than 10 years old or Euro 4 for trucks >3,5 tonnes and less than 5 years old or Euro 5 for trucks <3,5 tonnes. Cargo owners actively encourage their suppliers to consider alternative modes of transport and alternative fuels.

Last, one of the interviewees indicated the need for truck guidance systems in the seaports to reduce CO₂ emissions.

**Rail transport**

Almost all interviewees stressed the importance of having good and frequent rail connections to the hinterland. Their main arguments were:

- Rail is seen as a green modality.
- Rail enables the options of intermodal transport solutions into the hinterland.
- Rail provides competitive transit times from ports to hinterland at relatively low costs as compared to road transport.
- Rail is needed to deal with peak demands that arise from scale increases at the maritime side of the transport chain.
- Rail can alleviate the (risk of) congestion on the road.
- Furthermore, rail transport does not make use of the same gantry cranes as deep-sea, short-sea and inland waterway transport do and can therefore still provide reliable options during maritime peak periods.

Currently, there are large differences between the amount of intermodal rail options offered from seaports. This is illustrated by Figure 5.1.
Figure 5.1 illustrates the statements of the interviewees:

- Hamburg and Bremerhaven offer the most intermodal connections of all seaports in Europe.
- Both Rotterdam and Antwerp have a larger transhipment volume of containers, but these ports offer less intermodal connections by rail. This is also due to the fact that these ports offer a large number of intermodal connections by barge.
- Many other ports lack a sufficient number of intermodal connections by rail. This is for example the case for Valencia, Algeciras, La Spezia and Genova.
- However, the Adriatic ports offer a decent number of intermodal connections as compared to the transhipment volumes. The port of Koper offers 18 intermodal connections for 0.4 million TEU.

In comparison to diesel locomotives, electric locomotives operate cleaner and with less impact on climate change. Electrification of rail track is an important condition for a greener operation. Alternatively, diesel locomotives can make use of biofuels to counteract the climate change effects.

Longer trains can operate more efficiently and for this, TEN-T regulations require sidings and platforms which are suitable for trains of meters, in the ports, as well as in the inland destination areas. This is a minimum requirement that has been set in the TEN-T regulation. For example, currently Germany and Italy do not yet fully comply with the requirement. Seaports must use their influence to encourage hinterland countries to give greater priority to taking action in order to comply with the TEN-T requirements that are due in 2030.

*Short sea shipping and inland waterway transport*

It is important to focus not only on even larger inland vessels. The provision of facilities, such as bunker points for alternative and clean fuels, is a condition for sustainable behaviour of port users.
Some interviewees (cargo owners, as well as transporters) are involved in long-term contracts for the provision of services. The long-term nature of contracts makes it possible to invest in ships powered by LNG or that are diesel-electric. This may concern sea-going vessels, as well as ships sailing on inland waterways. However, operators observe that clients are sometimes still reluctant towards transport by barge as it is believed to be a slow mode.

To summarise, there is not just one best measure for authorities to implement in order to stimulate sustainability. The role of seaports in making supply chains more sustainable, can be manifold. Reductions of CO₂ and air pollution can take place in the hinterland part of the logistic chain, as indicated in Table 5.3:

Table 5.3: Reductions of CO₂ and air pollution in the hinterland part of the transport chain

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Less CO₂</th>
<th>Less air pollutants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logistic optimisation of transport over modalities</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Logistic optimisation of transport within modalities</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Slow steaming for SSS/IWT (ICT)</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Use of biofuels</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>Use of LNG for road transport/IWT</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Longer rail sidings and platforms</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Electrified rail transport</td>
<td>0/+</td>
<td>+</td>
</tr>
<tr>
<td>Use of clean fuels (GTL)</td>
<td>0</td>
<td>+</td>
</tr>
</tbody>
</table>

Source: Panteia, 2016

5.2.4 Suggested roles for seaports

To stimulate sustainability, we envisage the following roles for seaports:

- Seaports can provide bunkering facilities and fuelling stations for biofuels and alternative fuels such as LNG must be provided.
- Stimulate the use of biofuels or alternative fuels by creating incentives (discounts) or port access requirements.
- Encourage or oblige transporters to make use of the most recent technological developments in clean engines and alternative fuels.
- Seaports can stimulate knowledge development through pilot projects, for example regarding the use of hydrogen as a fuel.
- In road transport, seaports should support developments such as HGVs or platooning. When operational, HGVs and platooning must also be allowed in the port area.
- Seaports can take on a coordinating role and/or promote realisation of improvements in port access infrastructure. For instance, rail tracks should become electrified to enable electric locomotives.
- Multimodal options may partly depend on a seaport’s location and available access to hinterland connections by rail, inland waterways and short-sea connections. Where options are available, seaports can stimulate synchromodal transport. Different parties can be brought together, also the development of supporting ICT systems can be part of this. Port community systems can be extended to the hinterland.

33 After treatment equipment road transport/IWT was not mentioned in the interviews.
34 Synchromodal transport means that the logistics service provider chooses the best possible transport mode, carefully balancing time, cost and service levels. On the same corridor this can sometimes result in the use of road transport, in other situations rail transport or the use of inland barges.
6 European impact of sustainable logistics

In the previous chapter, the roles that seaports can have in working towards more sustainable logistic chains were identified. In this chapter, we look at the European dimension of greening the transport chain. For this, a transport model has been developed for the logistics chain that can calculate cost effects and environmental effects for the entire logistic chain from a seaport in Asia to any destination region in Europe. Based on the model outcomes, transport routes and transport modes can be selected that are able to perform transport against minimal costs or environmental effects. The environmental effects that are investigated are climate effects (related to the emission of CO$_2$) and air pollution (related to the emission of NO$_x$, SO$_2$ and PM). Based on the greening actions discussed with the interviewees, a number of scenarios are formulated of which the impact on the supply chains will be investigated. This provides input for the conclusions on where seaports’ efforts could best be focused.

6.1 Set-up of the model

In the following sections, the model used to assess the European impact of sustainable logistics will be described briefly. A more detailed model description is available in Appendix 1. Shadow prices have been used according to the minimum values applied in the CE Delft (2016) Cost benefit calculation tool for onshore power supply.

6.1.1 Selection of deep-sea ports, regions and terminals

In the model, all main deep-sea ports in Europe that are served by vessels on Far East – Northern-Europe and Far East – Mediterranean services are assessed. This yields the following seaports:

- Rotterdam
- Antwerpen
- Bremerhaven
- Hamburg
- Gdansk
- Felixstowe
- Le Havre
- Aarhus
- Goteborg
- Southampton
- Algeciras
- Marsaxlokk
- Barcelona
- Genova
- Fos-sur-Mer / Marseille
- Koper / Trieste
- Piraeus
- Constanta
- Istanbul
- Gioia Tauro
- Valencia
- La Spezia
- Rijeka
- Venice

Some of these ports serve mainly as gateways to the hinterland (Le Havre, Genova, Koper) whilst other have mainly a feeder function (Gioia Tauro, Algeciras, Marsaxlokk) or combine both functions (Rotterdam, Hamburg, Antwerp).

Port choice is an important driver in the logistic chain, as it determines the maximum size of intercontinental vessel that can be used and the distance to the hinterland, and the range and attractiveness of inland modes.

We have assessed all NUTS-3 regions in Europe in the model and included 440 inland terminals, ensuring multimodal connections by barge, rail and/or shortsea. It included at least 52 trimodal terminals, ensuring connections by barge, rail with truck, and in some cases, also feeder services. Figure 6.1 below shows the hierarchy of NUTS regions in Europe.

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35 Cost benefit calculation tool onshore power supply, Methodological note. CE Delft, January 2016
6.1.2 Network modelling

Deep-sea services
We have assessed the service profiles offered by deep-sea container lines between the Far East and Europe, including services to the Hamburg-Le Havre range, the Mediterranean, the Adriatic and the Black Sea. This included the 30 weekly loops offered by the major alliances in deep-sea shipping, that deployed as much as 447 vessels.

Factors that influence the emission of GHG and air pollutants for a certain port per TEU are:
- The TEU-capacity of the vessel deployed, its design speed and the corresponding daily fuel (HFO) consumption, as well as the operational speed;
- The number of kilometres travelled in SECA areas;
- The position of a port in the sequence of port calls and its geographical location compared to Far East ports. For example, vessels with deep drafts tend to have a first call in ports without draft limitations, such as Rotterdam or Le Havre. Afterwards, a usual call is one of the two major German seaports before calling at Antwerp. Thus, Antwerp is at the end of the sequence and containers designated for Antwerp have to make a detour via Hamburg. This leads to extra emissions.

Figure 6.2 indicates the minimum CO₂ emission\(^\text{36}\) involved with the transportation of one twenty-foot container from Shanghai to and from various base ports in Europe. It should be noted that this is only the maritime leg of the transport chain and that the average CO₂ emissions vary with the direction of the traffic: this is due to the fact that the amount of laden containers on the inbound leg is higher than the outbound leg.

\(^{36}\) As some ports are served with multiple loops, indicating the minimum option was chosen rather than the average one. Figure 4.8 in section 4.1 includes an overview of the minimum, as well as the average and maximum CO₂ emission per vessel deployed.
Figure 6.2: CO₂ emissions on the maritime part of the logistic chain to and from seaports

Source: Panteia, 2016
The following conclusions can be drawn from Figure 6.2:

- **Pireaus and Algeciras offer the lowest CO₂ emissions of all European ports:**
  - In case of Piraeus, the average distance to Shanghai is about 1 000 nautical miles closer as compared to Ligurian or Adriatic ports and about 2 500 nautical miles closer than ports of the Hamburg – Le Havre range. Moreover, the newest COSCO unites of 14 000 are deployed on a dedicated service with Pireaus as a first port of call.
  - Algeciras offers an advantage of about 1 000 nautical miles as compared to Hamburg – Le Havre range ports and serves as the first European port of call of the largest units (19 ,000 TEU) of Maersk and MSC.

- **Despite a longer distance and longer transit times, ports of the Hamburg – Le Havre range generally have a lower CO₂-emission per TEU than Ligurian or Adriatic ports.** This is due to scale enlargement: vessels deployed on the Far East – Northern Europe trade lane are generally larger than the units deployed on Mediterranean trade lanes. Moreover, the units are the newest and thus technically optimised for slow-steaming. This is also illustrated in Figure 4.7.

- **Le Havre and Rotterdam offer the lowest CO₂ emissions from all ports in the Hamburg – Le Havre range.** These ports offer a 24/7 deep water connection, without any draught limitations and/or tidal constraints. This proves an advantage over ports with an limited draft and therefore, deep-sea container lines opt to use Le Havre or Rotterdam as a 'first port of call'.

- **Adriatic seaports have a disadvantage of scale as compared to the average vessels deployed on Far East – Northern Europe or Far East – Mediterranean services.** Whereas the largest units to North-European ports now equal 19 000 TEU and to Mediterranean ports 14 000 TEU, vessels on the Adriatic trade lane generally do not exceed 10 000 TEU.

- **For Ligurian ports, the difference in CO₂ emissions per container between Hamburg – Le Havre range ports and Ligurian ports is about 50-100 kg per TEU.** However, there is an advantage of 250-300 kg CO₂ per TEU as compared to ports in the Adriatic range.

- **For Adriatic ports, the disadvantage as compared to ports of the Hamburg – Le Havre range equals 300-350 kg per TEU.**

- **The extra CO₂-emission involved with sailing to ports in the Baltic range (Aarhus, Gdansk and Goteborg) equal about 50-100 kg per TEU as compared to ports in the Hamburg – Le Havre range.**

### In the port

Although a ship at berth does not move, it uses energy to remain operational. Electricity that is needed for this can be generated by the ship’s own aggregates that are connected to the ship’s engines. In the model, this is taken into account depending on the engine power or auxiliary engines, averaging about 10 kg CO₂ per TEU per call.  

Also, transhipment of containers at deep-sea terminals results in emissions of GHG and air pollutants. In order to assess the CO₂ emissions involved with container handling, annual sustainability reports of multiple stevedores have been assessed. We have assumed a 14 kg CO₂ emission per container per handling.

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Hinterland

In the model, four options are assessed for transportation to the hinterland:
- Intermodal transport via rail transport,
- Intermodal transport via barge transport,
- Intermodal transport via feeder services and
- Direct trucking for the deep-sea terminal.

Panteia has gathered information about intermodal services in Europe, comprising:
- 401 shortsea connections for the deep-sea terminals of Europe.
- 134 barge connections for seaports connected to an IWT container network.\(^38\)
- 1,516 rail connections to various inland terminals in Europe.

For every intermodal connection, Panteia has estimated the internal costs, using annually updated cost models,\(^39\) as well as estimations of energy/fuel consumption and corresponding emission factors. For electrical rail transport, the energy mix of national railway infrastructure authorities has been taken into account.

For inland navigation, infrastructural constraints by means of draft limitations and height limitations have been taken into account, as well as fairway limits to vessel dimensions to give the best estimate of the vessels’ cost price.

For shortsea, differentiations have been made to the TEU size of the vessels’ deployed on regular services offered by feeders and the engine power installed for these vessels. Also, similar to deep-sea container transport, the services offered by feeders have been taken into account and differentiations in the emission of GHG and air pollutants have been applied based upon:
- The TEU-capacity of the vessel deployed, its design speed and the corresponding daily fuel (HFO) consumption, as well as the operational speed;
- The number of kilometres sailed in SECA areas;
- The position of a port in the sequence of port calls and its geographical location compared to Far East ports.

The model uses a shortest-path algorithm based upon the lowest sum of the internal and external costs and indicates the total emissions of the path from China to Europe taking into account all emissions during each leg (maritime, port, hinterland).

6.2 Impact of drivers on a European scale

The model designed can make various optimisations based upon different costs formulas: for instance based upon internal costs only, the emission of GHG or air pollutants, the external costs and the combination of the two. Also, it makes it possible to compare the allocation of different European regions to seaports based upon these cost optimisations, thus allowing a scenario analysis.

In this paragraph, maps will be presented that give an idea of the optimal seaport per region based upon:
- Internal costs;
- A combination of internal and external costs;
- The CO\(_2\)-emission per TEU based upon a costs optimisation for internal costs;

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\(^{38}\) This is the case for Rotterdam, Antwerp, Hamburg, Bremen, Le Havre, Marseille-Fos and Venice. Although Constanța is connected to the Danube river and inland navigation is possible, no regular container transport takes place on the Danube. Therefore, inland navigation from Constanța has not been taken into account.

\(^{39}\) Panteia cost models for inland navigation, rail transport, road transport and maritime transport.
- The CO₂-emission per TEU based upon a costs optimisation for internal and external costs;
- The emission of SO₂ per TEU based upon a costs optimisation for internal costs.

Figure 6.3 shows a map of the hinterlands of the port clusters when internal costs are taken into account.

Figure 6.3: Hinterlands of port clusters based on minimal internal costs

The following conclusions can be derived from Figure 6.3:

- The Hamburg – Le Havre range covers the whole of the Netherlands and Belgium and also about 50% of France. Furthermore, the region provides the lowest internal costs for the whole of Germany, with the exception of the regions on the borders of both Austria (in which the Adriatic ports are a good contender) and on the Polish border (fierce competition from Gdansk).
- The influence of the Ligurian ports, and most notably Genova, extends itself to Switzerland, which is nearly covered as a whole. However, the Hamburg – Le Havre range ports are able to compete near Basel due to the possibilities of using inland waterways. Therefore, nearly 20% of the Swiss customers can be best served by the Hamburg – le Havre range ports.
- The natural hinterland of the port of Piraeus is Greece and the southern part of Bulgaria, although some of these regions are also served via shuttle trains from the Hamburg – Le Havre range and the port of Constanta. More interesting is the fact that the Greece port has managed to capture a large part of the Italian hinterland by means of heavy feeder services from Piraeus to Adriatic ports as Bari, Ancona and Ravenna.

Source: Panteia, 2016
- The port of Constanta does not manage to extend its hinterland over the Romanian and Bulgarian borders.
- The geographical hinterland of the port does not necessarily reflect its hinterland in terms of customers. Therefore, we have also indicated the number of customers living in Europe per port region (see Figure 6.4). This draws the following conclusion:
  - The Hamburg – Le Havre range provides the lowest transport costs to serve 29% of the European hinterland. This mainly includes the German territory (79 million inhabitants) and a large part of France (40 million inhabitants).
  - The Ligurian ports provide the best option to serve 19% of the customers. These are mainly living in Italy, the eastern parts of Spain and the southern part of France.
  - The Adriatic ports serve 9% of the European customers: mainly inhabitants of Hungary, Austria and Italy.

Figure 6.4: Percentage of European customers that are served by a certain port region based on internal cost optimization.

Source: Panteia, 2016

At the borders of the ‘port region hinterlands’, different ports compete for the same customer. This happens for a large extent along the Alps, that form a natural barrier between the Northern-range ports (Hamburg – Le Havre range and Gdansk) versus the Southern range ports (both Ligurian and Adriatic ports). Therefore, cities such as Geneva, Basel, Munich and Vienna have the same competitive transit times and costs via Northern range ports as Southern range ports.

Variations however occur in the emission of GHG and air pollutants. This can be due to maritime differences, such as the less carbon-intensive vessels that are deployed on the Far East – North West Europe trade lane and the time spent in SECA-zones, but also in the hinterland chain, by means of intermodal connections via rail (generally the least carbon intensive mode) or barge. Figure 6.5 illustrates this for the transport of a 20-ft container from China to Munich via various European ports. Although the port of Koper offers the best connection in terms of costs, it lags behind the Hamburg – Le Havre range ports in terms of CO₂-emissions. Also the absence of a SECA-zone in the Mediterranean is clearly demonstrated in the graph.
Figure 6.5: CO₂ and air pollution caused by the transport of a 20-ft container from China to Munich via various European ports

![CO₂ and air pollution graph]

Source: Panteia, 2016

Figure 6.6 indicates the amount of CO₂ kilograms emitted per container from China to European regions. Figure 6.7 does the same, but then for SO₂ kilograms emitted per container. This gives an indication of the performance of SECA zones.

Figure 6.6: CO₂ emission of the entire transport chain, mapped onto destination-regions, based upon an internal costs optimisation.

![CO₂ emission map]

Source: Panteia, 2016
The following conclusions can be derived from Figure 6.6 and Figure 6.7:

- The CO$_2$ emission per container is the least in the southern part of Spain and Greece. Here, less than 900 kg of CO$_2$ are emitted when moving a 20-ft container from Shanghai to Europe. These low values are due to the relative close position to the Suez Canal as well as the carbon-efficient vessels that are deployed on loops to both Piraeus and Algeciras.
- Ports in the Hamburg – Le Havre region are a second best option for a container in Europe. Their hinterland is large and well connected to intermodal networks by either barge (Le Havre, Antwerp and Rotterdam) or by rail (all but Le Havre).
- There is no difference between the Hamburg – Le Havre range ports when it comes to SO$_2$ emissions. Economies of scale as well as the SECA zone have reduced the SO$_2$ emissions substantially.
- Also the Ligurian ports have a decent performance when it comes to CO$_2$ emissions. This is best demonstrated opposing the CO$_2$ emissions in the Ligurian hinterland versus the hinterland of the Adriatic ports.
- The Adriatic ports lack fuel-efficient vessels on their trade lanes to and from Asia and thus have a large disadvantage when compared to Ligurian ports as well as the Hamburg – Le Havre range. This is not only reflected in emissions of CO$_2$, but also in the emissions of SO$_2$.
- The EU Directive 2012/33/EU has already laid down a maximum sulphur content of 0.5% for fuel used outside the European ECAs in the territorial waters and exclusive economic zones of EU member countries for the year 2020. This will further reduce sulphur emissions.
Also, the IMO global fuel sulphur cap will globally reduce SO$_2$ emissions by setting the maximum sulphur content in HFO to a maximum 0.5%. This is planned for 2020, but the be definite after a review scheduled for 2018.

The internalisation of external costs (due to GHG and air pollutants) could affect the port choice of cargo owners. This is best demonstrated when shadow prices are applied to monetise the impact of GHG and air pollutant emissions, see Figure 6.8 and Figure 6.9. The first map indicates the hinterland lost by port clusters when external costs are internalised, whilst on the other hand the second map shows the port cluster that "wins" these regions.

**The following conclusions can be drawn from Figure 6.8 and Figure 6.9:**

- The ports in the Hamburg – Le Havre range extend their hinterland towards the south, at the price of Adriatic, and in a lesser extent, the Ligurian ports. Also the port of Gdansk loses some ground to the ports in the Hamburg – Le Havre range.
- The Ligurian ports win some ground of the Adriatic ports, but on the other hand lose ground in Spain to the port of Algeciras and towards the German and Swiss hinterland. Here, they will face tougher competition from the Hamburg – Le Havre range ports.
- The Hamburg – Le Havre range will extend their hinterland towards the south and will be much more competitive in servicing Switzerland, Bavaria (Germany) and Austria.

When competing on internal costs only, the ports in the Hamburg – Le Havre range serve 148 million customers in Europe. When the external costs due to GHG and air pollutants are internalised, these ports will serve another 20 million inhabitants, mainly at the costs of the Adriatic ports (Koper, Venice, Trieste and Rijeka). This way, the Hamburg – Le Havre range ports will serve 32% of the customers in Europe (see Figure 6.10).
Figure 6.8: Internalisation of external costs – Hinterland lost by port clusters

Source: Panteia, 2016

Figure 6.9: Internalisation of external costs – Hinterland won by port clusters

Source: Panteia, 2016
6.3 **Scenario analysis**

To assess the impact of measures on a European scale, six scenarios have been formulated. These scenarios are based on the developments that have been discussed during the consultation of market parties, trends in the transport market and legislation likely to be implemented within a medium time scale. In order to show maximum results, some of the scenarios based on rather far-reaching assumptions. The scenarios formed the input to the transport model used.

For each of the six scenarios, the impact on CO\(_2\) and air pollutants has been determined as well as possible port shift effects. For optimization of the supply chains, the sum of the internal and the external costs was used.

The following scenarios were selected:
- Enlarge capacity of all maritime ships with 1500 TEU
- Mediterranean Sea also becomes a SECA\(^{40}\)
- Large scale introduction of LNG
- 10\% of biofuels in 2020
- Digitalisation of the transport chain
- Higher share of renewable energy used by rail infra providers

The scenarios and their outcomes are further described in the next sections.

### 6.3.1 Enlarge capacity of all maritime ships with 1500 TEU

In this scenario, all maritime vessels will increase their capacity by 1 500 TEU. Only the trade lane to the Black Sea will be exempted: currently all vessels on this route are Bosporus-Max (300 x 48 meter) and no further scale increase is possible.

**Effects:** A further scale increase would hardly have any effect on the port choice in Europe. The Adriatic ports will gain some hinterland at the costs of the Hamburg – Le Havre range ports in Austria. Overall CO\(_2\) emissions are expected to go down. See Figure 6.11.

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\(^{40}\) Although a topical subject at the moment, Nitrogen Emission Controlled Areas (NECAs) scenario has not been included. NECAs are envisaged to be operational by 2021 for newly built vessels. It is therefore expected that first noticeable effects of NECAs will take place beyond the time horizon that this focuses on.
The effect is the largest in regions that are served via the Adriatic ports. Here, the vessels are generally the smallest and an increase of 1 500 TEU capacity will bring the CO$_2$ emission per unit transported down the most relatively. Possible restrictions in port capacity with regard to access channels, quay lengths or the reach of gantry cranes has not been taken into consideration when developing this scenario.

6.3.2 Mediterranean Sea also becomes a SECA

In this scenario, the whole Mediterranean Sea will become a SECA zone, including the coastal waters on the Atlantic Ocean, in such a way that all traffic from Suez to a European seaport will be within the limits of a SECA zone. This measure will have benefits on health as Sulphur Emissions will be greatly reduced. In this scenario we have assumed that all Mediterranean ports, including the African ports, on the Mediterranean Sea will comply to SECA standards and that none of the shipping lines reroutes traffic from the Suez Canal to the Cape of Good Hope.

**Effects:** This scenario has hardly any effect on port competition. There are minor (33) regions that switch seaports, most prominent a switch from Rijeka to Koper (16 regions). Furthermore, Hamburg – Le Havre range ports lose some ground to Ligurian ports (5 regions), but a few regions are won from Trieste (2 regions).

Figure 6.12 indicates the reduction of SO$_2$ emissions in Europe.
From Figure 6.12, the following conclusions can be drawn:

- The implementation of a SECA area in the Mediterranean Sea will have more effect on the Hamburg – Le Havre range ports than on Mediterranean ports. This is due to the fact that the transit through the Mediterranean Sea from Suez to the North Sea SECA area is over a much longer distance than the transit distance from Suez to one of the Mediterranean base ports (Genova, Marseille or Koper).

- The largest benefits are obtained at regions outside the boundaries of current SECA zones (North Sea and Baltic Sea) that are served via ports within the SECA area. This includes the shipments via Felixstowe, Southampton, Rotterdam and Antwerp to UK west coast ports (Greenock, Liverpool), Ireland. Also transhipment via Hamburg – Le Havre ports to the Iberian peninsula are affected.

- Some regions show an increase in SO₂ emission due to the implementation of SECA zones. This might be counterintuitive, but it can be explained by the fact that MGO (LSHFO is not allowed anymore) leads to higher internal costs. Therefore, some shipments change from ports that already had a low SO₂ emission to ports that are called by less efficient vessels.

- One of the consequences of a SECA zone might be the fact that operators and shippers reduce the distance in the Mediterranean SECA zone. Therefore, feeders from dedicated feeder ports, such as Gioia Taura, Marsaxlokk and Cagliari might lose ground to ports closer to the Suez Canal (Piraeus, Port Said).

- Additionally, shippers might deviate from the Suez Canal and switch to the Cape of Good Hope route. This will decrease the importance of ports as Algeciras and Tanger, but will increase all emissions on the journey from Asia to Europe.

- We have not assessed these options or alternatives, or a limited SECA zone in the Mediterranean Sea with only European ports in compliance. Additional research is required to assess the impacts.
6.3.3 Large scale introduction of LNG

In this scenario, all vessels calling at Hamburg – Le Havre range ports will be driven by LNG dual fuel engines. All international trucks will run on LNG as well as all inland barges operation on the Rhine river and serving terminals upstream from Koblenz.

**Effects:** This scenario will have significant effect on port choice if both internal and external costs are taken into account. In a scenario where port choices is optimised based upon internal costs, marginal changes take place.

Figure 6.13: Port regions with lowest costs in case of large scale breakthrough of the use of LNG as a fuel

![Port regions with lowest costs](image)

*Source: Panteia, 2016*

Figure 6.13 shows the port regions with lowest costs in case of large scale breakthrough of the use of LNG as a fuel. From Figure 6.13, the following conclusions can be drawn:

- One of the most notable effects is the fact that the market share of the Hamburg – Le Havre range ports is about to increase in Switzerland. Contrarily, the market share of the Ligurian ports will decrease. One of the reasons for this is the fact that both the external costs of maritime shipping and inland navigation will diminish to quite a large extent. Especially the reduction of external costs by inland navigation can be seen as a development towards sustainability.
- Moreover, the Hamburg – Le Havre range ports will further increase their market share in Austria at the cost of the Adriatic ports. Over 75% of the Austrian customers can be served 'optimally' via the Hamburg – Le Havre range ports.
- In France, the port of Le Havre will increase its competitive position at the cost of Fos-sur-Mer / Marseille.

41 UASC already operates six vessels that are LNG-ready. These vessels are all deployed on Far East – Northwest Europe trade lanes. Eleven vessels are yet to be put in service (15 500 TEU to 18 800 TEU). Also MOL has ordered six 20 000 TEU vessels that have the specifications which enable LNG use as fuel in the future remodelling, it added.
Figure 6.14: CO₂ savings in case of large scale breakthrough of the use of LNG as a fuel, mapped onto destination regions.

![CO₂ savings map](image)

Source: Panteia, 2016

Figure 6.14 shows the CO₂ that can be saved in case of large scale breakthrough of the use of LNG as a fuel. From Figure 6.14, the following conclusions can be drawn:

- When LNG is implemented on a large scale, a major shift of traffic from the southern range ports (Adriatic Sea, Ligurian ports) will take place to the Hamburg – Le Havre range ports. The most carbon-efficient vessels with dual fuel engines are currently deployed on the Asia – Northern Europe tradelane.
- Generally, no larger benefits than a 10% reduction can be expected. However, in case of a different port choice, larger benefits occur. This is forecast to happen if an optimisation is made based upon both internal and external costs.
- This effect can mainly be seen on the natural barriers of the Alps and Pyrenees.

6.3.4 10% of biofuels in 2020

In 2020, 10% of biofuel will be blended. This is assumed for the land transport side. There will only be an effect on CO₂ emissions and the effects will only be applicable to the climate effect for road transport and Inland Waterway Transport (IWT).

**Effects**: This scenario will have a very minor effect on port choice. As CO₂ emissions are expected to drop by 10% for road transport, which will be used during every single transport, either to complete the transport chain directly from the seaport or from an inland terminal. Seaports with a large share of rail transport to the hinterland will tend to have the least profit.

Most effects are visible in the southern part of Europe. The port of Algeciras, which is poorly connected by rail, gains some hinterland at the cost of seaports of Valencia and
especially, Barcelona that are connected better to rail. Moreover, intermodal services that run intra-Italy will face tougher competition from feeder services via Piraeus.

The effect on the total CO₂ emissions are limited to a decrease in the range of 0 to 4%. It must be noted that the result should be placed in perspective. The biofuels scenario that has been calculated is more realistic with regard to costs and realisation, than, for instance, the LNG scenario that was calculated earlier. If 100% biofuels were used the effect would probably have been around 40% decrease of CO₂ emissions.

6.3.5 Digitalisation of the transport chain

| By means of the use of ICT applications, load factors and utilisation degrees of intermodal hinterland transport modes is optimised. The load factors of feeder vessels, inland barges and trains increase from 75% to 90%. |

Effect: The effect of more efficient intermodal transport will increase the share of the Hamburg – Le Havre range ports. A large amount of market share will be gained in Switzerland, at the cost of the Ligurian ports. The Adriatic ports will lose some ground to the port of Constanta. By means of more efficient intermodal transport, Hamburg – le Havre range ports can also win ground in Bavaria at the cost of Adriatic ports.

Figure 6.15 indicates the effect of the measure. It should be noted that the general effects of the measure are within the range of 5-10%. Regions that are served by intermodal transport (or feeder services) gain advantages of increased load factors. However, the regions that are directly served by trucks from the seaport will not have any benefit from this scenario.

Figure 6.15: CO₂ savings as a result of digitalisation of the transport chain, mapped onto destination regions.

Source: Panteia, 2016
6.3.6 Higher share of renewable energy used by rail infra providers

In this scenario, the emissions (GHG and air pollutants) of rail transport are cut by 50% due to a larger share of renewable energy in the energy mix used by infrastructure providers. This does however come at a price: the energy charge per kilometer is expected to go up by 6%.

**Effects:** This scenario will have significant effect on port choice if both internal and external costs are taken into account. The ports of the Hamburg – Le Havre range will profit to a large extent. The effects on port choice are similar to the effects that can be achieved when internalising all external costs completely.

For CO₂ emissions, the largest effect can be obtained in Germany and, especially, Poland. In these countries, trains run on a large share of coal based energy. Contrary, to France, where trains run nearly climate neutral and therefore the effects in France are very limited (see Figure 6.16).

It can also be noticed that the energy mix used by rail infrastructure influences the degree of CO₂ reduction that can be achieved. This can be seen when comparing the reductions in France (carbon efficient rail transport) versus Germany or Poland (carbon intensive rail transport).

Figure 6.16: CO₂ savings as a result of carbon efficient rail transport, mapped onto destination regions.

Source: Panteia, 2016
6.4 Conclusions European impact

From the transport model, it is possible to conclude:

1. Regions in Europe show a clear division from which seaports they can be serviced best with respect to container transport from Asia, using minimum emission of CO₂ or air pollutants as a criterion. To a great extent the division follows the same pattern as when internal costs are minimised. Clearly the Alps also form a barrier here.

2. Depending on the modal share of the different hinterland modes, ports react differently to the scenarios that have been developed for both the maritime and hinterland legs of the transport chain. The geographical location of the port as well as the amount and the nature of the hinterland connections determines the impact of the scenarios. In order to benefit, ports need strong rail connections and, where possible, strong inland waterway connections.

3. In general, most scenarios do not cause major changes in the supply chains. However, some scenarios may influence the supply chains to the contestable hinterlands of the seaports, i.e. Switzerland and Austria.

4. Several scenarios for more sustainable logistic chains have been investigated with the transport model. These scenarios concern:
   - Enlarge capacity of all maritime ships with 1500 TEU
   - Mediterranean Sea also becomes a SECA
   - Large scale introduction of LNG
   - 10% of biofuels in 2020
   - Digitalisation of the transport chain
   - Higher share of renewable energy used by rail infra providers

5. Port choice effects are generally modest, except in the case of a large scale introduction of LNG and more renewable energy used by rail transport, where there is a shift towards the ports in the Hamburg- Le Havre region. Stricter sulphur standards will have a positive impact on public health, as in the case where LNG is introduced at a large scale.

6. In case of ongoing scale increase of ships, the effect is the largest in regions that are served via the Adriatic ports. Here, the vessels are generally the smallest and an increase of 1 500 TEU capacity will bring the CO₂ emission per unit transported down the most relatively. However, possible restrictions in port capacity with regard to access channels, quay lengths or the reach of gantry cranes were not taken into consideration when developing this scenario.

7. For the scenario where 10% biofuels will be blended, the effect on the total CO₂ emissions is limited. However, it must be remarked that the implementation of this biofuels scenario seems more feasible in view of legislation that is currently upcoming and the fact that the use of for instance LNG requires considerable additional investments in engines and refueling equipment. However, the costs of blended fuels are expected to be higher as compared to non-blended fuels or the LNG alternative.

8. Last, digitalisation of the transport chain is very interesting, as it can be realized at much smaller investments than the other scenario’s. However, it does require market parties in the transport chain to cooperate and to be transparent. This scenario is especially relevant for ports with large shares of rail transport and inland navigation.

9. The outcomes of the scenario calculations are summarized in Table 6.1.

---

42 Although a topical subject at the moment, Nitrogen Emission Controlled Areas (NECAs) scenario has not been included. NECAs are envisaged to be operational by 2020 for newly built vessels. It is therefore expected that first noticeable effects of NECAs will take place beyond the time horizon that this focuses on.
Table 6.1: Scenario outcomes

<table>
<thead>
<tr>
<th>Scenario</th>
<th>CO$_2$ reduction</th>
<th>Pollutants reduction</th>
<th>Port shift effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Enlarge capacity</td>
<td>5 to 15%</td>
<td>10 to 30%</td>
<td>Negligable</td>
</tr>
<tr>
<td>2. Med SECA</td>
<td>-</td>
<td>15 to 20% (SO$_x$)</td>
<td>Negligable</td>
</tr>
<tr>
<td>3. LNG</td>
<td>5 to 10%</td>
<td>-90%</td>
<td>Positive HLH</td>
</tr>
<tr>
<td>4. Biofuels</td>
<td>0 to 4%</td>
<td>-</td>
<td>Negligable</td>
</tr>
<tr>
<td>5. Digitalisation</td>
<td>5 to 10%</td>
<td></td>
<td>Negligable</td>
</tr>
<tr>
<td>6. Rail renewable</td>
<td>0 to 4%</td>
<td></td>
<td>Positive HLH</td>
</tr>
</tbody>
</table>

Source: Panteia, 2016
7 Main findings

7.1 How cargo owners and operators view sustainability

From the interviews with cargo owners and operators, we conclude that sustainability is becoming increasingly important in logistics. For many large cargo owners, sustainability is, as they say, first and foremost, part of their DNA. Apart from this, there may also be a commercial drive. The interviewees unanimously indicated that there is an increasing pressure from clients to become more sustainable. This is also true for the entire production chain, including transport. This applies in particular for cargo owners who are engaged in consumer goods, as consumers more and more have an apparent preference for products that are produced in a sustainable way. As such, profitability demands sustainability. Another way in which this statement holds true is the fact that sustainability may be the result of measures that increase efficiency which also lead to operational cost advantages. In these cases, one leads to the other! However, sustainability is not yet the decisive factor in logistics. Interviewees indicate that price and competitiveness still rank on top, followed by service and performance (reliability). After this comes sustainability. To illustrate this, interviewees indicated that a price increase of about 5% maximum in case of a more sustainable solution is considered acceptable. For this reason, legislation and incentives are needed in order to stimulate a further greening of the logistics chain.

Based on the feedback from the consultation, the following can be said about the role of ports for the three parts into which we have split the logistic chain.

7.2 General

1. The biggest reductions of CO₂ can be gained on the maritime and the hinterland leg of the transport chain. Generally speaking, CO₂ emissions in port only contribute to a very small percentage (±2%) of the total emission. Although the maritime part of the logistic chain is responsible for a large part of the GHG emissions and the air pollution, it is recommended that seaports focus in particular on the hinterland leg in their efforts for a more sustainable logistic chain, where seaports can be more influential.

Figure 7.1 shows the three parts of the transport chain and the influence that seaports authorities have on making a supply chain more sustainable.
2. Changes in port choice are not very likely to affect global CO\textsubscript{2} emissions to a large extent. However, for transport to contestable hinterlands (i.e. Switzerland and Austria), a different port choice can have substantial effects of the GHG and air pollutant emissions involved with the transport.

7.3 Maritime transport

1. Optimising the logistics chain — efficiency as well as sustainability — will become a competitive factor. Economies of scale can contribute towards achieving critical mass for sustainability. On the maritime side, the seaports make optimal use of their natural advantages. The capacity of berthing places and terminal equipment need to be geared to the vessels that call at the port. The role of seaports is to optimally tune the infrastructure and the facilities to the demand.

2. Environmental performance of maritime vessels is governed by international agreements from IMO and the EC. Seaports contribute to sustainable development through their contribution to the realisation of international and European legislation, also through their national governments.

3. SECA can be seen as a best practice to reduce sulphur emissions. Upcoming European legislative and IMO acts will cut the total SO\textsubscript{2} emissions involved with maritime transport by a factor 6.

7.4 Activities in the port

1. Seaports can set sustainability requirements for users that want to enter the port or companies that want to settle in the port.

2. Seaports can provide facilities to users that behave sustainably. Bunker points for users of alternative fuels, onshore power supply and biofuels are an example hereof.
3. Seaports can stimulate the exchange of information between operators in the port, such as for instance transporters and terminals. Adequate ICT support systems are needed for this.

4. There may be a huge potential for greening with Small and Medium Sized Enterprises (SMEs). As SMEs themselves often do not have the organising capacity, seaports can help by means of a coordinating role.

5. In the seaports, the port authorities can play an exemplary role by greening their own operational activities and services.

### 7.5 Hinterland transport

1. There are two possibilities with which transport can become more sustainable: by reducing the number of kilometres travelled or by greener transport.
   1.1 Less kilometres can be achieved by logistics network optimisation or vehicle fill optimisation. Part of this is also the provision of better information and more transparency between actors within the logistic chain.
   1.2 Green kilometres can be achieved by intermodal solutions, alternative fuels or innovation and technological development. Part of this is the provision of better information for actors within the logistics chain so that efficiency benefits arise from their cooperation. Seaports can play a coordinating role to create more transparency in the transport chain for the actors.

2. With regard to alternative fuels, interviewees indicated that 2017 will be a decisive year for LNG. The development of LNG is thrust by large parties that do not see LNG as an end solution in itself, but merely as a transition fuel towards biogas. Alternative fuels should not only be present at the origin of the trip, but also at the destination. Seaports can be a catalyst here toward building a rational fuelling network and to avoid overgrowth.

3. In road transport, LHVs and platooning will outgrow the experimental phase in the coming few years. Seaports must promote that these concepts are allowed in the port area as quickly as possible.

4. Despite the valuable sustainability improvements in road transport, it is generally felt that more rail connections to and from the ports will increase the opportunities for sustainability. For inland waterways and rail transport, seaports can play a leading role by steering cargo towards these green modalities. This can be done in various ways, for instance, if the seaport requires that a minimal part of the freight be shipped by rail and inland waterways. For hinterland transport, economies of scale can contribute towards achieving critical mass for sustainability: if sufficient volume can be pulled together in the hinterland, this may create a critical mass for rail transport. Extended gates are a good example of how this can be done. Seaports can create such conditions to ensure that cargo flows are discharged through sustainable modes.

5. Terminals play a crucial role in the logistics chain; they are the matchmaker between the maritime part of the transport chain and the inland part. Therefore, untapped potential can also be used by cooperation with terminals in the hinterland, harmonisation of the availability of alternative fuels and help in creating transparency to avoid unnecessary runs of empty containers. Rail and IWT are in a better position to match the cargo with the empty containers because of better buffer opportunities. Adequate ICT support systems are of paramount importance. Port community systems are a useful instrument, but there is a need for them to be rolled out into the hinterland and made suitable for reduction of CO₂. Transparency between the different parts of the transport chain is of utmost importance as it makes hinterland connections more seamless. Seaports can play a coordination role to increase transparency in the transport chain.
6. Although cargo owners indicate that they often cannot choose the ports their goods pass through based on sustainability as the main argument they also remarked that it is difficult for them to verify if a port is really green, because there is no independent verifier. A green certificate for ports is considered useful. For transporters, for example, various green labels exist. Also ESI is a good example.

7. A port is as green as the logistic chain that it is part of. In this study we have investigated the role of seaports in making supply chains more sustainable. However, the supply chain consists of many stakeholders that feel that they have a responsibility: for instance shippers, terminal operators, governments and infrastructure providers for seaports and inland ports. A sustainable logistic chain can be regarded a joint responsibility and mutual cooperation is of paramount importance.

7.6 Impact of scenarios on a European scale

Modelling calculations have been done in order to investigate the impact of drivers for sustainability on a European scale. From the modelling exercise, it is possible to conclude the following:

1. Regions in Europe show a clear division from which seaports they can be serviced best with respect to container transport from Asia, using minimum emission of CO₂ or air pollutants as a criterion. To a great extent the division follows the same pattern as when internal costs are minimised. Clearly the Alps also form a barrier here.

2. Depending on the modal share of the different hinterland modes, ports react differently to the scenarios that have been developed for both the maritime and hinterland legs of the transport chain. The geographical location of the port as well as the amount and the nature of the hinterland connections determines the impact of the scenarios. In order to benefit, ports need strong rail connections and, where possible, strong inland waterway connections.

3. In general, most scenarios do not cause major changes in the supply chains. However, some scenarios may influence the supply chains to the contestable hinterlands of the seaports, i.e. Switzerland and Austria.

4. In the scenario with a further scale increase there is hardly any effect on port choice in Europe. The effect is the largest in regions that are served via the Adriatic ports. Here, the vessels are generally the smallest and an increase of 1 500 TEU capacity will bring the CO₂ emission per unit transported down the most relatively. However, possible restrictions in port capacity with regard to access channels, quay lengths or the reach of gantry cranes were not taken into consideration when developing this scenario.

5. Setting stringent sulphur standards in the Mediterranean Sea will not affect the competitive position of the European ports. This can be regarded as a quick win for reducing air pollutants, having a positive impact on public health.

6. LNG will have significant impact for ports that rely on the hinterland modes inland navigation and short sea shipping. The impact of LNG on GHG reduction is limited (maximum about 10%). For air pollution the positive impact of LNG is far greater, especially for inland navigation that is having a competitive disadvantage in comparison to trucks when it comes to air pollutants. For short sea shipping, being in a SECA zone seems a prerequisite for the business case of LNG. LNG will also have a significant effect on the environmental performance of deep-sea container vessels. At this moment, six LNG-ready container vessels are in service and another 20 are yet to be built. For ports, this means that they shall provide legislative and infrastructural facilities to accommodate ship-ship bunkering of LNG.
7. For the scenario where 10% biofuels will be blended most of the effects are visible in the southern part of Europe. The effect on the total CO₂ emissions is limited to a decrease in the range of 0 to 4%. However, although the effect seems modest it must be remarked that this biofuels scenario is more realistic with regard to costs and realisation, than, for instance, the LNG scenario. In case of a 100% biofuels the effect would likely be around 40%.

8. Digitalisation of the transport chain creates opportunities to increase the utilisation rate of the hinterland modes, and thus reduce both internal and external costs. This is especially relevant for ports with large shares of rail transport and inland navigation. This digitalization scenario can be realized at much smaller investments than the other scenarios. However, it does require market parties in the transport chain to cooperate and to be transparent.

9. When the emissions (GHG and air pollutants) of rail transport decrease as a result of a larger share of renewable energy in the energy mix used by infrastructure providers, there will be a significant effect on port choice if both internal and external costs are taken into account. The ports of the Hamburg – Le Havre range will profit to a large extent. The energy mix used by rail infrastructure influences the degree of CO₂ reduction that can be achieved. The largest effect can be obtained in Germany and, especially, Poland. In these countries, trains run on a large share of coal based energy. This is in contrast with France, where trains are already nearly climate neutral.
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  o North Sea Baltic Corridor
  o Mediterranean Corridor
  o Orient/East-Med Corridor
  o Rhine-Alpine Corridor
  o Atlantic Corridor
  o North Sea-Mediterranean Corridor
  o Rhine-Danube Corridor
  o Baltic-Adriatic Corridor


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Appendix 1  Model description

A model has been developed for the logistics chain that can calculate cost effects and environmental effects for the entire logistics chain from a seaport in China to any destination in Europe. Based on the model outcomes, transport routes and transport modes can be selected that are able to perform transport at minimal costs and/or environmental effects. The environmental effects that are investigated are climate effects (related to the emission of CO₂) and air pollution (related to the emission of NOₓ, SO₂ and PM). Well-to-wheel (or propeller) emission factors have been applied, using relevant sources such as the IMO GHG Study of 2014.

Conceptual model

In the figure below a conceptual overview of the model is presented. The model determined the costs from one destination in China to all possible destinations in Europe.

Figure: Conceptual overview of the transport model

The first step is to go from a Chinese port to a seaport in Europe. After that, four transport options are included: road, short-sea, inland waterway and rail. The links that are included were based upon current inland freight services available at specific European seaports.

From European seaports it is possible to reach all the 1375 NUTS-3 destinations that are included in the model by road. Furthermore, the model includes a elaborated and Europe-covering range of intermodal options via:

- short-sea shipping (feeder services) offered from any of the deep-sea ports included in the model.
- as well as inland waterway transport. Wherever it is possible to transport containers from a seaport via an inland waterway for all seaports that offer...
intermodal connections by barge: Antwerp, Bremen, Fos-sur-Mer, Hamburg, Le Havre, Rotterdam and Venice. Approximately 90 destination inland waterway terminals are included.

- Or transport by rail. The rail connections that are included are based upon the Interactive map offered by DB Netze\(^43\) that includes over 700 rail-road terminals in Europe and 800 intermodal services in 33 countries offered by circa 150 intermodal rail operators. In total there are 1537 connections included. The model can take both direct and indirect connections (via hubs where wagon sets can interchanged between intermodal trains) into account. An example of an indirect connection: from Algeciras there is only a connection to Barcelona and Madrid. However, from Barcelona it is possible to reach Antwerp.

Our model includes a total of 497 short-sea, inland waterway and rail terminals. For each of these terminals it is possible to reach each final destination, using last-mile services via road transport.

**Costs**

The model calculates the most efficient route, using (1) only internal costs, and (2) a combination of internal and external costs. The external costs are based on the emissions of CO\(_2\), SO\(_2\), NO\(_x\), and PM and shadow prices applied. For every mode the CO\(_2\)-, SO\(_2\)-, NO\(_x\)-, and PM-emissions per container for every service is determined. The shadow prices used to calculate the costs in Euro are shown in the table below.

### Table: Shadow prices used to calculate the costs in Euro

<table>
<thead>
<tr>
<th>Emissions costs (inland modes)</th>
<th>Emissions costs (sea modes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO(_2) € 85 per tonne</td>
<td>CO(_2) € 2,320 per tonne</td>
</tr>
<tr>
<td>SO(_2) € 16,643 per tonne</td>
<td>SO(_2) € 120,600 per tonne</td>
</tr>
<tr>
<td>NO(_x) € 11,606 per tonne</td>
<td>NO(_x) € 11,606 per tonne</td>
</tr>
<tr>
<td>PM € 197,630 per tonne</td>
<td>PM € 197,630 per tonne</td>
</tr>
</tbody>
</table>

*Source: Pantela, 2016*

For sea transport the costs for SO\(_x\) and NO\(_x\) are less, in comparison to these costs for inland waterway, rail and road. Approximately 33% less for SO\(_x\) and 80% for NO\(_x\).

Per mode the internal and external costs will be discussed.

**Deepsea and short-sea**

Deepsea and short-sea will be discussed simultaneously, because the cost calculation method is the same in general.

**Internal costs**

The internal costs for the deep- and short-sea is the sum of the capital costs and the operating costs. Both are based on the vessel size and the length of the trip\(^44\). The length of the trip is split into sailing time and port dwell time. The sailing time depends on port-to-port distances; the port dwell time is assumed to equal 1.5 day per port call. The total port dwell time costs are equally divided over the different ports. Apart from operating costs, fuel costs are taken into account as well, using all available information on the daily fuel consumption of vessels at the design speed. In order to compensate for slow steaming (at 18 knots an hour for seagoing vessels), we

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\(^{43}\) The interactive map is accessible via [http://fahrweg.dbnetze.com/../_kv_terminals_karte.html](http://fahrweg.dbnetze.com/../_kv_terminals_karte.html)

have applied a correction factor that equals the relation between fuel consumption and the vessel speed.\textsuperscript{45}

The second cost sort that contribute to the total internal costs are the port dues. These costs differ per port and the costs calculation may vary. Apart from port dues, also costs for pilotage, towage and mooring are taken into account for different European ports. The third cost sort that contributes to the total internal costs are container rental costs. We have assumed these costs to equal € 200 per trip. The figure below shows an overview of the steps to calculate the internal costs for deepsea and short-sea.

Figure: Overview of steps to calculate the internal costs for deepsea and short-sea

\textbf{External costs}

In the figure below an overview is shown of the steps that are taken in order to calculate the external costs for deepsea and short-sea.

Both heavy fuel oil (HFO) and marine gas oil (MGO) are calculated. We have assumed that both deep-sea and short-sea vessels use marine gas oil in SECA areas. The fuel consumption is calculated using the distance of a route, the speed of the ship and the fuel consumption per tonne per day at design speed, corrected for slow steaming at

\textsuperscript{45} In general, this yields a power curve formula with a power of 3.3.
18 knots per hour. Distances are determined using the Voyage planner of Marinetraffic\(^{46}\)

The fuel consumption per tonne per hour is differentiated for every vessel deployed on liner services. Using fleet databases, we could estimate the daily fuel consumption per vessel. A weighted average is calculated for every services, based on the ships that are used and the number of TEU that these ships can transport. Emission factors have been derived the IMO Tier 2 emission factors for main engines and have been applied differently for HFO and MGO fuel.

After the determination of \(\text{CO}_2\), \(\text{SO}_2\), \(\text{NO}_x\), and PM-emissions per container for every service, the lowest possible costs will be used as input for the model. The Sulphur Content in HFO is assumed to equal 2.7%.

Figure: Overview of steps to calculate the external costs for deepsea and short-sea

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\(^{46}\) This voyage planner takes in to account port-to-port routes, obtained from AIS-mappings: [http://www.marinetraffic.com/nl/voyage-planner](http://www.marinetraffic.com/nl/voyage-planner)
Inland waterway
Both the internal and external cost calculations for the inland waterways will be explained in the next sections.

Internal costs
The total costs per container are dependent on the costs of the used vessel and the load of that vessel. The costs of the vessel are based on the time needed for a trip between the seaport and the intermodal terminal. The time is determined by taking into account different sailing conditions, such as:
- constraints as a result of the size of the vessel,
- the maximum allowed draught for the vessel (assuming normal water levels on the Rhine river)
- and a maximum number of layers of containers that can be stacked, given the bridge clearances (at normal water levels at free flowing rivers).

The emission factors applied relate to the CCNR stage 2 standards\(^\text{47}\). Costs originate from annually updated cost models from Panteia\(^\text{48}\). The figure below shows the way the internal costs for inland waterway transport are calculated.

Figure: Overview of steps to calculate the internal costs for inland waterway transport

\[ \text{Inland waterway} \]

\[ \text{Weight load [kg]} \]

\[ \text{1 TEU} = 11 \text{ tonne} \]

\[ \text{Costs vessel [€]} \]

\[ \text{Weight load [TEU]} \]

\[ \text{Costs per container per link [€]} \]

Source: Panteia, 2016

External costs
The external costs are determined based on the diesel consumption between the origin and destination port per ship. A dedicated IWT model, used in different European studies (Platina II, Impact Assessment of measures for reducing emissions of inland navigation) is used to predict fuel consumption by barges and convoys. This model, effects of low and high water levels, sailing conditions (river, canal or lake) and directions (upstream vs. downstream) and partial loads are considered, as well as empty trips.

\(^{48}\) [http://webshop.panteia.nl/Binnenvaart](http://webshop.panteia.nl/Binnenvaart)
This consumption can be converted into fuel consumption in kilogram for the total trip. Based on this fuel consumption, the different emissions are determined. The figure below shows a schematic overview calculation of the external costs for inland waterway transport.

Figure: Overview of steps to calculate the external costs for inland waterway transport

---

Diesel consumption between origin and destination port per ship (l)

Fuel consumption OD port per container (kg)

Factor CO₂: 3.2

Factor SO₂: (0.1*20)

Factor NOₓ: 6 g / KWh

Factor PM: 0.3 g / KWh

CO₂ per container per link (kg)

SO₂ per container per link (kg)

NOₓ per container per link (kg)

PM per container per link (kg)

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Source: Panteia, 2016

**Rail**

Both the internal and external cost calculations for the rail mode will be explained in the next sections.

**Internal costs**

The internal costs for the rail mode are divided into access charges, energy costs, personnel costs, traction costs, wagon costs and marshalling costs. The access charges differ from country to country and have been derived from OECD (2008)49. Each country has its own access charge. The energy costs are dependent on the distance travelled. The personnel costs are related to the labor costs and the time the train is running, which is based on the distance. The traction costs and wagons are based on the time the locomotive and wagons are used; the more the locomotives and wagons are used, the more expensive the rental costs.

The marshalling costs are fixed for every link and set at € 800 for a roundtrip.

After summing up all these costs, a profit margin of 15% and an occupancy rate of 75% is taken into account to estimate the costs per TEU transported. The figure below shows the way the internal costs for rail transport are calculated.

Figure: Overview of steps to calculate the internal costs for rail transport

Source: Panteia, 2016

**External costs**

External costs of the rail transport are based on the energy consumption, which is determined from the distance travelled per country. Conversion factors for different countries are used to determine the total emissions. These are based upon IFEU (2014). The figure below shows a schematic overview calculation of the external costs for rail transport.
Figure: Overview of steps to calculate the external costs for rail transport

Road
Both the internal and external cost calculations for the road transport will be explained in the next sections

Internal costs
The total internal costs of each trip are calculated based on the fixed and variable costs. The fixed costs are based on the time a trip takes. The variable costs are related to the number of kilometers of a trip. Both time and kilometers are obtained from ETIS (2010). Costs for container transporting trucks are obtained from annually updated transport models from Panteia. The costs when using a truck and driver from the origin country and a truck and driver from the destination country are then compared and the least expensive combination is chosen. The figure below shows the way the internal costs for road transport are calculated.

Source: Panteia, 2016

Panteia (2016), Kostenvergelijking en kostenontwikkelingen voor het beroepsgoederenvervoer over de weg in Europa
Figure: Overview of steps to calculate the internal costs for road transport

<table>
<thead>
<tr>
<th>Road</th>
<th>Fixed costs [€ per year]</th>
<th>Time of a trip [hour]</th>
<th>Distance [km]</th>
<th>Variable costs [€ per km]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fixed costs [€ per trip]</td>
<td></td>
<td></td>
<td>Variable costs [€ per km]</td>
</tr>
<tr>
<td></td>
<td>Total internal costs</td>
<td></td>
<td></td>
<td>of a trip [€]</td>
</tr>
</tbody>
</table>

Source: Panteia, 2016

**External costs**

The external costs are related to the distance between the origin and destination and the fuel consumption of the truck. This has been set at 1 litre of diesel for every 3.2 kilometres. Using emission factors for Euro VI trucks, emissions of NOₓ and particles have been calculated. We have assumed a load factor of 1.5 TEU per truck. The figure below shows a schematic overview calculation of the external costs for road transport.

Figure: Overview of steps to calculate the external costs for road transport

Source: Panteia, 2016