Background Report | November 2017

Decarbonisation-driven future changes in European transport

Project „Deep Decarbonisation Pathways for Transport and Logistics Related to the Port of Rotterdam“ (PoR Transport)

Deliverable Work Package 2

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on behalf of

Port of Rotterdam

Wuppertal Institut

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The overarching conclusions of the synthesis report are decisive.
Wuppertal Institute (2018): Deep Decarbonisation Pathways for Transport and Logistics related to the Port of Rotterdam. Synthesis Report. Authors: Stefan Lechtenböhmer, Dorothea Schostok, Georg Kobiela, Katharina Knoop, Andreas Pastowski, Simon Heck. On behalf of the Havenbedrijf Rotterdam Nv.
https://nbn-resolving.org/urn:nbn:de:bsz:wup4-opus-71405

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Status: November 2017

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1 Introduction

The Rotterdam Port Authority commissioned the Wuppertal Institute to investigate potential deep decarbonisation pathways for its transport business and sector for the period until 2050.

The key issues to be analysed in the framework of the study are:

- How can freight transport activity linked to the Port of Rotterdam be decarbonised?
- How will a decarbonised world in 2050 affect transport and logistics at the Port?
- How can the Port of Rotterdam support the decarbonisation of (maritime) transport?
- How can the Port adapt its business model to a climate-friendly future?

This is a follow-up project to an earlier study in which the Wuppertal Institute conducted for the Rotterdam Port Authority which focused on decarbonisation pathways for the Port's industrial cluster. In general, the Port of Rotterdam, with annual CO_2 emissions of well over 30 million tonnes, has been showing a keen interest in learning about ways to significantly reduce its greenhouse gas (GHG) emissions for years. If significant emissions abatement was achieved, the Port would make an important contribution to the implementation of the Paris Agreement and the achievement of the current European Union (EU) target of reducing GHG emissions by 80 to 95 per cent by 2050.

This deliverable presents in further detail the analysis done in the framework of Work Package 2. The main question to be answered was

What are the likely changes in the European transport sector if Europe will reduce its GHG emissions until 2050 in line with what has been agreed politically (i.e. GHG emission reduction by 80 to 95% by 2050, relative to 1990)?

In order to answer this question, a meta-analysis of scenario studies has been conducted. It comprised scenarios with a focus on the energy systems or transport scenarios for global, European as well as country-specific developments in the period up to 2050. Global developments and overseas trade were included in the analysis as they strongly influence the volume and share of cargo handled at the Port of Rotterdam in 2050.

The findings of this Work Package 2 constitute the basis for the assumptions underlying the scenario development in the framework of Work Package 4. It encompasses the quantification of the potential future transport activity linked to the Port of Rotterdam and the resulting environmental impact in 2050. The assumptions made for the scenario and the reasoning behind are also included and explained in this report.

2 Methodology and sources

2.1 Methodology

In order to identify the likely changes in a decarbonised European transport sector by 2050, sustainability-oriented scenario studies are examined which provide quantitative and/or qualitative estimates on the development of particular aspects of the transport system. The focus of this analysis lies on two indicators which strongly influence future GHG emissions in the Port of Rotterdam area:

- *Freight transport demand*
  The analysis of this indicator is divided into three sub categories:
  - Overall freight transport demand (globally/EU/the Netherlands):
    Freight transport activity in tonne-kilometer (tkm), i.e. the product of the freight's weight and the distance travelled. This indicator includes changes in the average distances of freight transport (e.g. in the case of growing international trade), which constititute an important factor especially in the future level of GHG emissions from international shipping.
  - Composition of cargo:
    One important factor influencing the future level of global trade activity and thus freight transport is the demand for different types of goods. Measures aiming at GHG emission reduction in Europe certainly influence e.g. the consumption of fossil fuels and thereby also the corresponding transport volumes. Besides energy producers and consumers, emitters of process emissions such as basic materials processing industries will strive for GHG emission abatement. The implementation of innovative production processes could have an impact on demand for, sourcing and transport of commodities such as ores and metals as well as intermediate products, such as processed chemicals. Lastly, by adopting more sustainable lifestyles and e.g. demanding mainly locally sourced products, also „ordinary" consumers can affect trade activity levels.
  - Transport routes:
    Depending e.g. on global economic (e.g. labour costs) and political (e.g. crises in exporting countries) developments, effects of decarbonisation efforts in Europe (e.g. demand for products sourced in other countries than currently imported products) as well as demand for certain products, transport routes are subject to changes. Especially in the case of international shipping, these changes can have an impact on the GHG emissions attributed to the Port of Rotterdam. Therefore, they are examined in further detail in this study.

Freight transport demand is also strongly influenced by GDP development (IEA 2017, p. 88). While this analysis does not concentrate on the scenario studies' assumptions regarding GDP growth, the strong influence of economic developments on transport demand should always be taken into account.

- *Share of freight transport modes/modal shift*
  Maritime shipping, road and rail transport as well as inland navigation differ considerably with regard to their particular energy efficiency, if measured per tonne kilometre. Therefore, GHG emissions in transport and logistics vary significantly

if a modal shift between different transport means occurs. This analysis shows in how far different scenario studies expect modal shifts to occur in freight transport by 2050.

Another very important indicator, the fuel mix and energy demand of freight transport modes in 2050, is not analysed in further detail here. Instead, it is part of Work Package 1 on „Current and potential future technologies for transport decarbonisation“. Linked to this indicator are the cost of transport, which in turn affect the demand for freight transport.

2.2 Sources

Before starting the meta-analysis of scenario studies, a literature research had been conducted in order to identify relevant suitable scenario studies to be included in the analysis. The literature research consisted of three steps:

- *Step 1: Analysis of EU-related scenario studies (focus: energy system)*
  In order to allow for comparability with the study on the industrial cluster of the Port of Rotterdam, the first studies to be analysed were those also examined (with a different focus) for the previous study:
  - Energy Roadmap 2050 (EC 2011)
  - energy [r]evolution (Greenpeace et al. 2015)

  Moreover, more recent versions of studies by the International Energy Agency and the European Commission which were analysed in the framework of the previous project have been included:
  - Energy Technology Perspectives 2017 (IEA 2017)
  - European Strategy for Low-Emission Mobility (EC 2016)

  During the literature research further suitable scenario studies could be identified:
  - Scenario-based assessment of the competitiveness of the European transport sector (CERTH/HIT et al. 2014)
  - Renewables in Transport 2050 (FVV 2016)

  However, the analysis of these scenario studies only yielded insufficient data for answering specific aspects of the research question and developing hypotheses on the future development of certain indicators as a basis for the scenario development in Work Package 4. Therefore, a search for further scenario studies providing more detailed information on the likely future changes of the transport and logistics sector was conducted:

- *Step 2: Inclusion of studies with a narrower focus*
  During the literature research in step 2, suitable studies concentrating on the following aspects could be identified:
  Focus transport and logistics sector:
  - ITF Transport Outlook 2017 (OECD/ITF 2017)

  Specific transport modes (e.g. maritime shipping/road/rail/inland navigation):
  - Study on the Analysis and Evolution of International and EU Shipping (TPR 2015)

Transport and logistics in specific countries:
- 2016 Benelux report freight transport (Benelux Union 2016)
- Nederland in 2030 en 2050: Twee referentiescenario's (CPB/PBL 2015)
- Renewbility III (Öko-Institut et al. 2016), focus on Germany
- Klimafreundlicher Verkehr in Deutschland (WWF et al. 2014), focus on Germany
- Treibhausgasneutraler Verkehr 2050 (Öko-Institut 2013), focus on Germany

Time frame shorter than 2050:
- GHG emission reduction potential of EU-related maritime transport and on its impacts (TNO 2015)

These studies provide many valuable information on the potential future development of the transport and logistics sector by 2050. Nevertheless, a third step was added to gather further data on future production and consumption levels influencing the type and amount of cargo handled by the Port of Rotterdam:

- *Step 3: Inclusion of non-transport parts of decarbonisation studies*

The studies which were identified focus on the following issues:
Deep decarbonisation strategies for the energy system:
- Treibhausgasneutrales Deutschland (UBA 2014)
- Wuppertal Institute studies

Production of bulk materials:
- IEA 2017
- Wuppertal studies

Effects in food sector
- Treibhausgasneutrales Deutschland (UBA 2014)

The analysis of the different types of scenario studies showed that only very few scenarios provide data on both international shipping and hinterland freight transport. This is probably due to the international nature of shipping (as of air transport) which makes it hard to attribute the resulting emissions to specific countries. Currently, emissions from international shipping are accounted for in the national greenhouse gas inventories, but only in such a way that those fuels bunkered at ports are recorded in the accounts. This approach puts countries with important bunker ports (such as the Port of Rotterdam) at a certain disadvantage.

The differences between freight transport by sea or in by road, rail and inland navigation in the hinterland made it seem reasonable to also examine them separately in our analysis. Therefore, the above-mentioned methodological approach has been applied first to maritime shipping (Chapter 3.1) and then to hinterland transport (Chapter 3.2).

3 Results and discussion

3.1 Maritime shipping

Currently, 80 per cent of global trade (in physical units) is carried out by the shipping sector. Nevertheless, shipping is only responsible for 2 per cent of CO_2 emissions from fuel combustion (IEA 2017, p.88). In the future, the analysed scenario studies expect the level of global GHG emissions from international shipping to rise. IEA 2017 (p. 257) credits this to the expected increase of demand for shipping services[1] and the lack of regulation to constrain GHG emissions. However, if the 2 degree target or even a level below 2 degrees should be achieved, international GHG emissions must be significantly reduced also in maritime shipping. According to the IEA's most recent scenarios, the pathway towards a temperature rise beyond 2 degrees („Beyond 2°C Scenario" or B2DS) can only be realised if in 2060 (well-to-wheel) GHG emissions per tonne kilometre are 69% lower than in the baseline scenario (called „Reference Technology Scenario" or RTS) and 70% lower than in 2015. It should be noted that the RTS scenario reflects the world's current ambitions and already takes into account existing political energy- and climate-related objectives, such as the Nationally Determined Contributions pledged under the Paris Agreement (IEA 2017, p. 8).

As pictured in Figure 1, the IEA projects the application of different kinds of measures in international shipping for the sector's contribution to significant global emission reductions (IEA 2017, p. 258). The largest GHG emission abatement potential is attributed to operational and technological efficiency improvements in combination with wind assistance. A decrease in future transport activity (due to avoided fossil fuel demand) or variations in the ships' fuel mix (due to the use of advanced biofuels) only play a minor role in the B2DS scenario.

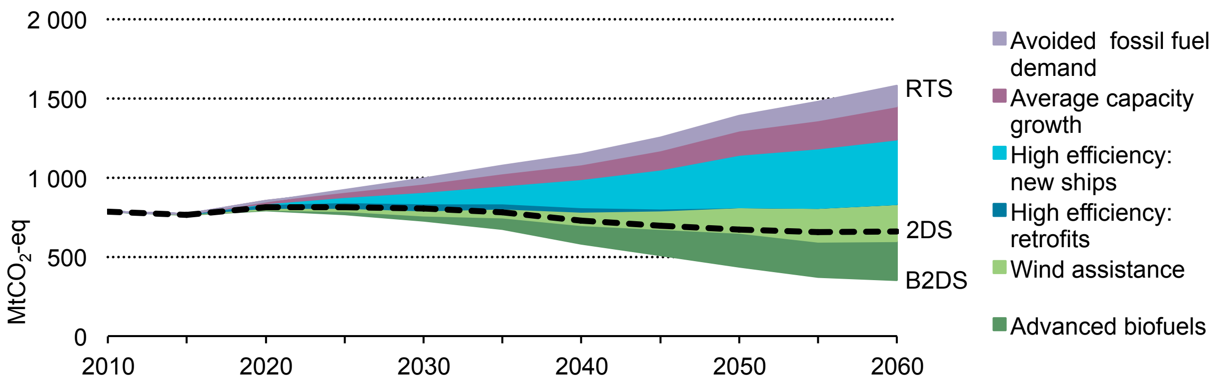

Figure 1 Well-to-wheel GHG emission reductions in international shipping in the B2DS relative to the RTS

Source: IEA 2017, p. 258

[1] On the global level, an average annual real GDP growth rate of 2.9 per cent is assumed for 2014 to 2060 (IEA 2017, p. 408). The EU economy is projected to grow by 1.5 per cent annually in the same period of time. GDP growth rates are assumed to be identical across scenarios.

In the following, it will be described how different scenario studies expect the maritime shipping sector to develop in the long-term. The analysis focuses on the likely changes in the transport sector if Europe will reduce its GHG emissions until 2050 in line with what has been agreed politically.

3.1.1 Transport Activity

Historic developments and forecasting method

Over the last four decades, global demand for maritime shipping has been growing constantly[2]. As Table 1 shows, the level of global sea freight work (maritime transport activity in tonnes multiplied with the covered distance, here nautical miles) in 2012 was 268 per cent higher than in 1970. Increases in transport volumes of all types of cargo[3] contributed to this development.

While developments in the area of freight transport activity can also be stated in simple weight units (usually tonnes, t), this analysis focuses on the level of freight transport activity (or freight work, mostly in tonne-kilometer, tkm, i.e. the product of the freight's weight and the distance travelled). This indicator includes changes in the average distances of freight transport (e.g. in the case of growing international trade), which constititute an important factor in the future level of GHG emissions.

As noted by the IEA (2017, p. 88), „[s]hipping activity is closely linked to gross domestic product (GDP) growth". Between 1970 and 2012, along with freight work, global GDP[4] rose by a similar degree, resulting in an increase of 252 per cent (TNO 2015). For the decades since 1970, GDP and freight work have been developing at similar rates. As this relationship has proven comparatively stable in the past, it is often used as proxy to forecast the future development of freight work.

Table 1 Development of global freight work and global GDP in billions since 1970

Year		1970	1980	1990	2000	2007	2010	2012
Total Dry Bulk except coal	ton nm	1 900	3 000	3 500	4 300	7 200	8 300	9 200
Coal	ton nm	600	900	1 900	2 400	3 900	4 400	5 000
Other Dry cargo	ton nm	2 200	3 500	3 900	7 400	12 400	12 600	14 400
Total oil transported	ton nm	6 500	10 200	7 200	9 600	11 500	11 600	12 200
Other Cargo	ton nm	1 500	2 300	2 200	3 200	4 400	5 300	5 400
Freight Work	ton nm	12 600	19 800	18 700	26 800	39 300	42 200	46 200
Global GDP constant 2005	USD	16 200	23 100	32 300	41 500	52 300	53 900	56 900
Freight increase from 1970			58%	49%	113%	213%	236%	268%
GDP increase since 1970			43%	100%	157%	224%	233%	252%

Source: TNO 2015, p.15

[2] The main drivers underlying global demand for maritime shipping are outline in Chapter 2.1.

[3] The figures on actual freight work from 1970 to 2010 base on UNCTAD figures published in the IMO 2014 GHG study (IMO 2014). Freight work here includes: dry bulk excluding coal; coal; other dry cargo; oil transport (crude & products); other cargo (chemicals, LNG, LPG, other liquids). Coastal national transport between domestic ports or crude by shuttle tankers to land terminals domestically is not included in Table 1.

[4] Expressed in constant PPP-adjusted USD

Many current scenario studies (see e.g. TNO 2015) assume that the future level of maritime transport demand will develop in line with the economic growth rate, i.e. a one-to-one percentage development. Using an average expected future GDP growth rate, this assumption is applied in scenarios for worlwide maritime freight work but also for freight transport activity in particular regions, such as the EU.

Further, the assumption of a one-to-one future development relationship of GDP and maritime transport demand is not only used as a basis for the studies' (mostly rather unambitious) business-as-usual or reference scenarios. In contrast, it also serves as a basis for several climate protection or GHG emission abatement scenarios. TNO 2015 e.g. bases its scenarios, including the „CO_2 abatement scenarios" for Europe for 2030, on an average European GDP growth rate of 1.55% for the years 2012 to 2030 (TNO 2015, pp. 35, 67)[5].

Other studies – among them the second IMO GHG study (IMO 2009) – use the same methodology in a slightly different form for forecasting future transport activity. The studies' authors base their calculations on the assumption that a certain decoupling of freight work from GDP takes place, assuming e.g. a 0.8-to-one percentage development. As a result, maritime transport activity increases e.g. by 80% if GDP doubles.

Country-specific studies have also been analysed. However, since only one suitable scenario study for the Netherlands for 2050 could be identified, some sustainability-oriented scenarios for Germany were taken into account to amplify the data base. Scenarios like the „Klimaschutzszenario 2050" (Climate protection scenario 2050, Öko-Institut/Fh ISI 2015, p. 110) or „Renewbility III" (Öko-Institut et al. 2016) base their forecasts for future freight transport activity on studies by other organisations, e.g. (IMO 2009), (UNCTAD 2011) and the German goverment's traffic forecast for 2030. The growth rate derived from other studies combined with the expected (decreasing) German share of global GDP[6] then leads to the amount of freight transport activity for Germany e.g. in 2050.

The definition of country-specific data for seaborne trade activity constitutes another methodologic difficulty in the modelling process. While most studies only include goods transferred via German ports, others – such as THGNV (Öko-Institut 2013, pp.14f) – also encompass trade flows initiated in Germany but processed via foreign ports, mainly the ZARA ports (Zeebrugge, Amsterdam, Rotterdam, Antwerp) (causative principle). This underlines the fact that most scenario results are not easily comparable and it has to be taken into account that definitions vary between studies.

[5] Conducting a sensitivity analysis with a lower GDP growth rate of 0.77 per cent (and an proportionate development of freight work), however, it is concluded that the assumed GDP growth rate has an „enormous influence" on the annual CO_2 emissions of European maritime transport (TNO 2015, p. 37)

[6] Öko-Institut (2013, p. 15) e.g. assumes that Germany's share of global GDP will decrease from 5.2 per cent in 2010 to 2.37 per cent in 2050.

Future transport activity under decarbonisation

Global level

On the global level, all analysed baseline scenario studies expect a strong future increase in maritime transport activity. This development is attributed to growing populations and a rise in global GDP[7]. Especially long-distance international trade is projected to increase, leading to higher average freight transport distances and a disproportional growth of seaborne freight work (in tkm) compared to seaborne trade volume (in t) (Öko-Institut et al. 2016, p.148).
Compared to the baseline scenarios, climate protection or GHG abatement scenarios expect lower growth rates for maritime freight transport activity (see Figure 2). However, none of the analysed scenarios assumes a negative development of global seaborne trade activity.

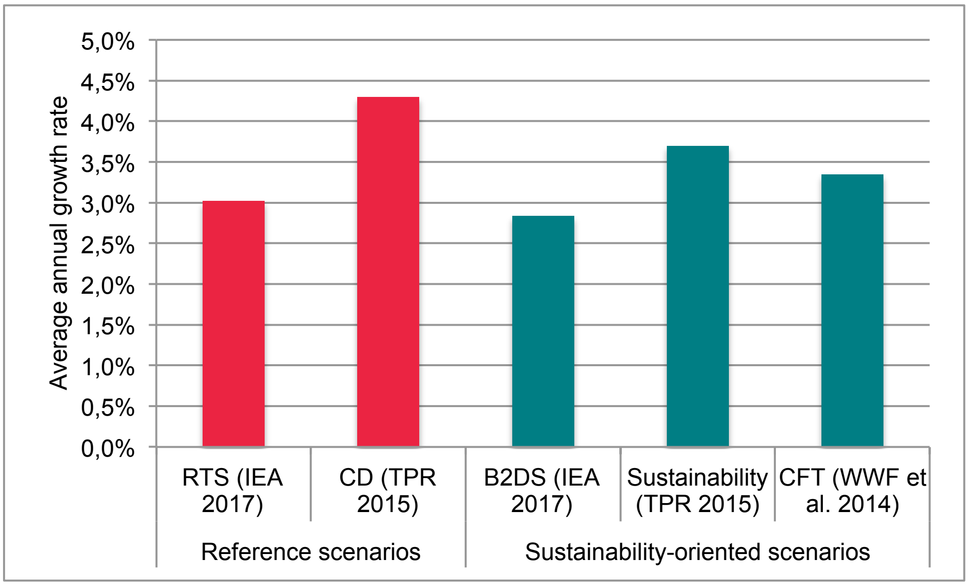

Figure 2 **Assumed average annual development of future seaborne trade activity on the global level in different scenarios***

Source: Own figure

** The period of time for which the growth rate is assumed slightly varies between the scenarios: 2015-2060 for RTS & B2DS, 2010-2050 for CD & Sustainability, today (assumption: 2012)-2050 for Cft*

With regard to the baseline development, e.g. in the IEA's ETP 2017 „Reference Technology Scenario" (RTS) – which mirrors the world's current ambitions – annual maritime freight activity is assumed to grow from 99 trillion tkm in 2015 to 377 trillion tkm in 2060 (IEA 2017, p.258). Thus, the average annual growth rate amounts to 3.02 per cent. Compared to the TPR's (2015) „Conventional development" (CD) scenario, a high economic growth scenario with an energy system dominated by fossil fuels, this growth rate can be considered relatively modest. In line with GDP development, the CD scenario projects an average annual freight activity increase of 4.3 per cent.

[7] The IEA's ETP 2017 (p. 408) study e.g. assumes a global average annual real GDP growth rate of 2.9 per cent for 2014 to 2060, see 1.

If additional very ambitious climate protection measures would be implemented rapidly, as assumed in the same studies' „Beyond 2°C Scenario" (B2DS), the increase could be lower. Nevertheless, it would still amount to 349 trillion tkm in 2060 (IEA 2017, p. 258), resulting in an average annual increase of 2.84 per cent. The difference compared to the baseline results from lower demand for trade in fossil fuels. The issue that demand reduction could partly be compensated by a growing trade of advanced biofuels and the feedstock required for their production has not been taken into account in the scenario.
Another sustainability-oriented scenario, the „Sustainability Scenario" by TPR 2015 (p. 59), implies an annual average increase of global maritime transport of 3.7 per cent between 2010 and 2050. Again, this value is based on the assumption that maritime freight growth is in line with GDP growth (TPR 2015, p. 59).
The scenario „Climate-friendly transport" (CFT, WWF et al. 2014) assumes that – with regard to current developments and assumptions by the IMO (2009) – global seaborne trade activity will annually increase by about 3.5 per cent (on average).

EU level

The analysed scenario studies project overall seaborne trade activity in the EU to increase, but to a lesser extent than on the global level. For the EU, this assumption is also mostly derived from the expected average future economic growth rate. Since this is lower in the EU than globally, so are the projected future seaborne trade activity and the EU's future share of global maritime transport activity. Baseline scenarios for the EU expect maritime transport activity in the EU to rise on average by at least 1 per cent annually between 2010 and 2050. If the implementation of additional sustainability-enhancing measures is assumed, seaborne trade activity in the EU is expected to rise slowlier, i.e. by about 1 per cent or less (see Figure 3).

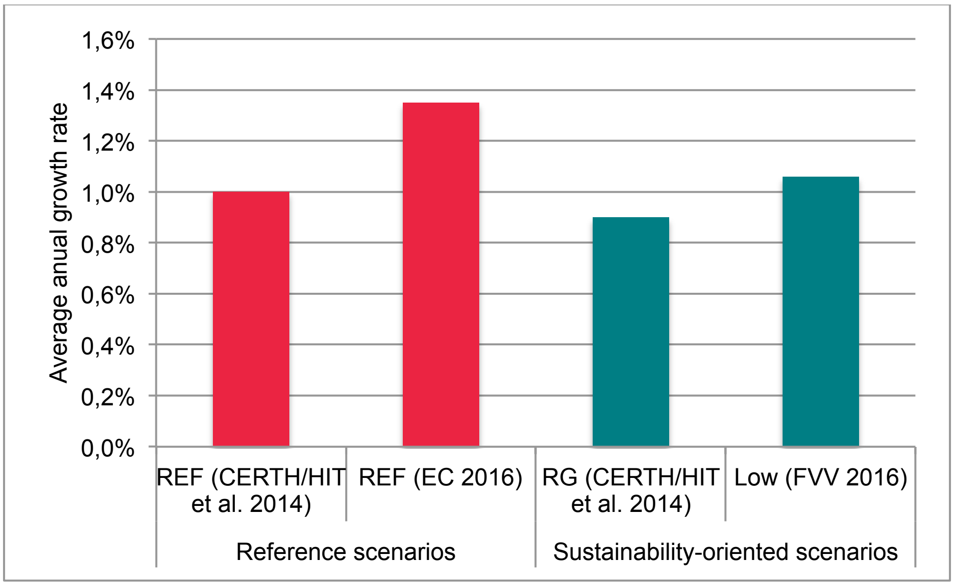

Figure 3 **Assumed average annual development of future seaborne trade activity in the EU in different scenarios between 2010 and 2050**

Source: Own figure

The EU's 2016 Reference scenario indicates that international seaborne trade activity could rise on average by 1.35 per cent per year. This assumption is ascribed to a rising demand for oil, coal, steel and other primary resources. Sourcing these resources from more distant places would further increase the average freight transport distances travelled (EC 2016, p.27). The Reference Scenario from the FUTRE study assumes an average annual growth of searborne trade activity of 1 per cent per year between 2010 and 2050.

In contrast, the FUTRE study's „Responsible Growth Scenario“ takes into account a more sustainable consumption of private households and a trend towards more regional production cycles and demand for regional products (CERTH/HIT 2014, p. 60). As a result, maritime freight activity at EU level would experience an average annual growth rate of 0.9 per cent (CERTH/HIT 2014, p. 60). Overseas good transport demand in the „Renewables in transport“ (FVV 2016) study increases every year on average by 1.06 per cent between 2010 and 2050[8]. The TPR's (2015, p. 61) „Sustainability Scenario“ assumes growth in Europe's seaborne trade activity which is diminished by re-shoring, i.e. the return of production activity from China to Europe as a result of rising wage and transportation costs in Asia. This also increases the share of intra-European maritime transport.

The Netherlands

With regard to the development of seaborne trade activity in the Netherlands, one scenario study detailing data on future developments until 2050 could be identified. Although the form of the given information is not completely in line with those from the studies cited above (see remarks below), it was included in the analysis to give an impression of the future developments expected for transshipment via Dutch sea ports.

The PBL/CPB's scenarios for Prosperity and Living Environment (2015) consist of two scenarios for the period until 2050, the „High Scenario“ and the „Low Scenario“. While the first assumes increasing global cooperation and growth in world trade, the second one is based on an increasingly fragmented world and limited growth of international trade (Benelux Union 2016, p.68). Furthermore, the „High Scenario“ assumes the implementation of certain climate protection measures. In contrast, the „Low Scenario“ has no explicit focus on preventing climate change. One the one hand, it encompasses a higher oil price and results in lower final energy demand and GHG emissions than the „High Scenario“. On the other hand, the assumed CO_2 price as well as the share of energy from renewable sources are lower in the „Low Scenario“ than in the „High Scenario“ (CPB/PBL 2015, p.37).

[8] Although this study uses a different definition of „Overseas shipping“, which is not explicitly described in the study but results in significantly higher maritime goods transport demand for the different years, it is assumed to be reasonable to compare the implied average annual growth rates to those from other studies.

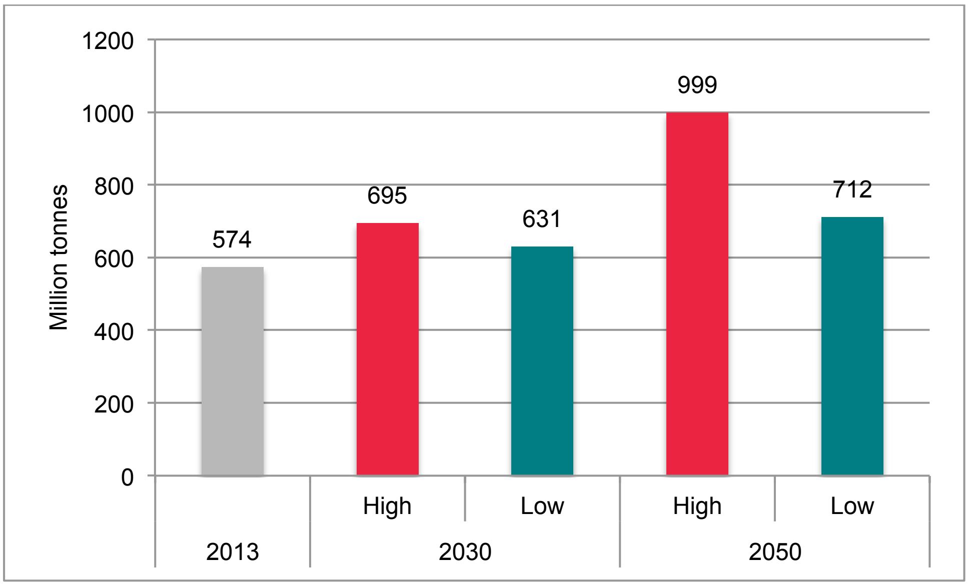

Figure 4 **Assumed development of transshipment via Dutch sea ports between 2013, 2030 and 2050 in the CPB/PBL's High and Low Scenarios (2015) in million tonnes**

Source: Own figure

Overall, the level of transshipment via Dutch sea ports is expected to rise in the future (see Figure 4). It should be noted that this study does not provide data on seaborne trade activity (in tkm, thus taking transport distances into account) but only on *trade volumes (in t)*.

In the „High Scenario“, transshipment increases by 74 per cent or an annual average of 1.5 per cent between 2013 and 2050. The „Low Scenario“ comprises a significantly slower growth of transport volume. It totals 24 per cent between 2013 and 2050, amounting to an annual increase of 0.6 per cent.

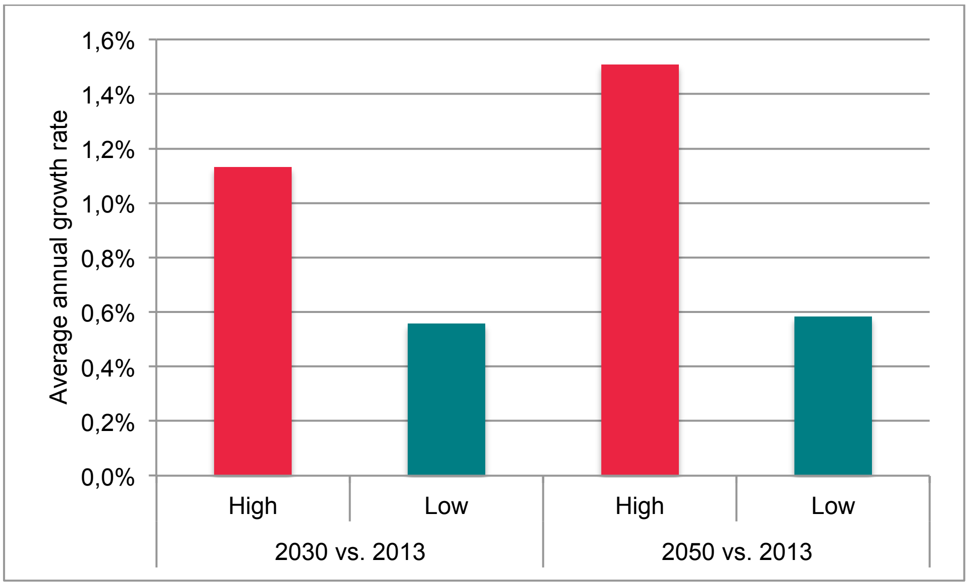

Figure 5 **Assumed average annual growth rate of transshipment (% of volume in mio. t) via Dutch sea ports between 2013, 2030 and 2050 in the PBL/CPB's High and Low Scenario (2015)**

Source: Own figure

According to Benelux Union 2016 (p. 69), the increases of transshipment volumes will partly result from the use of larger container ships. In view of the potentially higher volumes, the authors believe that capacity limitations will not be an issue for the Benelux sea ports „until well after 2030“ (Benelux Union 2016, p. 69). However, they recommend to „join forces to promote innovative forms of hinterland transport, such as synchro-modal transport, to increase the region's advantage in this area in Europe“ (Benelux Union 2016, p. 8).

The FUTRE study (CERTH/HIT 2014) features a figure illustrating the expected future changes in seaborne trade activity also for the Rotterdam region in 2030. It compares results for its „Responsible Growth Scenario“ with data from *its own reference scenario* (in percentage change of tkm)[9]. Figure 6 endorses the projections from Benelux Union 2016 in so far, as it shows that – even in an environment of lower economic growth[10]–, the Benelux sea ports are expected to reach a level of seaborne trade activity increase similar to that of the study's reference scenario.

[9] Unfortunately, the study does not provide the figure's underlying data.

[10] For both scenarios, an average annual GDP growth rate of 1.0 per cent is assumed – in CPB/PBL (2016, p. 27) for the Netherlands between 2013 and 2050, in CERTH/HIT (2014, p. 15) for the EU as a whole between 2010 and 2050.

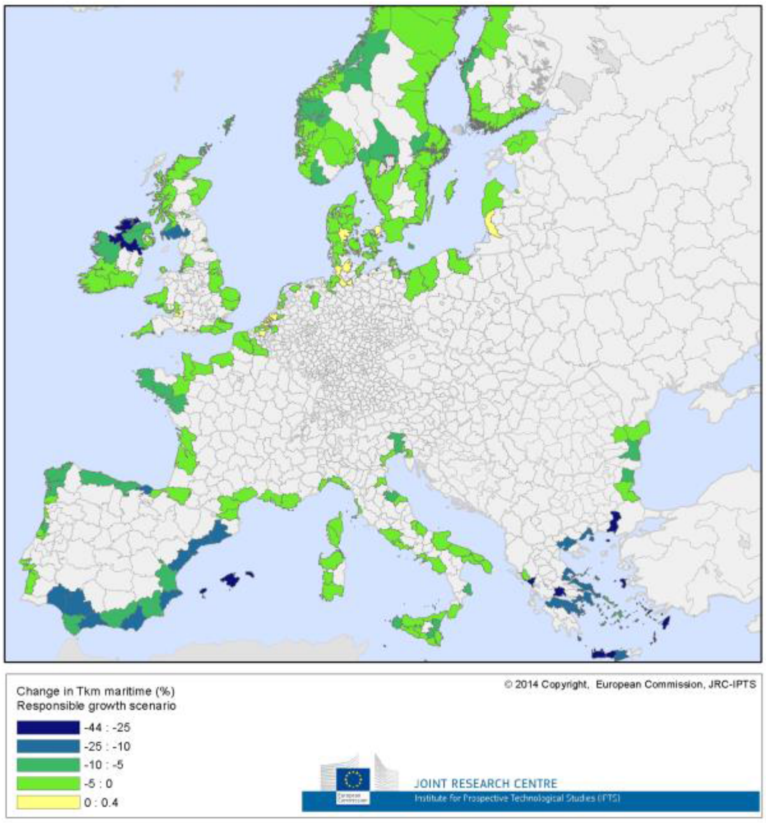

Figure 6 **Regional distribution of changes in maritime freight transport activity levels for the Responsible Growth scenario in 2030 (% in relation to the Reference scenario)**

Source: CERTH/HIT 2014, p. 90

Composition of cargo

One important factor influencing the future level of global trade activity and thus seaborne freight transport is the demand for different types of goods. Measures aiming at GHG emission reduction in Europe certainly influence e.g. the consumption of fossil fuels and thereby also the corresponding transport volumes. Besides energy producers and consumers, emitters of process emissions such as basic materials processing industries will strive for GHG emission abatement. The implementation of innovative production processes could have an impact on demand for, sourcing and transport of commodities such as ores and metals as well as intermediate products, such as processed chemicals. Lastly, by adopting more sustainable lifestyles and e.g. demanding mainly locally sourced products, also „ordinary“ consumers can affect seaborne trade activity levels.

In the following, it will be outlined which kind of development the analysed scenario studies expect for the various types of cargo transported by maritime shipping by 2050. Since the composition of freight is not in the focus of most scenarios, information on the type of cargo is mostly provided not in quantitative but in qualitative form, if it is included at all. As almost no region- or country-specific information is provided, the following scenario assumptions refer to global developments unless stated otherwise. However, some information on the potential impact of decarbonisation measures on the composition of maritime cargo was found for Germany. These will be shortly discussed and might be used as an indicator for the development in the Netherlands.

Wet bulk

Currently, the majority of wet bulk transports at the Port of Rotterdam are imports of fossil fuels (crude oil and petroleum products, such as fuel oil from Russia, diesel, gasoline and kerosine) as well as exports of petroleum products. Other important types of wet bulk are chemical base products (for packaging, construction etc.), vegetable oils (mainly palm oil, soy bean oil, rapeseed) and energy gasses (liquified natural gas, LNG).

Analysing the baseline scenarios, the TPR's (2015, p. 65) „Conventional High Economic Growth Scenario" assumes that **maritime gas but also oil transport** will „flourish" since fossil fuels remain the main source of energy. In order to satisfy global demand, innovative technologies are used to exploit deep sea or polar sources for oil and gas. Consequently, demand for oil tankers, liquified petroleum gas (LPG) and LNG vessels grows comparatively strongly (TPR 2015, p. 65).

In comparison with the reference scenarios, the sustainability-oriented scenarios especially deviate in terms of the maritime transport of fossil fuels.
For the global level, the TPR's 2015 „Sustainability Scenario" still projects a modest growth in the transport of conventional energy carriers such as oil (and also coal) (p. 60). Relatively, LNG transports achieve the highest growth rates. However, the increase in fossil fuel transports is comparatively low due to strong energy efficiency improvements and a rising use of energy from renewable sources. As the switch to renewables on the global level is expected to be realised rather in the long-term, demand for fossil only decreases after 2030. The developments towards more sustainability are possible because of technological progress and facilitated by international environmental regulations (TPR 2015, p. 60).

Considering country-specific scenarios, the „Renewbility" baseline scenario (Öko-Institut et al. 2016, p. 149) assumes that oil and petroleum freight levels at German ports rise by 24 per cent. As opposed to this, the study's „Efficiency Scenario" expects the overall amount of fossil fuels transported by sea via German ports to decline while the amounts of other types of cargo rise, especially container transport (see Figure 7 and Figure 8; container transport constitutes the major part of the category „Other dry cargo"). However, among the fossil fuels the level of oil and petroleum products is projected to stay more or less constant because oil and natural gas are predominantly imported into Germany via pipelines. As their share in the category „Oil & petroleum products" amounts only to about 2 per cent, demand reductions in the use of oil and natural gas are not adequately mirrored here. Generally, it should be noted that these developments are expressed *in freight volumes (t)* and do not take into account distances travelled.

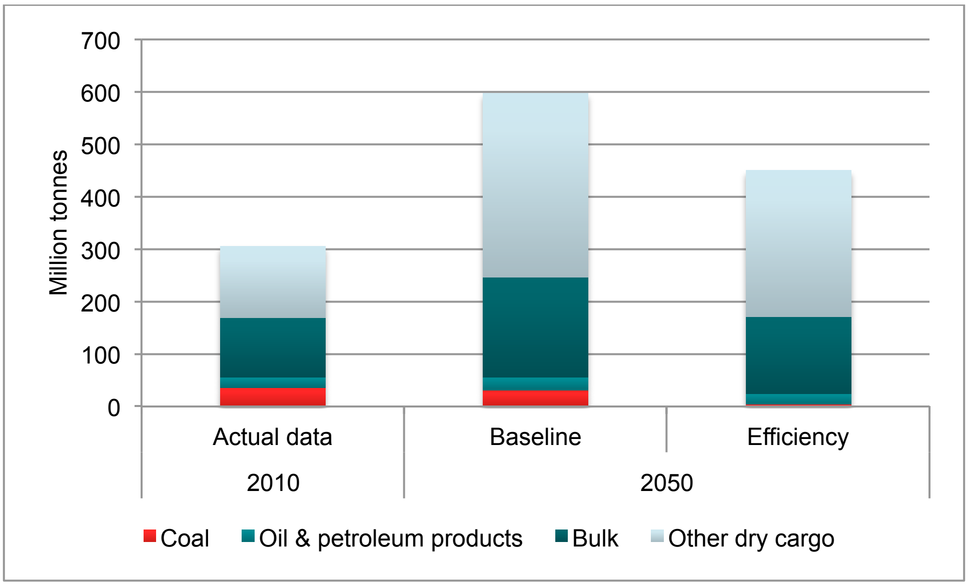

Figure 7 Composition of seaborne trade in Germany in 2010 and 2050 in the Renewbility study's (Öko-Institut et al. 2016) Baseline and Efficiency scenario (in Mio. t)

Source: Own figure

Linking the composition of cargo with seaborne trade activity in Germany (*in tkm*), the study „Klimafreundlicher Verkehr in Deutschland" assumes that maritime shipping of fossil fuels (including coal, here covered in the „Dry bulk" section below) via German ports can be reduced by 95 per cent by 2050 as energy supply will be decentralised and based on renewable energy sources (WWF et al. 2014, p. 29). The „Renewbility" study (Öko-Institut et al. 2016, p. 168) states that due to large cuts in fossil fuel demand in Germany the overall amount of international maritime transport from German ports (*in tkm*) could rise by only about half the volume of the baseline scenario (66 per cent vs. 120 per cent) by 2050. This requires that the energy transition will be implemented as assumed in the study's „Efficiency" scenario.

The impact of potentially lower oil, gas and coal flows on future petrochemical activities in European ports is explicity recognized by the TPR 2015 study. Noting that the transport of energy products would become "a less important activity for carriers and ports" (TPR 2015, p. 61), the advise is to rather concentrate on the expected increase in container transport activity. This includes investments in port and infrastructure management to optimise the use of the available port facilities[11] and sustainable hinterland transport modes (TPR 2015, p. 61).

→ Assumptions of seaborne trade volumes in 2050 for PoR transport decarbonisation 2050 scenarios:

[11] Specifically, the study claims that „Information technology in combination with (semi-)automated vehicles and vessels increases the capacity of the infrastructure, reduces waiting times, and optimises the use of existing infrastructure" (TPR 2015, p. 61).

	Scenario 2050 D	Scenario 2050 DD
Crude oil	change 2050 vs. 2015: - 77 %	change 2050 vs. 2015: - 100 %
	The focus on energy efficiency measures and renewable energy deployment in the EU leads to decreasing seaborne crude oil transportation. While fuel demand in heating is completely abolished, reductions in transport are about 2/3 and in feedstock -20 % (in line with production values by IEA 2017a). Business activity at the PoR is also directly affected by the closing of local oil refineries.	Additional disruptive technological innovation, especially in the transport and basic materials industries, allows for a complete substitution of crude oil products and thus renders seaborne crude oil transportation unnecessary. All remaining use of hydrocarbons is supplied by synthetic fuels/feedstocks.
Mineral oil products	change 2050 vs. 2015: - 77 %	change 2050 vs. 2015: - 100 %
	The decline in transport volumes of mineral oil products equals that of crude oil. It is assumed that there will be little import/export when overall production and use of oil products is phased out.	See 2050 D.
LNG	change 2050 vs. 2015: +/-0 %	change 2050 vs. 2015: -100 %
	As in the case of other fossil fuels, very little LNG is expected to be consumed in 2050. However, as its combustion results in lower GHG emissions than that of other fossil fuels, it is used mainly in the transport sector where few alternatives to fossil fuels are available, as well as backup for power generation.	As in the case of other fossil fuels, it is assumed that LNG can be substituted by the direct use of electricity or by synthetic methane and, consequently, there will no longer be demand for the seaborne transportation of LNG.

Studies such as TPR (2015, p. 103) and IEA (2017, p. 258) mention a potential effect of **replacing fossil fuels by alternative energy carriers such as biofuels** on seaborne trade activity and routes. Nevertheless, this assumption has not been incorporated into their particular scenario modelling processes. Instead, IEA (2017, p. 258) mentions that „[s]ome of the demand reduction could be compensated by increasing trade of advanced biofuels and the feedstock required for their production". TPR (2015, p. 103) stresses that „[a]lternative energy carriers, such as biofuels, might be part of new activities in the ports replacing loading, unloading, storage and processing activities for conventional energy carriers". Generally, the future use of biofuels and thus their transport demand is a rather controversial topic due to the competition in the usage of biomass with food production and land use issues. While biofuels constitute a suitable replacement for fossil fuels, it is a topic of debate how much biomass can be provided in a sustainable way around the world. The Port of Rotterdam would probably benefit from increased transport volumes of biofuels as it could be supplied from there to the hinterland.

→ Assumptions of seaborne trade volumes in 2050 for PoR transport decarbonisation 2050 scenarios:

	Scenario 2050 D	Scenario 2050 DD
Liquid biomass	change 2050 vs. 2015: +100 %	change 2050 vs. 2015: +/-0 %
	Since this scenario focuses on biofuels as the main substitute for fossil fuels, the transport volumes of liquid biomass increase strongly compared to 2015 (to 22.8 million tonnes (all import) in 2050 compared to 0 in 2015).	This scenario assumes that synthetic fuels substitute fossil fuels where required. Hence, no seaborne transportation of liquid biomass is assumed for 2050 (as for 2015).

Studies like IEA's ETP (2017, p. 222) further consider **hydrogen and PtX technologies** as complements for electrification or low-carbon biofuels as a future propulsion method in transport. However, the future demand is expected to be comparatively low as a result of different barriers, e.g. limited availability of low-cost electricity and sustainable biomass. If the decarbonisation efforts rather focus on full electrification, this also leads to lower demand for hydrogen and synthetic fuels (and gases) compared to a pathway concentrating on indirect electrification by synthetic energy carriers. Overall, based on a study by the Wuppertal Institut (2017), we estimate that between 20 and maximal 100 million tonnes of methanol could be imported into Germany by 2050. These numbers rest on the assumption that all feedstock as well as the remaining transport activity would be supplied by imported methanol.

As Rotterdam oil and oil product shipment roughly equal the size of German external trade, we use these numbers as proxy for Rotterdam imports of synthetic fuels – assuming that neighbouring regions such as BENELUX will follow similar decarbonisation routes.

If PtX fuels will replace conventional fuels in transport and also stationary uses, the market region for gasoline and oil products seems to be a potential market area also for these fuels. Suppliers of these products could benefit from potential first mover advantages.

→ Assumptions of seaborne trade volumes in 2050 for PoR transport decarbonisation 2050 scenarios:

	Scenario 2050 D	Scenario 2050 DD
Hydrogen	change 2050 vs. 2015: 0 %	change 2050 vs. 2015: +100 %
	As direct import/export activities of hydrogen in 2050 are currently considered unlikely, no future transport activities are assumed in this regard.	Hydrogen imports from renewable electrolysis, e.g. in the North Sea, might become relevant by 2050. However, it is assumed that most of it will be transported via pipeline.
Power-to-X fuels/ gases	change 2050 vs. 2015: 0 %	change 2050 vs. 2015: +100 %
	As this scenario focuses on biofuels as the main substitute for fossil fuels, no imports of synthetic fuels are assumed.	Instead of biofuels, synthetic fuels substitute fossil fuels as feedstock for the chemical industry and non-electrified transport. Based on these assumptions, a seaborne transport volume of 71.5 million tonnes (all import) is assumed for 2050 (compared to 0 in 2015, calculated as 100 % methanol).

With regard to **chemical base products**, ETP (IEA 2017, p. 169) expects increasing demand on the global level by 2060, both in the baseline „Reference Technologies Scenario“ as well as in the „Beyond 2 Degrees Scenario“. The lower growth rate in the sustainability-oriented scenario results from improved collection rates in plastics recycling. Future transport volumes of chemical base products to and from the EU will depend on the future market share of the EU in global production and the development of net exchange in markets. Not on EU but on OECD level, the „B2DS“ expects a decline in the production of high value chemicals of 20 per cent between 2014 and 2050 (IEA 2017, Data sheet „ETP2017_industry_summary“).

→ Assumptions of seaborne trade volumes in 2050 for PoR transport decarbonisation 2050 scenarios:

	Scenario 2050 D	Scenario 2050 DD
Chemicals and other wet bulk	change 2050 vs. 2015: -10 %	change 2050 vs. 2015: -10 %
	As a result of increased material efficiency and technological innovation, demand for chemicals decreases slightly compared to 2015. The production of high-value chemicals within the EU decreases by 20 % (IEA 2017) but imports are projected to rise by 10 %.	See 2050 D (but switch to organic and synthetic sources).
Vegetable oils	change 2050 vs. 2015: +/-0 %	change 2050 vs. 2015: -50 %
	As the majority of vegetable oil is used as an input into food production, its future transportation level is difficult to estimate and thus expected to remain constant.	A more sustainable lifestyle and less meat consumption result in lower demand for animal feed and, consequently, its feedstock.

Dry bulk

As is the case with oil and gas, the sustainability-oriented scenarios mostly differ from the baseline scenarios with regard to the maritime transport of a conventional energy carrier, **coal**. While the TPR's 2015 „Sustainability Scenario" still expects a modest growth in the global demand for fossil fuels such as coal (p. 60), the rise is rather low due to the effects of energy efficiency measures and the further dissemination of renewable energy carriers.
On the country level, the „Renewbility" study's baseline scenario assumes coal transports to decline by 14 per cent (Öko-Institut et al. 2016, p. 167, see also Figure 14 and Figure 8). The study's „Efficiency scenario" especially expects a strongly decreasing demand for coal as a result of climate protection measures. The amount imported by maritime transport falls by 88 per cent compared to 2010 (Öko-Institut et al. 2016, p. 167). This could partly result from innovations in industrial production processes (e.g. steelmaking) in which hydrogen or electricity replace coal as a source of energy. While the plant or steel mill's new source of energy would probably still be supplied by ship from Rotterdam, production might move closer to the coast as a result of changing locational advantages.

→ Assumptions of seaborne trade volumes in 2050 for PoR transport decarbonisation 2050 scenarios:

	Scenario 2050 D	Scenario 2050 DD
Coal	change 2050 vs. 2015: -71 %	change 2050 vs. 2015: -85 %
	Coal used for power generation will be phased out and amount to zero in the PoR hinterland by 2050 in both scenarios. Coal in steel generation will decline by 10 % due to higher shares of secondary steel making and more recycling. The market share of the PoR in coal transportation is projected to remain stable.	As well as the phase out of coal in power generation, its use in steel generation decreases even further than in the 2050 D scenario due to higher shares of secondary steel making and more efficient production technology which reduces or even replaces the use of coal (top gas recycling uses less coal and direct reduction uses hydrogen instead of coal).

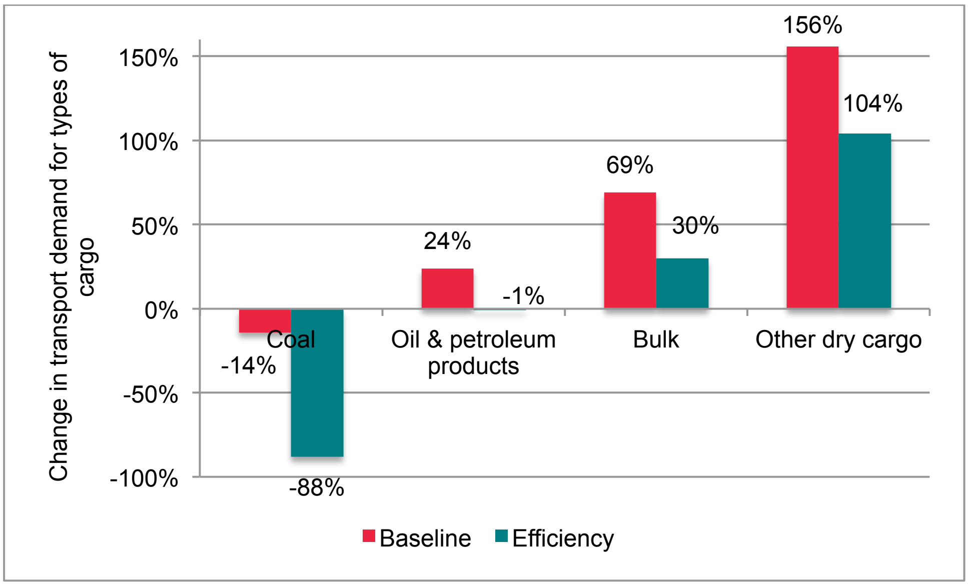

Figure 8 **Changes in the composition of seaborne trade in Germany between 2010 and 2050 in the Renewbility study's Baseline and Efficiency scenario (in per cent)**

Source: Own figure

The second good currently dominating the dry bulk transport especially to Rotterdam is **iron ore**. With respect to this particular ore, the IEA (2017, p. 169) projects higher global demand in its baseline as well as sustainability-oriented scenarios, albeit lower increases in the latter case because of material efficiency improvements. For the OECD, the IEA's „Beyond 2 Degrees Scenario" expects a decrease of crude steel production of 8 per cent between 2014 and 2050 (IEA 2017, Data sheet „ETP2017_industry_summary"). Improved post-consumer scrap recycling as well as reuse and higher (semi-)manufacturing yields cause this development (IEA 2017, p. 169). Decreasing steel production in the OECD could mean lower volumes of iron ore imported via the Port of Rotterdam. However, if market concentration activities should result in Duisburg being a favoured primary steel production site, the market share of the Port of Rotterdam might even increase (as more than 70 per cent of the port's incoming iron ore volume goes to Duisburg). Besides imports, seaborne transport volumes could be positively influenced by increased exports of scrap.

→ Assumptions of seaborne trade volumes in 2050 for PoR transport decarbonisation 2050 scenarios:

	Scenario 2050 D	Scenario 2050 DD
Iron ore	change 2050 vs. 2015: -55 %	change 2050 vs. 2015: -10 %
	While oxygen steel production in Europe is expected to decline only slightly, secondary steel production will be reduced significantly and imports of steel slabs are projected to rise.	Crude steel production is expected to remain at current levels, but the shares of electric arc/secondary steel are projected to increase, resulting in the import of scrap instead of ore. Furthermore, there is a switch towards hydrogen-based steel making, leading to increased material efficiency.

Regarding the transshipment of **raw materials** in general, the FUTRE study's „Unlimited Scenario" (CERTH/HIT 2014, p. 9) expects that it will increase strongly due to a further dissemination of 3D printing. While the products would be produced

closer to the consumers, the raw materials would travel longer distances (CERTH/HIT 2014, p. 7).
In terms of other raw materials, such as aluminium oxyde and hydroxyde as well as lime, which are used for aluminium and cement production, ETP (IEA 2017, p. 169) expects a rise in demand for both in the baseline „Reference Technologies Scenario“ as well as in the „Beyond 2 Degrees Scenario“. Considering the environmental protection scenario, production in the OECD only rises between 2014 and 2050 in the case of cement (+12 per cent) but not aluminium (primary and secondary, -13 per cent). While this could mean that transport volumes might develop similarly, this is quite hard to estimate.
Focussing on Germany, the „Renewbility“ study states increases in bulk freight transport, which encompasses raw materials such as mineral ores, stones and earths, in both types of scenarios. Instead of increasing by 69 per cent in the baseline scenario, the rise of transport demand only amounts to 30 per cent in the „Efficiency Scenario“[12].

→ Assumptions of seaborne trade volumes in 2050 for PoR transport decarbonisation 2050 scenarios:

	Scenario 2050 D	Scenario 2050 DD
Other dry bulik	change 2050 vs. 2015: -78 %	change 2050 vs. 2015: -78 %
	This value is an extrapolation of the Port of Rotterdam's "Lean & Green scenario", which assumes a strong decline in other dry bulk by 2040.	See 2050 D.

How the seaborne freight transport demand for dry **biomass** might develop is also a topic of debate. While it could replace fossil fuels as an energy carrier in many applications, particularly the amount of biomass which can be sourced sustainably is discussed controversially.
The ETS study (IEA 2017, pp. 316, 322) suggests in its baseline „Reference Technologies Scenario“ that in view of its function as an energy carrier, the traditional inefficient consumption of biomass (especially for cooking and heating in developing countries) will decrease. Demand will nevertheless rise (for primary biomass supply from 63 exajoules (EJ) in 2015 to 99 EJ in 2060) because biomass will increasingly be used as a source of heat for buildings and especially industry as well as an energy source for transport and bioelectricity. In the ETP's (IEA 2017, p. 316) „Beyond 2 Degrees Scenario“ it is assumed that biomass plays an important role in achieving GHG emission reductions. Hence, consumption of primary biomass surges to 145 EJ in 2060. It is mainly used in sectors where alternative decarbonisation options are limited (e.g. transport) but also in combination with carbon capture and storage (CCS) in the power sector, industry and biofuels production to achieve „negative emissions“ (IEA 2017, p. 316). Since „[t]he range of estimates of sustainable bioenergy potential have narrowed and estimates within the 100 EJ to 300 EJ range may be considered reasonable“ (IEA 2017, p. 316), it is assumed that all biomass consumed in the „B2DS“ can be sourced sustainably. However, this is only possible if several new

[12] In this scenario, bulk transport volumes (of mineral ores, stones, earths) are assumed to develop proportionally to the relevant production outputs (basic oxygen steel, cement, glass/bricks/gypsum) (Öko-Institut et al. 2016, p. 149).

technologies, especially for transport fuels, are developed and deployed.
In contrast to the ETP study (IEA 2017), energy [r]evolution (Greenpeace et al. 2015, p. 318) projects the worldwide (energetic) use of a even more limited amount of biomass (77 EJ primary biomass in 2050 in its „Advanced Energy [R]evolution Scenario“) due to strict sustainability criteria in the sourcing process. Here, global sustainable biomass potentials are assumed to account for less than 100 EJ (Greenpeace et al. 2015, p. 60). Therefore, in its decarbonisation scenarios biomass is only applied where few alternatives exist: as a fuel for aviation and shipping and as a source of industrial process heat (Greenpeace et al. 2015, p. 9). The fact that the energy [r]evolution scenarios do not consider any trade in biomass between world regions would have a strong impact on transport activity in the Port of Rotterdam (Greenpeace et al. 2015, p. 60).

Besides its energetic value, biomass also constitutes a raw material for production processes. In this regard, ETP (IEA 2017, p. 169) projects a rising global pulp production from increased recycling as well as virgin materials in both types of scenarios. Paper and paperboard production (excluding recovered paper) in the OECD is expected to increase by 15 per cent between 2014 and 2050 in the „B2DS“ (IEA 2017, Data sheet „ETP2017_industry_summary“). In OECD Europe, biomass can be sourced mainly in the north and east while potentials are especially scarce in the south (Greenpeace et al. 2015, p. 63). As a result, the Port of Rotterdam could face strong competition with ports both in the Baltic Sea as well as in the North Sea.

→ Assumptions of seaborne trade volumes in 2050 for PoR transport decarbonisation 2050 scenarios:

	Scenario 2050 D	Scenario 2050 DD
Dry biomass	change 2050 vs. 2015: +/-0 %	change 2050 vs. 2015: +/-0 %
	The level of transported dry biomass is expected to remain constant as no major imports for a bio economy are projected.	See 2050 D.

Another important type of dry bulk mostly imported to Rotterdam is **agribulk**. Globally, corresponding with rising income levels TPR (2015, p. 6) expects a rising demand for agricultural products, especially in East and South Asia. This might result in increasing export flows from Europe to developing and emerging economies. Moreover, a potential further industrialisation of agriculture in the EU could cause higher import volumes of animal feed. A stronger focus on sustainability could, however, diminish the surge in agribulk transport activity. This development could e.g. be fostered by consumers increasingly demanding regionally produced food and animal feed. Additionally, lower meat consumption would lead to lower imports of oil seeds and animal feed. The expansion of organic farming could reduce the use and thus transport demand for fertilizers.

→ Assumptions of seaborne trade volumes in 2050 for PoR transport decarbonisation 2050 scenarios:

	Scenario 2050 D	Scenario 2050 DD
Agribulk	change 2050 vs. 2015: +/-0 %	change 2050 vs. 2015: -50 %
	The amount of agribulk transported via the Port of Rotterdam is not projected to change by 2050.	The amount of transported agribulk declines due to a more sustainable lifestyle and lower food demand (smaller population, reduced food waste, focus on regional products, less meat consumption resulting in lower demand for animal feed etc.).

Break bulk

In the following, potential developments in global trade flows of break bulk will be described. However, as scenario studies – contrary to e.g. port statistics – hardly differentiate between maritime transport destinations, no division will be made between container transports labelled as „direct deep sea“, „transshipment“ and „short sea“ shipping. The same is true for the differentiation between break bulk transported in container ships in comparison to that shipped by roll-on/roll-off ships (RoRo). Hence, the following results only give an indication of how the maritime transport demand for break bulk in general is expected to develop in the future.

A common assumption is, for both baseline and sustainability-oriented scenarios, that the share of transport demand for manufactured products and associated container transport will increase in the future (e.g. OECD/ITF 2017, p.73, TPR 2015, p. 60, WWF et al. 2014, p. 167). This is expected since the GDP and living standards especially in China, India and other Asian countries are projected to rise. As a result, the production and consumption of low-value manufacturing products could shift gradually towards high-value manufacturing products (OECD/ITF 2017, p. 73). At the same time, the level of global interactions is assumed to stay constantly high (TPR 2015, p. 61). Hence, there is a good chance for increasing exports of break bulk from Europe to developing and emerging countries. The increase might turn out lower if a focus on sustainability makes people worldwide consume less and or mainly buy regional products. Also re-shoring of production activities, e.g. from China back to Europe, could result in declining transport volumes.
In the country-specific „Renewbility“ study, the largest change of seaborne transport activity in Germany is also expected with respect to other dry cargo, i.e. mainly container freight. It is projected to increase by 156 per cent in the baseline development or still double by 2050 in the climate protection scenario (Öko-Institut et al. 2016, p. 167; see Figure 14 and Figure 8).

→ Assumptions of seaborne trade volumes in 2050 for PoR transport decarbonisation 2050 scenarios:

	2050 D	2050 DD
Container	change 2050 vs. 2015: 92 %	change 2050 vs. 2015: 92 %
	Here we use the mean value of extrapolated values from the Port of Rotterdam's „Lean & Green“ and „Green Unlimited“ scenarios.	see 2050 D
RoRo	change 2050 vs. 2015: 47 %	change 2050 vs. 2015: 47 %
	see „Container“	see „Container“

Maritime freight routes

As stated before and regardless the level of sustainability orientation, for the time up to 2050 the analysed scenarios expect a higher level of maritime freight transports from and to emerging and developing countries[13], especially China and India. OECD/ITF (2017, p.57) e.g. states an average annual growth rate of 17 per cent for maritime trade corridors connecting developing economies until 2050. By 2050, OECD/ITF (2017, p.57) expects the transportation corridor between the United States and Asia to experience the highest flow of goods in both directions. Trade routes between industrialised economies are also projected to increase but at lower levels. This applies e.g. for trade between Europe and North America via the North Atlantic (OECD/ITF 2017, p. 74). For Europe, the scenarios project increased trade flows with Asia through the Mediterranean corridor (OECD/ITF 2017, p. 74).

Some assumptions on future maritime freight route developments exist which are not directly linked to a particular type of cargo.
In the TPR's (2015, p.67) „**Conventional High Economic Growth Scenario**" the implementation of fewer GHG emission abatement measures causes ice to melt faster and opens up the Northwest Passage for longer periods during the year. As a result, the North Sea Route is more and more used for flows between North Europe and Nord East Asia (TPR 2015, p. 67).
In contrast, the FUTRE study's „**Responsible Growth Scenario**" projects a shift from longer distances towards more regional freight transport, due to the trend towards more regional production cycles and demand for regional products (CERTH/HIT 2014, p. 60).

Oil and petroleum products

Analyses of the historical worldwide petreoleum flows show that these have been rather unstable and that world-wide flow patterns for oil products can change significantly within a decade (TPR 2015, p.5). Quite recently, e.g., Europe switched from mainly importing oil from the Middle East to mostly buying Russian oil (TPR 2015, p.5). Thus, even developments of future flows, volumes and directions in baseline scenarios are relative hard to project.

Current existing uncertainties include Russia being the main supplier of petroleum flows for Europe. According to TPR (2015, p.5), more than half of the flows between those trading partners are accomplished by maritime transport. In 2013, the largest flows went to the Port of Rotterdam which imported about 47 million tons of mineral and crude oil (products) (Port Statistics). In view of the current geopolitical developments, TPR (2015, p. 5) considers it a possibility that the EU could shift its import patterns „towards unconventional oil and gas from the USA and Canada, deep sea oil from Brazil or back to the Middle East as the prominent supplier".
Besides imports, also export flows in petroleum products are of importance for maritime freight transport in Europe. Since both Asian and Middle East countries are

[13] This assumption is usually based on higher projected GDP and population growth for those countries compared to industrialised countries.

augmenting their capacities for storing and refining petroleum products, this will probably result in increasing competition for European ports with a large petrochemical cluster, such as Rotterdam (and Antwerp) (TPR 2015, p. 5).

Keeping those uncertainties in mind, in its „**Conventional High Economic Growth Scenario**“, the TPR (2015, p. 65) expects conventional energy sources to prevail. Increasing shares of oil and especially gas are sourced in Brazil, Africa, and at the North Pole. Furthermore, the scenario projects a strong demand for higher port facilities to store liquid gas and increased operation of the petrochemical industry (TPR 2015, p. 67).

As most **climate protection scenarios** assume the implementation of energy efficiency measures and an increased use of energy from renewable sources, this primarily results in reduced demand for maritime transport of oil and petroleum products and thus lower levels of maritime transport of these goods. However, effects on maritime transport routes might occur as well.
The switch towards more sustainable fuels results e.g. in the the TPR’s (2015, p. 103) „Sustainability Scenario“ in comparatively higher increases in gas transports. If high amounts of LNG are imported from places different to the fossil fuel mix in the baseline scenarios, maritime transport routes might change. These routes also depend on the further development of LNG facilities at European ports. According to TPR (2015, p. 103), „[f]or ports with a strong position in handling energy carriers, such as coal or oil, or ports with a large petrochemical processing industry, a substantial transition is needed to maintain their competitive positions“.
While hinting at the potential replacement of fossil fuels by alternative energy carriers such as biofuels, TPR (2015) and IEA (2017) do not discuss in how far this could effect maritime freight routes.

Other dry cargo

Currently, the largest trade flows of manufactured products are between China and North America as well as Europe. In the case of Europe further important trade flows in this category exist with North America, South Asia, Russia and Africa (TPR 2015, p. 6). Altogether, Europe is both a major importer and exporter of manufactured goods.

Generally, future import and export flows of manufactured goods are – as overall seaborne trade activity – assumed to develop in line with GDP. As a result, TPR (2015, p. 6) considers them „somewhat more stable and more predictable than the flows for natural resources“. In accordance with expectations for GDP development, the future dominant container flows are believed to be South-South relationships, especially between South Asia and East Asia but also Africa and South America (TPR 2015, p. 60). Furthermore, the scenarios expect higher future demand for agricultural (e.g. milk, meat) and manufactured products (e.g. cars, cosmetics) in emerging and developing countries. Thus, the importance of export flows to these regions is projected to increase for Europe (TPR 2015, p. 6).

Compared to the **baseline scenarios**, the seaborne trade activity levels of other dry cargo are lower in the analysed **sustainability-oriented scenarios**. The storyline of the FUTRE study's „Responsible Growth Scenario" e.g. expects people from industrialised countries to consume less (CERTH/HIT 2014, p. 14). The TPR's (2015, p. 61) „Sustainable World Scenario" assumes a re-shoring of industrial production activities from China back to Europe (due to increasing wages and transportation cost in Asia). As a result, the share of intra-European maritime transportation might rise.

Bulk

Today, the most important global trade flows of coal, ore, chemical or agricultural bulk products are between China (importing minerals and building materials) and Latin America and Australia (supplying natural resources). Europe mainly imports bulk products from South America and Africa (TPR 2015, p. 6).

Since rapidly industrialising countries display the highest demand for bulk products like coals and ores, emerging economies e.g. in South Asia are projected to become important destinations for those materials in the future (TPR 2015, p. 6).

The largest difference in future bulk flows to and from Europe could occur with regard to the seaborne transport volumes of coal. In the TPR's (2015, p. 65) „**Conventional High Economic Growth Scenario**", coal continues to play an important role as an energy source for European power plants. The scenario assumes that the future European coal demand will be satisfied by imports from different, partly distant places, among them Colombia and Canada (TPR 2015, p. 67).
As oil and other petroleum products, global growth in coal consumption is expected to be low in the TPR's (2015, p. 55) „**Sustainability Scenario**". The implementation of energy efficiency measures and the deployment of renewable energy sources will lead to a reduction of coal flows to European ports (TPR 2015, p. 61).

3.1.2 Transport modes/ modal shift

Among the different freight transport modes, with 71 per cent in 2015 the largest share of tonne-kilometres is by far performed by maritime transport (OECD/ITF 2017, p. 56). At the same time, international shipping is the most energy-efficient freight transport mode (if measured per tonne-kilometre) (IEA 2017, p. 257).

For the future, the analysed scenario studies project slight changes. The OECD/ITF's (2017, p. 57) baseline scenario, e.g., expects an increase in maritime tranport's share of tonne-kilometres from 71 per cent to 75 per cent by 2050. Examining the potential for modal shift, the study notes that there is no **suitable alternative for the long-distance transport of low value goods**, such as raw materials (OECD/ITF 2017, p. 57). The same is true for most maritime transport flows from Asia to industrialised countries.

On the contrary, OECD/ITF (2017, p. 57) states that in a baseline scenario shipping via the traditional **maritime route will no longer a competitive option for other kinds of products**, such as high-tech goods. The situation is aggravated by the fact that factories in China and elsewhere are more often located further inland, thus increasing the road haulage and sometimes being subject to uncompetitive port handling times (OECD/ITF 2017, p. 57). The alternative mentioned by OECD/ITF

(2015, p. 57) and also included in TPR's „Sustainability Scenario" (2015, p. 103) is an Eurasia land bridge between Europe and China. New road and rail routes through Kazakhstan, Russia and then Europe have been developed and could be operated successfully in the case of active co-ordination and partnership between European countries, Russia and China (TPR 2015, p. 103). Altogether, TPR 2015 (p. 61) suggests that capacities will not be sufficient to become a real competitor for the Suez Canal route. Nevertheless, the land bridge is considered „an interesting alternative for specific niche markets and regions" as it is „especially competitive for flows between West China and East Europe with a high value of time" (TPR 2015, p. 61). If and how the Eurasia landbridge results in lower GHG emissions than maritime transport is not elaborated further in the TPR's „Sustainability Scenario". This could, however, be achieved if road and rail transport work independent of fossil fuels and maritime shipping does not.

Another development is the EU Commission's support for „motorways of the sea" which aims at replacing land-based road freight by increased levels of short-sea shipping (WWF et al. 2014, p. 29; EC 2016, p. 124). This matches the current situation in which shipping constitutes the most energy-efficient freight transport means per tonne-kilometre. How this development could manifest in the overall modal share in 2050 is, however, not specified in the study.

Comparing the outcome of two different scenarios – one with a high trade elasticity to GDP, one with a lower elasticity – the OECD/ITF study (2017, p.74) notes that there are no large differences regarding transport mode shares. This result holds despite the fact that the scenarios significantly differ with respect to the composition of the traded commodities.

3.2 Hinterland transport

In comparison to shipping, GHG emissions from land-based transport of course constitute the majority of overall global GHG emissions from transport. According to the IEA's (2017, p. 218) „Energy Technology Perspectives", these overall transport emissions (including shipping) are going to increase by 52 per cent from 9.5 gigatonnes of CO_2 equivalent ($GtCO_2$-eq) in 2015 to 14.4 $GtCO_2$-eq in 2060 if no additional climate protection measures are implemented. How this trend can be reversed is detailed in the sustainability-oriented „Beyond 2 Degrees Scenario". Figure 9 illustrates the amount of well-to-wheel (WTW) GHG emissions avoided in the B2DS relative to the baseline „Reference Technology Scenario" (RTS).

Among the different transport modes, it is comparatively more difficult to decarbonise freight transport. However, to achieve the GHG emission reduction targets, it is particularly important that land-based freight modes such as trucks and light-duty vehicles cause significantly fewer GHG emissions. As Figure 9 shows, emission abatement by those freight modes makes up the majority of emissions avoided in 2060 in the B2DS (IEA 2017, p. 219).

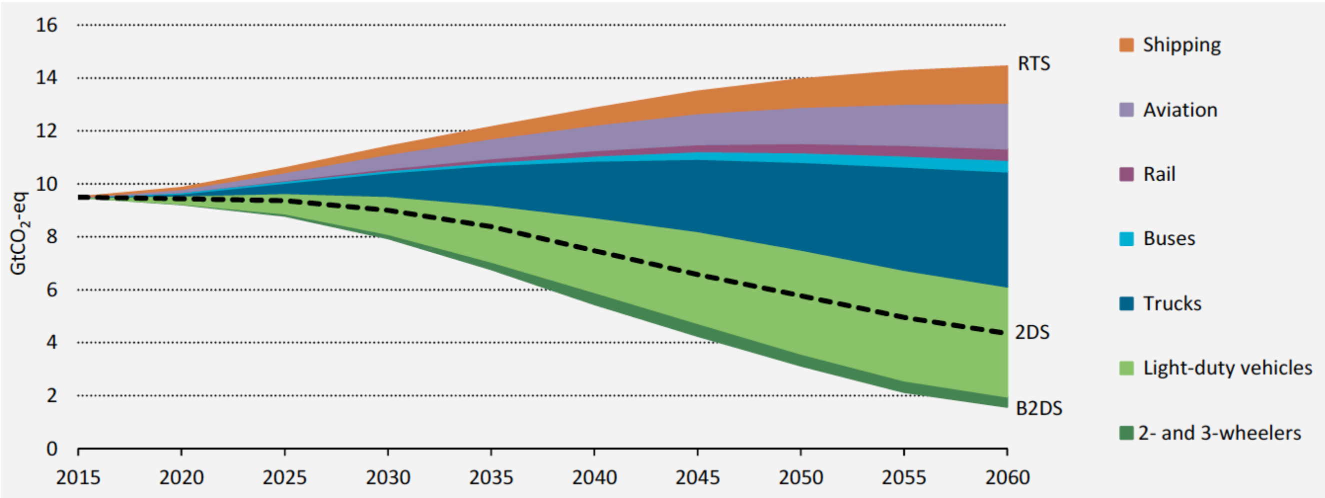

Figure 9 **Well-to-wheel GHG emission reductions from transport in the B2DS relative to the RTS**

Source: IEA 2017, p. 219

Overall, realising the B2DS pathway requires global WTW GHG emissions from transport to decline by 83 per cent between 2015 and 2060 (IEA 2017, p. 219). Roughly equal policy efforts would lead to reductions of 72 per cent in non-OECD countries (where emissions would otherwise more than double in the RTS compared to 2015) and 95 per cent in OECD countries (where total WTW emissions are believed to have already peaked). Considering different GHG emission reduction measures, in OECD countries the largest mitigation potential is attributed to electric propulsion systems (see Figure 10). Similar levels of emission savings can be obtained through vehicle efficiency improvements, the use of biofuels as well as measures to avoid transport or shift it to less GHG-intensive transport modes (IEA 2017, p. 220).

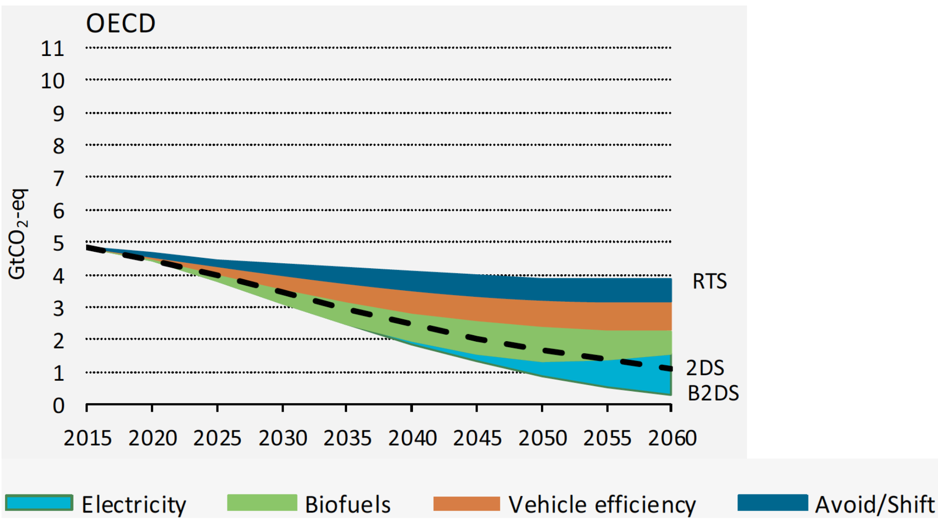

Figure 10 **Well-to-wheel GHG emissions in OECD coutries by scenario, 2015-2060**

Source: IEA 2017, p. 220

3.2.1 Transport activity

Not only maritime transport activity, but also demand for freight transport in general is closely linked to GDP development (Greenpeace et al. 2015, p. 293; OECD/ITF 2017, p. 56). Thus, forecasts for hinterland transport demand usually mirror those for maritime transport described in Chapter 3.1.1 (see e.g. OECD/ITF 2017, p. 56).

Future transport activity under decarbonisation

Global level

Among the analysed scenario studies, only „Energy Technology Perspectives 2017“ (IEA 2017, Data sheet „ETP2017_transport_summary“) included modelling of global freight transport activities into its study (albeit inland navigation is not considered here).[14] For the period up to 2050 it projects strong growth in the overall demand for transport services, from about 38,600 trillion tkm in 2014 to 107,800 trillion tkm (RTS) and 97,600 trillion tkm (B2DS), respectively, in 2050 (see Figure 11). Hence, the rise in transport activity in the sustainability-oriented B2DS is slightly lower than in the baseline scenario. Furthermore, the share of rail transport is larger in the climate-protection scenario (26 per cent in 2050 vs. 21 per cent in the RTS and 28 per cent in 2014).

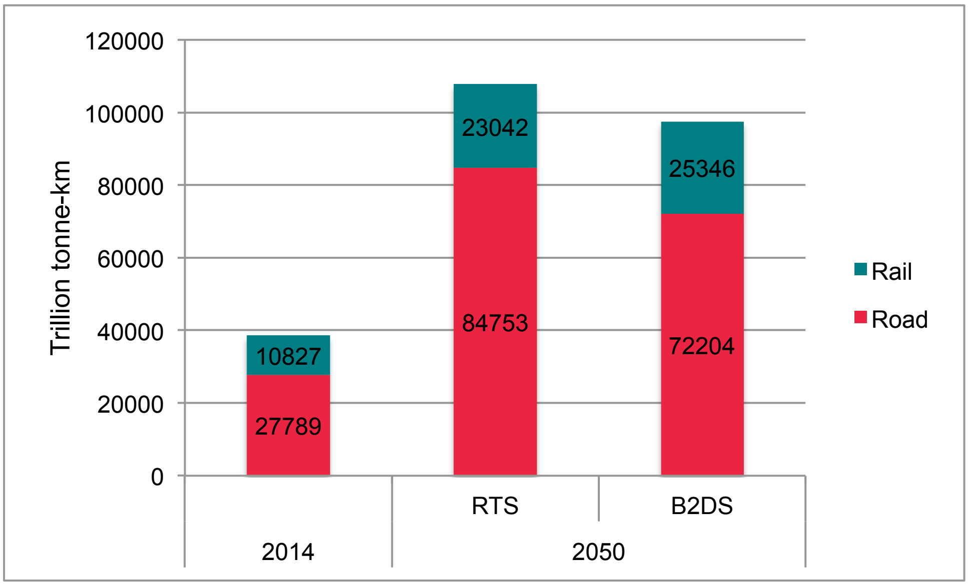

Figure 11 Assumed development of future road and rail freight transport activity on the global level between 2014 and 2050 in the „Energy Technology Perspectives 2017“ scenarios (IEA 2017) (in trillion tkm)

Source: Own figure

If average annual growth rates between 2014 and 2050 are considered, they are thus higher for road transport (3.2 per cent in the RTS and 2.7 per cent in the B2DS) than for rail transport activity (2.1 per cent in the RTS and 2.4 per cent in the B2DS, see

[14] Greenpeace et al. (2015, p. 293) states that since „[i]t is difficult to estimate a reduction in freight transport [..] neither Energy [r]evolution scenario includes a model for reduced volume for required freight transport“.

also Figure 12). In accordance with the larger overall share of rail transport in the B2DS, the average annual increase of rail transport activity is also higher in the B2DS than in the RTS.

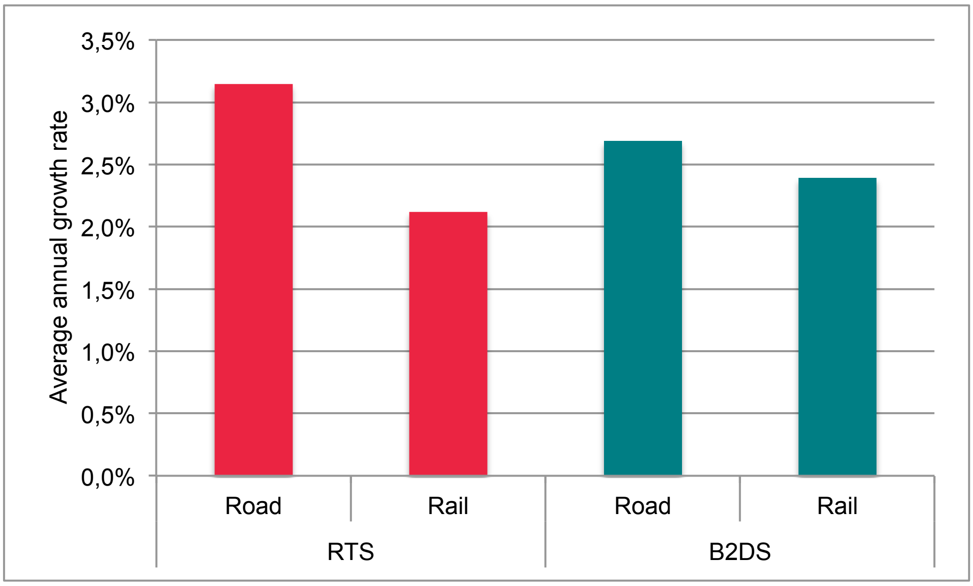

Figure 12 **Assumed average annual development of future road and rail freight transport activity on the global level in the „Energy Technology Perspectives 2017“ scenarios by 2050 (IEA 2017)**

Source: Own figure

Comparing the average annual growth rates of the the different transport modes for 2060[15], the IEA's „Energy Technology Perspectives“ expects the highest annual growth rates for road freight, followed by maritime and rail transport (see Figure 13). This order applies to both scenarios, the baseline RTS as well as the sustainability-oriented B2DS. As in other projections, the overall growth of transport demand by 2060 is lower in the B2DS than in the baseline scenario.

[15] A comparison of 2050 data is not possible as IEA 2017 does not provide specific data for maritime transport for 2050.

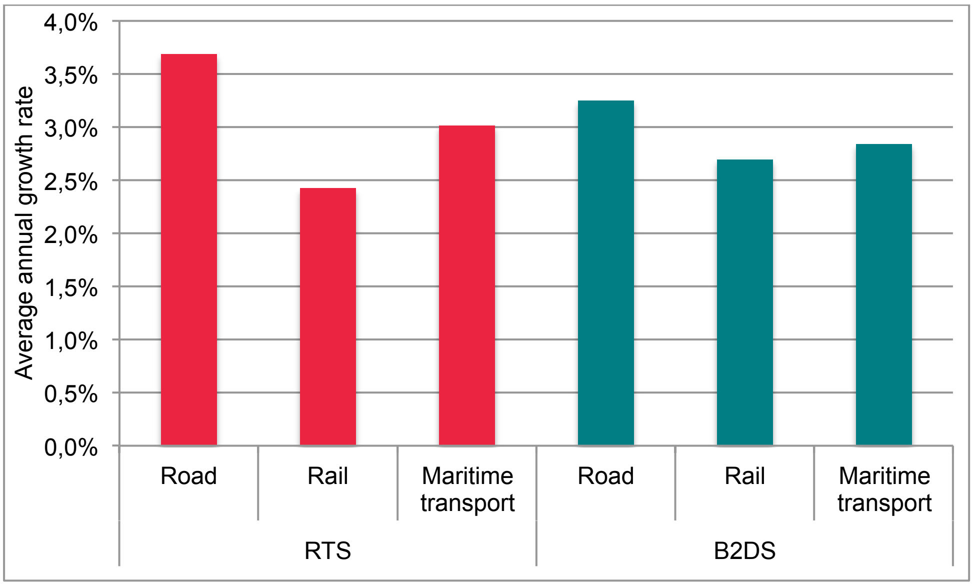

Figure 13 Assumed average annual development of future road, rail and maritime freight transport activity on the global level in the „Energy Technology Perspectives 2017" scenarios by 2060 (IEA 2017)

Source: Own figure

EU level

Overall hinterland freight transport activity is expected to rise for the EU as well, but not as much as globally. Considering the different types of hinterland transport, growing demand figures are part of every scenario (both baseline and sustainability-oriented scenarios) and apply to all types of transport modes analysed (road, rail and inland navigation).

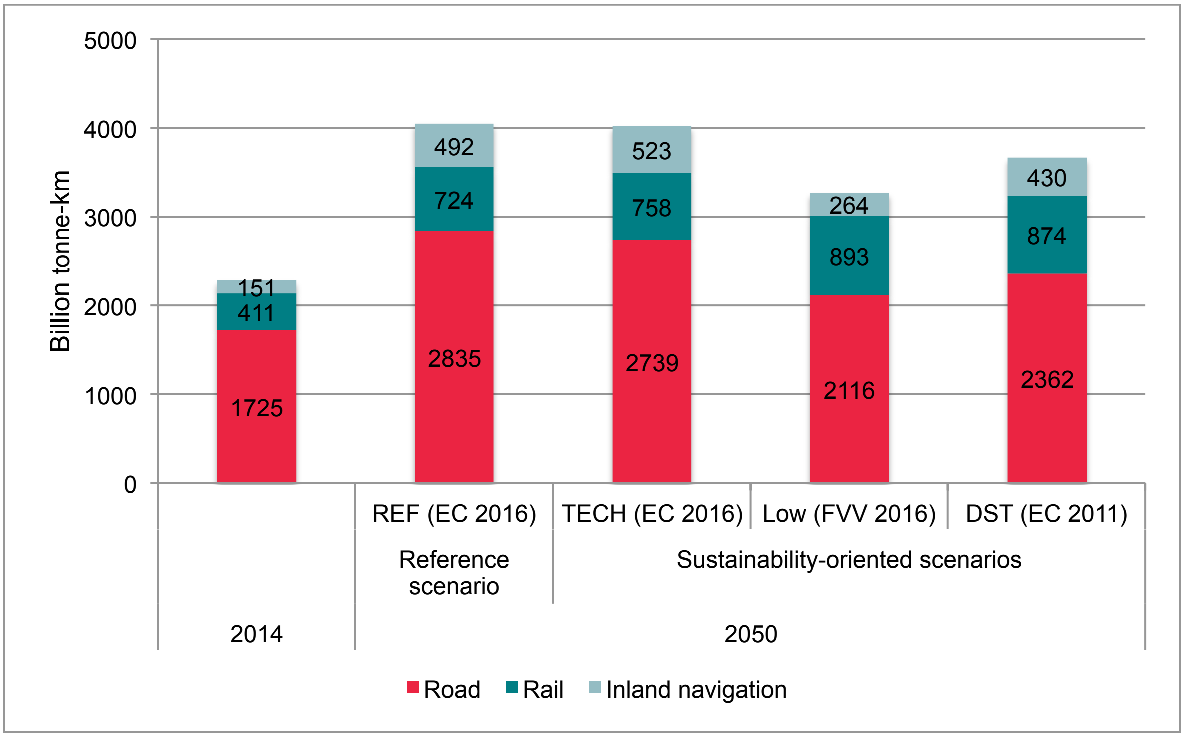

Figure 14 Projected freight volume in the EU (billion tonne-km) in 2050 according to different scenarios

Source: Own figure

** IEA 2017 does not provide these kind of data for inland navigation*

The EU Reference Scenario (EC 2016) expects a rise in **road transport** activity from 1,725 tkm in 2014 to 2,835 tkm in 2050 (plus 64 per cent) (see Figure 14). Other scenarios with a stronger emphasis on climate-protection measures project increases to between 2,116 tkm (plus 23 per cent, FVV 2016) and 2,739 tkm (plus 59 per cent, EC 2016). The average annual growth rates of road transport implied in the analysed scenarios amount to around 1.4 per cent for the baseline case and between 0.57 per cent (FVV 2016) and 1.29 per cent (EC 2016) in the sustainability-oriented scenarios (see Figure 15).

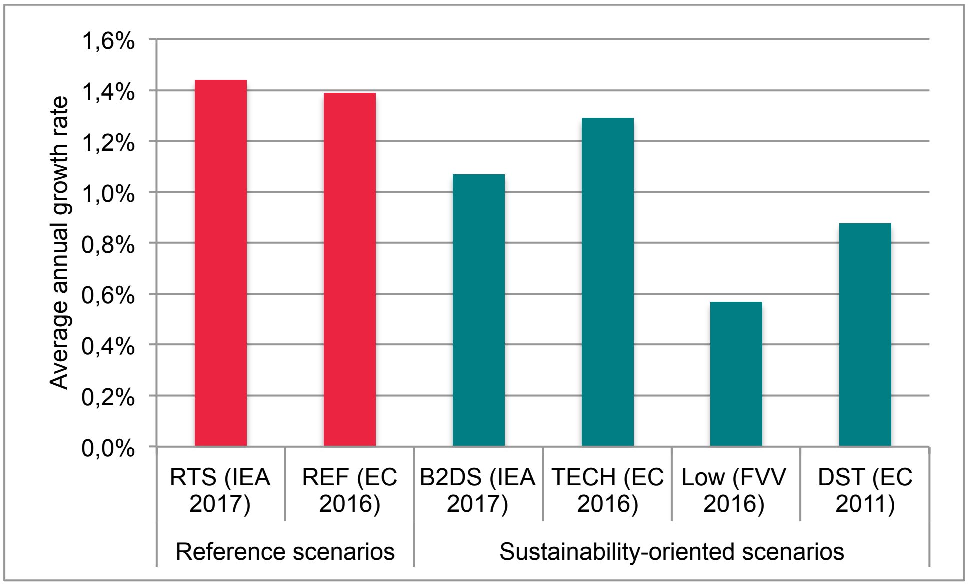

Figure 15 Assumed average annual development of future road freight transport activity in the EU in different scenarios by 2050

Source: Own figure

In comparison, **rail transport** activity is expected to become relatively more important in 2050, especially in a decarbonised future. In the EU Reference Scenario's baseline case, total tonne-kilometre of freight transported by rail increases by 76 per cent from 411 billion tkm in 2014 to 724 tkm in 2050 (EC 2016, p. ???). Since most sustainability-oriented scenarios include a modal shift to rail transport as a climate protection measure, rail transport plays an even more important role in those scenarios. In these cases, the absolute level of tkm develops to between 758 tkm (plus 85 per cent, EC 2016, p. ???) and 893 tkm (plus 117 per cent, FVV 2016) in 2050. The corresponding average annual growth rates of rail transport activity in the EU amount in the baseline scenarios to 1,1 per cent (IEA 2017) and 1,6 per cent (EC 2016), respectively (see Figure 16). The sustainability-oriented scenarios project average annual growth rates of rail freight activity of between 1,4 per cent (IEA 2017) and 2,2 per cent (FVV 2016).

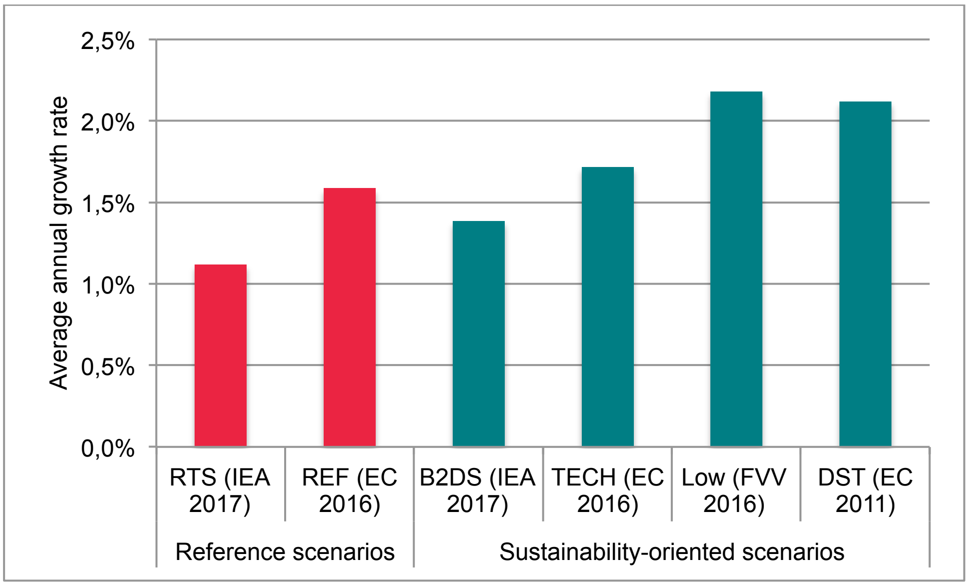

Figure 16 Assumed average annual development of future rail freight transport activity in the EU in different scenarios by 2050

Source: Own figure

The analysed scenario studies show mixed expectations with respect to the future development of demand for **inland navigation**. The EC's 2016 Reference scenario projects a rise of inland navigation activity from 151 tkm in 2014 to 492 tkm in 2050 (plus 226 per cent). Prospects given for 2050 in the sustainability-oriented scenarios are in a relatively wide range, from 264 tkm (plus 75 per cent, FVV 2016) to 523 tkm (plus 247 per cent, EC 2016). As no specific data for inland navigation is given in IEA (2017), fewer data on this transport mode could be analysed. The available data imply expected average annual growth rates which are generally higher than those for the other hinterland transport modes. This can probably also be attributed to efforts to shift freight transport from the road to more sustainable transport modes, e.g. the „Motorways of the Sea“ initiative by the EU (+ check, more infos, e.g. link?). While the average annual growth rate in the baseline scenario is 3,3 per cent, growth rates in the sustainability-oriented scenarios reach 1,6 per cent (FVV 2016) to 3,5 per cent (EC 2016) (see Figure 17).

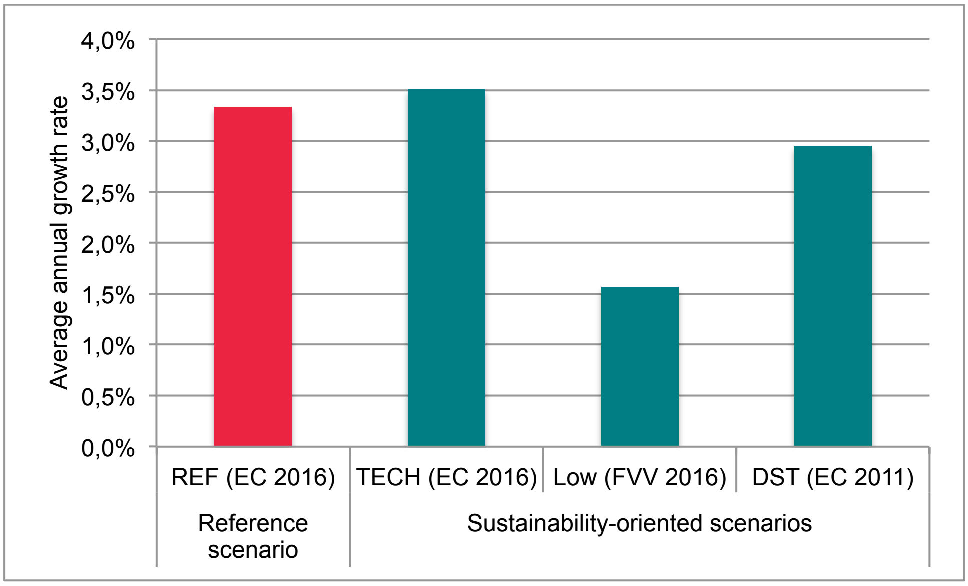

Figure 17 **Assumed average annual development of future inland navigation activity in the EU in different scenarios by 2050**

Source: Own figure

The Netherlands

As in the case of maritime transport, the CPB/PBL's scenarios for Prosperity and Living Environment were the only scenarios identified which provide data on the development of hinterland trade activity in the Netherlands by 2050. As mentioned before, the form of the given information is not completely in line with those from the studies cited above (see page 19).

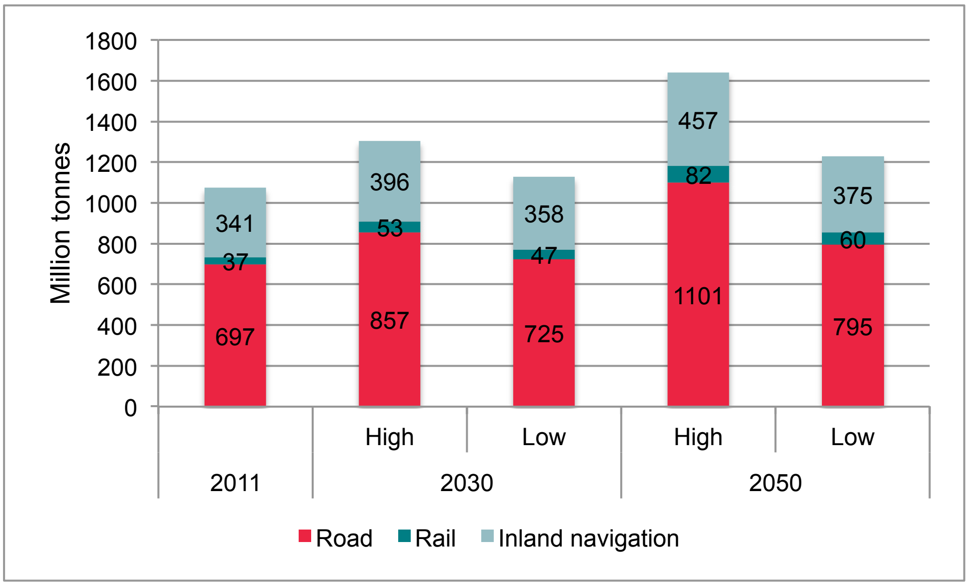

Figure 18 **Assumed development of hinterland transport in the Netherlands between 2011, 2030 and 2050 in the CPB/PBL's High and Low Scenarios (2015) in million tonnes**

Source: Own figure

For 2050, both the „High Scenario“ as well as the „Low Scenario“ project higher overall hinterland trade volumes *(in t)* in the Netherlands compared to 2011 (see Figure 18). This development appears reasonable as the expected increase in transshipment at Dutch ports (see Figure 4) also leads to higher demand for hinterland transport because the majority of goods does not remain at the port[16]. However, the growth in domestic transport is limited since the number of journey declines due to efficiency improvements in logistics (Benelux Union 2016, p. 69). Future transport demand is expected to increase for all types of hinterland transport. While the increase in percentage points varies between road, rail and inland navigation, the modal share varies only slightly between the two scenarios.

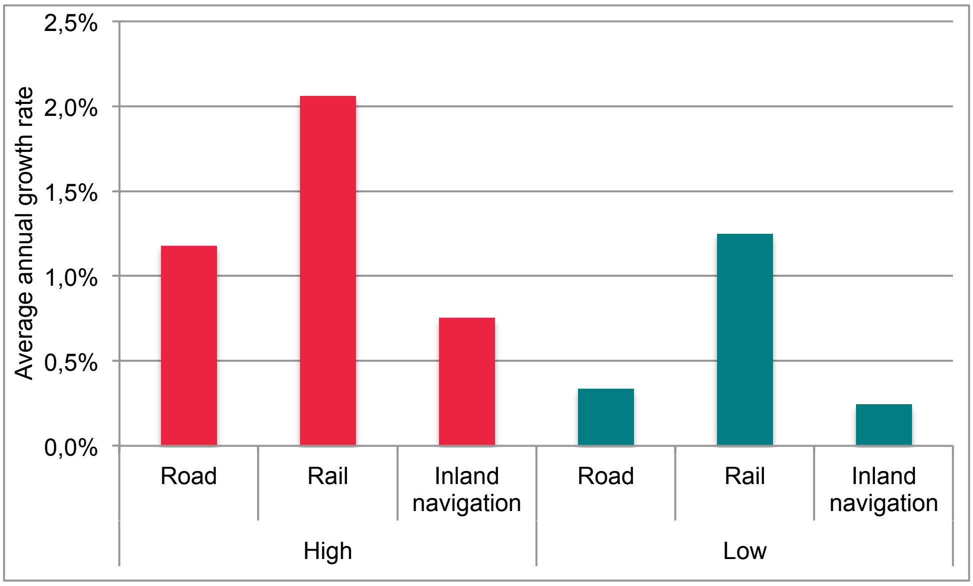

Figure 19 **Assumed average annual development of future road, rail and maritime freight transport volumes in the Netherlands in the CPB/PBL's High and Low Scenarios (2015) by 2050**

Source: Own figure

Road transport increases from 697 t in 2011 to 857 t in 2050 in the „High Scenario“ (plus 58 per cent) and 725 t in the „Low Scenario“ (plus 14 per cent). The average annual growth rates amount to 1.2 per cent and 0.3 per cent, respectively (see Figure 19).

As for maritime transport, the CERTH/HIT 2014 study also provides a figure depicting the expected future changes in road (and rail) trade activity for the EU, including the Rotterdam region, in 2030. Figure 20 illustrates the results of the comparison of the study's „Responsible Growth Scenario“ with data from *its own reference scenario* (in percentage change of tkm). It shows that even in a sustainability-oriented scenario demand for road transport around Rotterdam in 2030 is expected to be only 0 to 5 per cent lower than in the baseline case[17]. The reduction in transported goods is attributed to lower demand due to higher product prices resulting from the „internalisation of technology, transport and energy costs as well as environmental and social

[16] The future development of the share of goods which remain in the port area for further processing is also a topic of debate, see also the Chapter on „Composition of cargo“.

[17] However, tkm by truck are expected to decline substantially in other parts of Europe, especially France, Spain and Finland.

burdens" (CERTH/HIT 2014, p. 14). In sum, on the EU level the political goals for freight transport stated in the EU's Transport White Paper from 2011 will be fulfilled, e.g. the 30 per cent shift of road freight over 300 km to rail/waterborne transport by 2030 (CERTH/HIT 2014, p. 15).

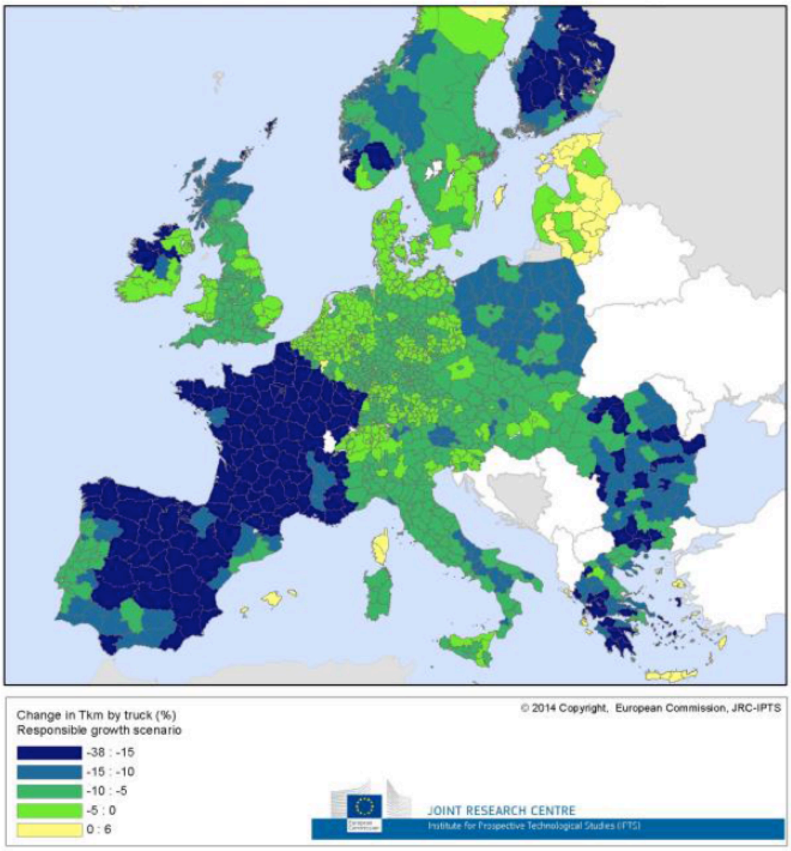

Figure 20 Regional distribution of changes in road freight transport activity levels for the Responsible Growth scenario in 2030 (% in relation with the Reference scenario)

Source: CERTH/HIT 2014, p. 90

In comparison, the demand for **rail transport** in CPB/PBL (2015) shows a significantly stronger rise in terms of percentage growth between 2011 and 2050. Future transport volumes of 82 t („High Scenario") and 60 t („Low Scenario") mean increases of 122 per cent and 62 per cent by 2050. Annually, the average growth until 2050 is 2.1 percent and 1.2 per cent. As a result, the modal share of rail transport surges from 3 per cent in 2011 to 5 per cent in 2050 (##link chapter on modal shift?).

The FUTRE study's (CERTH/HIT 2014) figure shows that in the „Responsible Growth Scenario" rail freight transport in the Rotterdam region in 2030 will be around 0 to 10 per cent lower than in the study's baseline scenario (see Figure 21). As in the case of road transport, rail transport demand reduction is due to the internalisation of costs resulting in higher product prices (CERTH/HIT 2014, p. 14). The decline of overall EU rail transport demand appears to be comparatively small compared to the Reference Scenario because a modal shift takes place from road to rail transport. The same applies for freight transport via inland waterways (CERTH/HIT 2014, p. 14), but no figure has been created for illustration purposes.

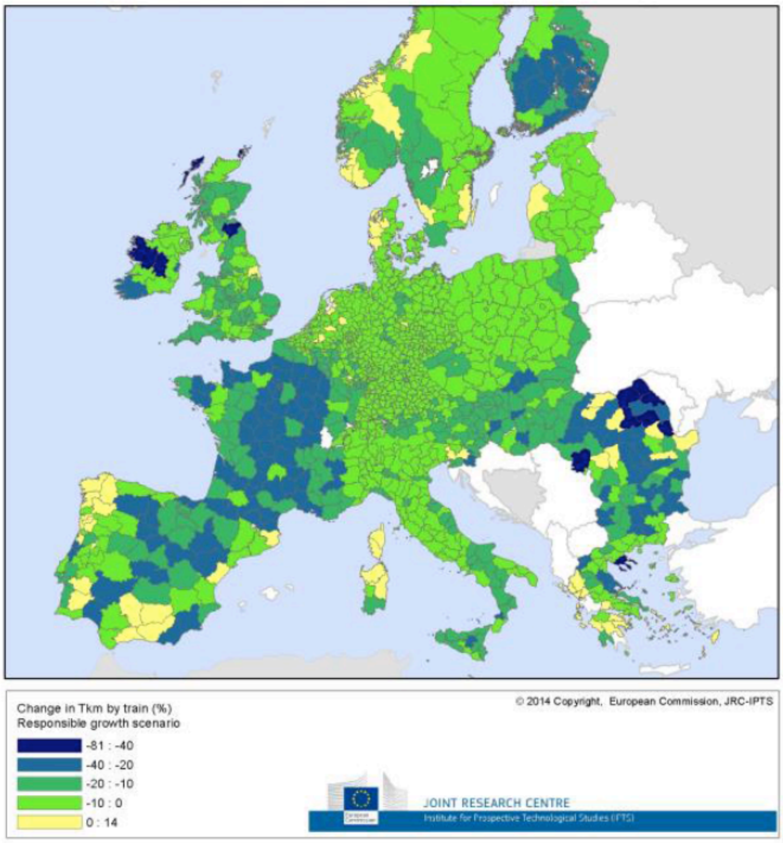

Figure 21 Regional distribution of changes in train freight transport activity levels for the Responsible Growth scenario in 2030 (% in relation with the Reference scenario)

Source: CERTH/HIT 2014, p. 90

With regard to the projections for the relative development, the scenario figures for **inland navigation** are lower than for the two other types of hinterland freight transport. The absolute levels of demand for inland navigation are projected to rise from 341 t in 2011 to 457 t in the „High Scenario“ (plus 34 per cent) and 375 t in the „Low Scenario“ (plus 10 per cent). In average annual growth rates, this implies increases of 0.8 per cent and 0.2 per cent for the period up to 2050. The fact that the modal share of inland navigation decreases after 2030 seems to be based on the assumption that a specific CO_2 tax will be levied on this transport mode (Benelux Union 2016, p. 69).

Composition of cargo

The composition of cargo transported in the hinterland of the port of Rotterdam by 2050 is not explicitly adressed in any scenario study. Estimates of the development of this factor should naturally base on data for the composition of cargo of future seaborne trade activity at the Port as discussed in detail from page 19 on.

Differences between the cargo reaching and leaving the Port of Rotterdam by sea and its hinterland transport result from the amount and type of (usually imported) goods which remain in the port area for further processing (see also footnote 16). Öko-Institut et al. (2016, p. 165) e.g. project that for coal imported to Germany by sea this share is going to rise from 2.5 per cent in 2010 to 30 per cent in 2030. This development is attributed to the assumption that increasingly higher shares of imported coal will be deployed in power stations near the coast (and thus in the port areas). After 2030, the level is expected to stagnate at around 30 per cent.

Freight routes

Beside the possibility of increased transport activity via an Eurasian land bridge between Europe and China (see Chapter 3.1.2), a change in freight routes affecting future hinterland transport of the Port of Rotterdam has not been discussed in any of the analysed scenario studies. As long as no major changes of hinterland freight routes will occur in the future, the impact of these on GHG emissions linked to the Port of Rotterdam will be rather small. A more important factor for overall GHG emission development is the mode chosen for freight transport, which will be discussed in the next Chapter.

3.2.2 Transport modes/ modal shift

Among the different transport modes, international shipping is the most energy-efficient option for transporting freight, if measured per tonne kilometre (IEA 2017, p. 257). Besides the replacement of land-based road freight by short-sea shipping, which is e.g. supported by the EU Commission but the potential for which has not been quantified in the analysed scenario studies, regarding hinterland transport the focus lies on shifting freight from road to rail transport or inland navigation[18].

As depicted in Figure 22, among the various hinterland transport modes, currently rail transport is the most energy-efficient means, followed by inland navigation (world average). Road transport by long-haul heavy-duty vehicles (HDV) is about two times less efficient than inland navigation and medium-duty vehicles (MDV) are by far the worst performers.

The Greenpeace energy [r]evolution scenarios base on the assumption that strong efficiency gains will be achieved by 2050 with respect to all hinterland transport modes. Although the road transport modes are expected to attain the highest absolute energy efficiency improvements, railway and inland navigation are projected to remain the modes with the lowest relative energy demand per tkm (Greenpeace et al. 2015, p. 294). Since rail freight transport is assumed to require e.g. 80 per cent to 90 per cent less energy per tkm in 2050 compared to long-haul HDVs, a shift from road to rail is considered the most desirable option for modal shift in hinterland transport. Goods transported by HDVs are generally better suited for a transport modal shift because goods transported by MDVs mostly go to regional destinations and thus do not match the long-distance nature of freight rail transport (Greenpeace et al. 2015, p. 295). A modal shift from road to inland navigation is often not feasible because the use of ships largely depends on geographical conditions.

[18] Greenpeace et al. 2015 (p. 294) also analyses the potential for air traffic substitution by high speed rail. For OECD Europe, the relative substitution potential amounts to 30 per cent for domestic flights and 15 per cent for intraregional flights in 2050.

Overall, as the relation between the transport modes' energy intensities is not expected to change considerably in the future, the GHG emission reduction effect of modal shifts are even larger if the shift is implemented already in the short-term.

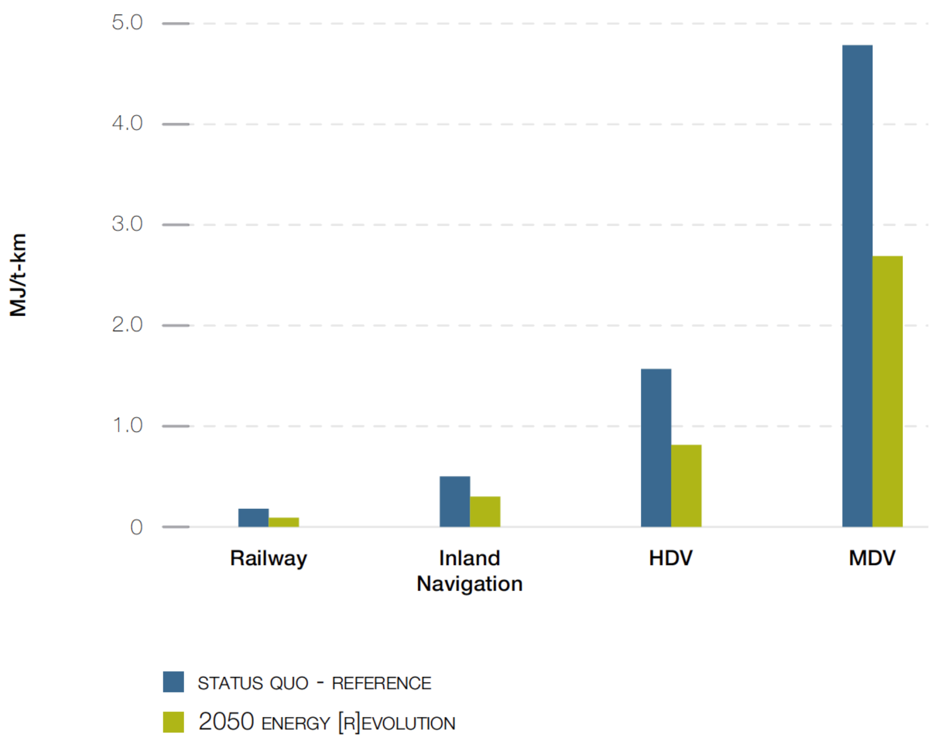

Figure 22 World average freight transport energy intensities for today and 2050 in MJ/tkm*
**values weighted according to stock and traffic performance*

Source: Greenpeace et al. 2015, p. 294

EU level

Analysing the scenario studies with respect to modal shifts in freight transport, they usually expect shifts from road to rail transport and inland navigation by 2050. While this change is only quantified in some studies, others e.g. only state that „it is assumed that a modular shift from road to rail and/or to battery or fuel cell power transport vehicles takes place" (Greenpeace et al. 2015, p. 293).

The European Commission's „Reference Scenario" (2016) expects the share of road transport in overall hinterland transport to decline from 75 per cent in 2014 to 70 per cent in 2050 (see Figure 23). Interestingly, the share of rail transport is projected to remain more or less constant at 18 per cent while additional freight is transported by means of inland navigation (7 per cent in 2014 vs. 12 per cent in 2050).

Compared to the baseline case, by 2050 the share of freight transport by road decreases further to between 68 per cent (EC 2016) and 64 per cent (EC 2011) in all sustainability-oriented scenarios. Additionally, with between 19 per cent (EC 2016) and 27 per cent (FVV 2016) all show (at least slightly) larger increases in the share of rail transport. The climate protection scenarios differ in so far as the scenarios „Low" (FVV 2016) and „Diversified Supply Technologies" (DST, EC 2011) expect a strong shift from road to rail transport (plus 52 per cent and plus 33 per cent of rail transport, respectively, vs. 2014). Meanwhile, rail transport in the „Tech Scenario“ (EC 2016) rises by only 5 per cent compared to 2014. Instead, similarly to the study's Reference Scenario, a relatively large shift to inland navigation takes place (plus 97 per cent vs. 2014). This means a huge difference especially in comparison to the „Low Scenario“, in which the share of freight transport by inland navigation in 2050 (8 per cent) is projected to be only 22 per cent higher than in 2014.

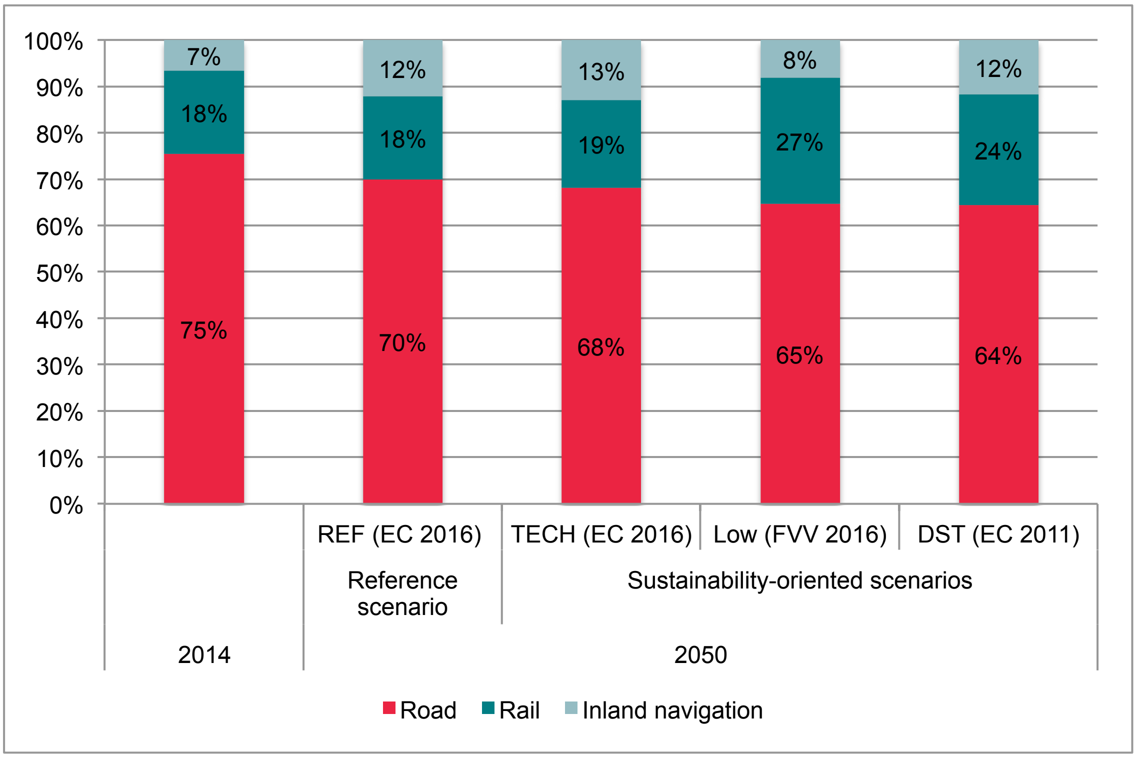

Figure 23 **Assumed modal share in hinterland freight transport in the EU in different scenarios by 2050 (% share of tonne-km)**

Source: Own figure

The Netherlands

For the Netherlands, the CPB/PBL's scenarios for Prosperity and Living Environment (2015), which do not have a particular focus on sustainable development and only provide data in tonnes (not tkm), show a slightly different picture.

In both scenarios, „High“ as well as „Low“, the share of road freight transport is not projected to be lower in 2050 than in 2011 (see Figure 24). It is even expected to rise from 65 per cent in 2011 to 67 per cent in 2050 in the „High“ scenario which assumes increasing global cooperation and growth in world trade.

Nevertheless, a certain modal shift is assumed to occur in those scenarios. It consists of decreasing shares of inland navigation (minus 12 per cent and minus 4 per cent between 2050 and 2011) which are compensated by increases in the share of freight transport by rail (plus 45 per cent and plus 42 per cent between 2050 and 2011). As mentioned before, lower demand for inland navigation services is attributed to the scenario assumption that a specific CO_2 tax will be levied on this transport mode (Benelux Union 2016, p. 69).

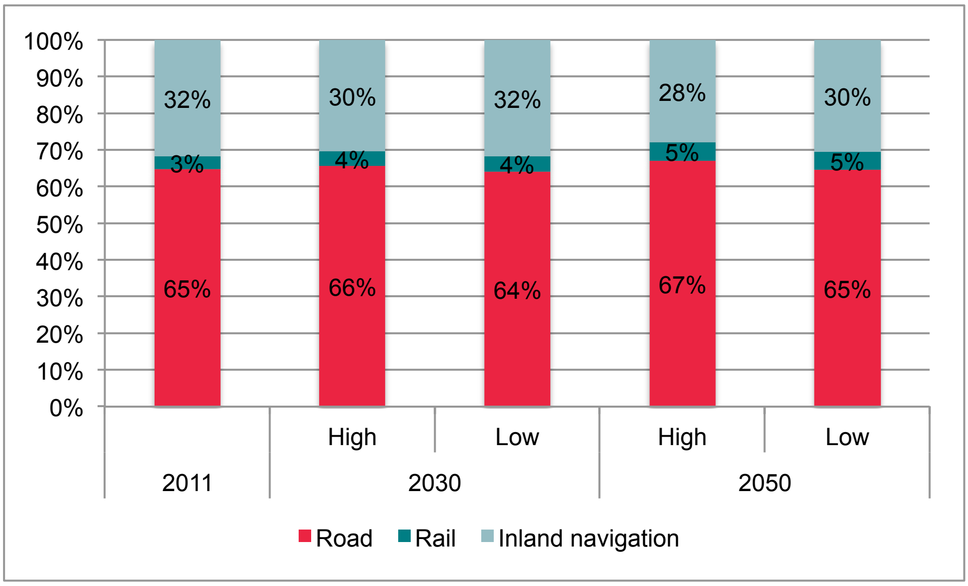

Figure 24 **Assumed modal share in hinterland freight transport in the Netherlands in the CPB/PBL's High and Low Scenarios (2015) by 2050 (% share of tonnes)**

Source: Own figure

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