OUTLOOK HINTERLAND AND CONTINENTAL FREIGHT 2020

Topsector Logistiek

Colophon

Outlook Hinterland and Continental Freight 2020

Commissioned by Topsector Logistiek
August 2020

Authors
Matthijs Otten (CE Delft)
Eric Tol (CE Delft)
Peter Scholten (CE Delft)
Paul van de Lande (TNO)
Maarten Verbeek (TNO)
Herman Wagter (Connekt)

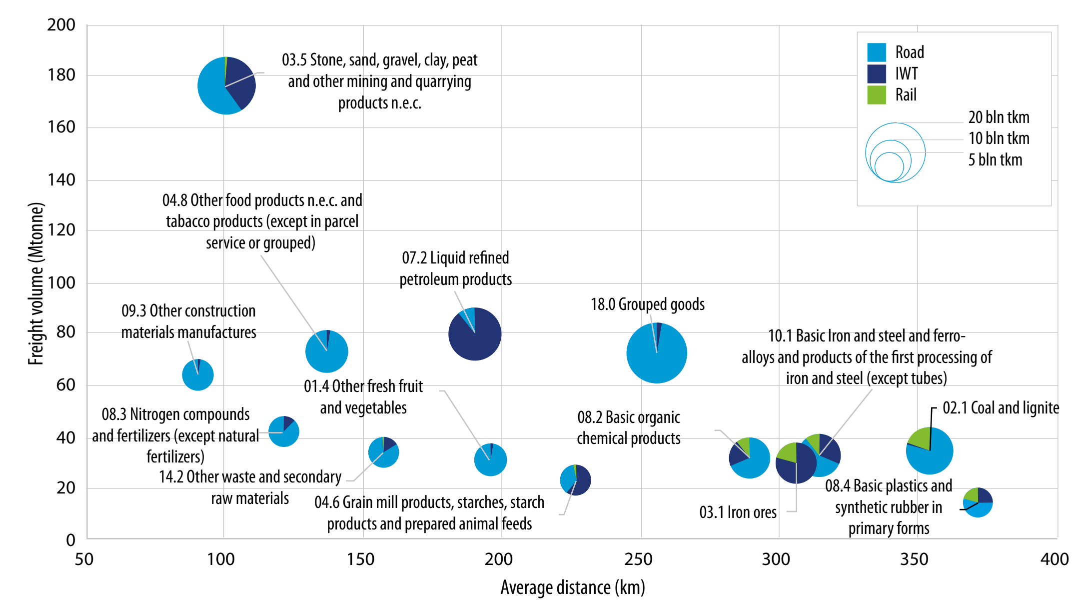
Photography
Danny Cornelissen
Chris Pennarts
Photostock, wikipedia
Scania (page 33)

Table of content

Management summary

The objective of this Outlook on Hinterland and Continental Freight (HCF) is to determine what needs to be done in the medium term in order to meet the 2030 and 2050 decarbonization objectives for HCF flows in the Netherlands, as described in the Paris and Dutch ('Klimaatakkoord') climate agreements.

A detailed analysis of volume versus distance/modality reveals the different characteristics of freight categories and flows within the hinterland and continental freight transport.



The freight categories with an average distance below 200 km are mainly transported by road, except for the heavy bulk categories stone and sand, and liquified petroleum products. The freight categories with an average distance above 200 km show more inland waterway (IWT) and rail transport, except for grouped goods. The higher average distance is mainly due to rail transport, with an average (tonne-weighted) transport distance of 650 km in HCF transport. The figure points out that for a practical strategy to decarbonize HCF-transport a differentiated approach is needed taking into account the different charactristics of freight segments.

Four different strategies have been detailed in this Outlook:

1. Logistics optimization to reduce unused capacity;
2. ZE technology for road transport;
3. New concepts for short and long distance rail transport;
4. New concepts for inland waterways container transport.

Logistics optimization and new concepts for 'IWT container transport' do have some potential to reduce CO_2 emissions, in the range of 5 to 20%. The implementation of these innovations will require concerted efforts and the willingness to change established procedures. The biggest reduction in emissions will require the use of low-emission (LE) or zero-emission (ZE) driveline technology for road and IWT transport.

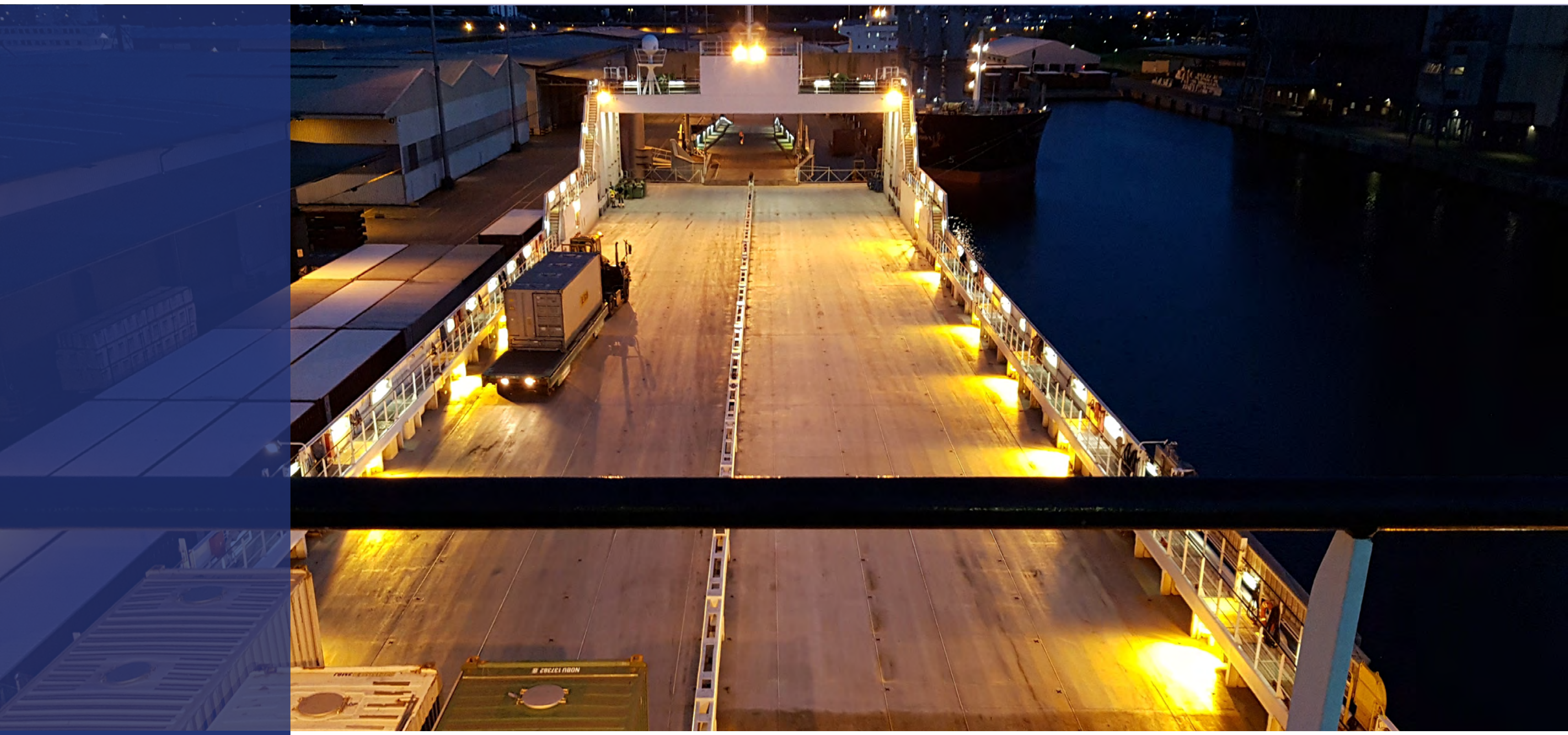
Battery-electric drives for road and IWT have the potential to scale quickly in volume, with the limitation of a limited range and an extended charging time. Electric road systems (ERS) can be a solution to extend the range. The application requires good coordination on (international) corridors.
Hydrogen fuel-cells also have more potential for longer ranges, but the generation of green hydrogen comes at a serious efficiency penalty in the conversion between the primary renewable electricity source, and the resulting electrical energy powering the electrical motor in the vessel or vehicle: for the same kWh of primary energy a hydrogen vehicle drives about 1/3 of the distance compared to a BEV.
The limited supply of advanced biofuels or E-fuels, combined with the competition for this type of fuel by air transport and maritime transport, leads to the expectation that biofuels and E-fuels will not be the longer term solution for HCF transport. In the short and medium term, however, advanced biofuels for road and IWT can play a role in the transition: for the longer term it is expected that advanced biofuels will be used primarily by maritime and air transport.

Fortunately the flows of goods in HCF can be supported by a strategy based upon ZE-corridors with (relatively short range) ZE-connections between the corridor and the destinations.

Natural ZE-corridors are based upon pipelines and electrified rail transport. The potential of rail transport in corridors is higher than currently utilized, as the modal split difference in flows between Italy and Spain shows. A pan-European focus on developing freight optimized rail corridors, with support for powering reefer containers (conditioning) during the trip would contribute substantially to the required decarbonation of the HCF-flows.

ZE-corridors based upon road transport or inland waterways require serious investments in ZE-technology (drive technology, energy supply, or overhead power supply). The advantage of concentrating these investments in strategic high-volume-corridors is that their utilization factor will be relatively high, supporting the business case.

The feeder-connections between the ZE-corridor and the origin/destination can be supported by short range ZE-vehicles.

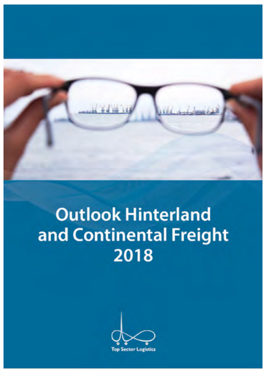


1 Introduction

1.1 Retrospect on Outlook HCF 2018

The Netherlands have developed a thriving logistics sector, thanks to its position in the Rhine-Scheldt Delta, the availability of large areas of arable land, a great amount of multinational and innovative industries and an open economy with one of the highest levels of imports and exports per capita. In combination with a dense population there is an immense challenge for the logistics sector to meet the decarbonization objectives of the Paris Climate Agreement. The report 'European environment - state and outlook 2020' of the European Environment Agency designates transport as 'one of the biggest challenges ahead to decarbonising the economy'.

The Topsector Logistics has issued a first Outlook on Hinterland and Continental Freight in 2018. The main objective of this publication was to develop plausible scenarios that illustrate the way forward for the Dutch logistics sector. A distinction between five logistical segments was made, namely dry and liquid bulk flows, consumer goods, industrial goods (semi-fished products), and perishables, which enable the description of specific decarbonization paths. The current study shows that the overall CO_2 emission of hinterland and continental freight transport amounted to 6.0 megaton per year in 2018. In the first issue it was estimated that storage and transhipment accounts for another 0.7 megaton .



This first Outlook on Hinterland and Continental Freight (HCF) concluded that it is still possible to meet the Paris decarbonization objectives for all the segments defined, albeit that all possible measures and technologies must be applied and an approach on a system level is needed. The impact of the transition towards a non-fossil economy will be immense. On the one hand because of the expected ongoing growth of production, consumption, trade and related transport and logistics activities. On the other hand, because of the dependency on fossil fuels of the present logistics sector. With the exemption of rail transport, the energy demand for all other transport modes is almost 100 % based on fossil fuels.

The Outlook on HCF of 2018 showed the impact of the expected decline of the flows of coal and liquid fuels. Particularly inland shipping and rail transport will be affected by the loss of these commodities. The competitive position of these modalities can come under pressure, as will its innovative power. There is a risk for the modal shift ambitions of the authorities in the Netherlands and the EU. A backshift towards road transport is likely if inland navigation and rail lose their market power.

In short, the main challenge for the international logistics sector in the Netherlands is to retain its position in the 'Gateway to Europe' and in the meantime lower the emission of greenhouse gasses to practically zero in the next 30 years. The impact on individual companies can be immense, whereas new technical and organisational concepts will need to be developed and implemented in order to meet the Paris demands.

1.2 Objective of Outlook HCF 2020

The first HCF Outlook has described the transition paths towards 2050 for the five HCF segments on an aggregated level. The objective in this Outlook on HCF 2020 is to determine what needs to be done in the medium term in order to meet the Paris decarbonization objectives. The previous HCF Outlook clearly showed that the different HCF segments follow different transition paths towards decarbonization. Particularly heavy road transport and inland shipping are likely to have more difficulties in applying zero-emission technologies in the short and medium term, contrary to city logistics, where battery electric vehicles are likely to be widely applied within the next years. Additionally, in the Climate Agreement of the Dutch Government, it has not been clarified either which zero-emission technologies can be applied for heavy duty transport. This means that the HCF segments need to catch up after 2030 in order to meet the reduction demand for 2050. The objective of this outlook is to shine a light on the way the sector needs to anticipate on the challenge for decarbonization after 2030.

This Outlook 2020 starts in chapter 2 with an overview of the hinterland and continental freight flows. The figures presented in the previous outlook have been updated and extended. Prognoses for 2030 are introduced, as well as analyses on the geography of the flows and the contents of containers. This chapter also provides insight in the specification per segment of the overall decarbonization targets.

New 2018 data on load factors, and origin and destination of HCF transport have been used in chapter 3 on logistics efficiency. The outlook 2018 showed a clear need for an efficiency improvement as starting point for all segments. With these new data available, a macro assessment on inefficiencies and potential savings has been carried out.

In order to illustrate the transition path and deepen the insight on the decarbonization potential of the transport modes, a case study approach has been used. Chapters 4, 5 and 6 describe the cases for road, inland waterway and rail. The cases show the challenges encountered, the possible scenarios and the way new concepts can help in reaching the decarbonization objectives. This chapter ends with a consideration on the way the three transport modes need to interact in order to reach the decarbonization requirements in 2050.

Chapter 7 and 8 of this Outlook focus on the way the synergy between the concepts and technologies can be achieved and provide conclusions and recommendations for implementation.

2 Hinterland and continental freight transport: present and projected flows

This chapter presents an overview of HCF transport and logistics in the Netherlands and the challenge to decarbonize HCF transport. First, in section 2.1, we explain the scope of the Outlook HCF. Next, in section 2.2, we give more insight on the freight and transport volumes of the HCF segments distinguished: dry bulk, liquid bulk, non-perishables, perishables and industrial goods. In section 2.3 an assessment of projections of freight volume towards 2030 of the HCF segments is presented. In section 2.4 we discuss and quantify the challenge to decarbonize HCF transport for the different modes and segments. The chapter ends with a wrap-up of the most important findings in section 2.5.
The data presented in this chapter have been produced with detailed statistical information provided by the Dutch national statistics bureau CBS on tonnes and tonne-kilometres of HCF transport. For translation of transport performance into CO_2 emissions, CE Delft's STREAM model has been applied. The results have been scaled to the total CO_2 emission reported by CBS (seen annex Chapter 2).

2.1 HCF transport: scope and context

The freight transport market is an international market. The transition towards a single market in the EU in combination with an ongoing globalisation has resulted in a huge increase in transport flows between the European countries and a strong internationalization of the freight transport sector itself. Cross-border transport has become increasingly important. This is the case for all transport modes. The illustrated map in Figure 1 shows the share of transport volume to and from the Netherlands in megatons (Mt) per mode, with a total of 1,925 Mt freight.

Figure 1
HCF Scope and volume per flow direction

HCF flow directions

HCF transport	Mt freight
Import + Export (no sea/airport involved)	**207**
Import	105
Export	102
Hinterland NL	**235**
Port-to-port (within same sea/airport)	42
Port-to-port (between different sea/airports)	43
Sea/airport to hinterland	85
Hinterland to sea/airport	64
Hinterland International	**220**
Sea/airport to hinterland	153
Hinterland to sea/airport	67
Transit	**77**
Total	**739**

This Outlook on Hinterland and Continental Freight transport focuses on land-based international transport passing through the Netherlands or having its origin or destination in Netherlands (green flow in Figure 1). The modes considered in HCF are road, rail and inland waterway transport (IWT). All the hinterland transport that these modes entail is in the scope of HCF, i.e. all freight entering or leaving the Netherlands via a Dutch sea- or airport with an origin or a destination in the Netherlands or abroad. Aviation and maritime shipping are not covered, because there is no undisputable way of assigning CO_2 emissions from those modes and because under the IPCC allocation rules, the emissions of international aviation and shipping are not allocated to countries. Pipeline transport is also excluded from this Outlook, since it already has a very high efficiency and specific application (see blue flows in Figure 1). The table in Figure 1 gives more detail on the transport direction of the 739 Mt HCF freight. Clearly, there is more transport from the seaports to the hinterland than vice versa. The transport flows between the seaports are substantial (1/3 of Hinterland NL). A significant part (25%) concerns transport of liquefied petroleum products.

The total freight and transport volume per type of link are depicted in Figure 2. The Figure on transport volume differentiates between tonne-kilometres (tkm) on Dutch territory and abroad. Clearly, HCF transport involves more kilometres abroad than in the Netherlands. This is especially true for import and export which is not related to a sea- or airport. IWT has a large share in hinterland transport and also rail has a relatively large share. Comparison of the tonne-km modal share on Dutch territory and abroad reveals that the transport distances of IWT abroad are relatively short compared to road and rail. An important reason is that IWT is mainly focussed on transport between the Dutch ports and Germany or Belgium with their extended IWT infrastructure network, whereas rail and road transport involve a higher share of transport to countries further away such as Italy and Poland. (See also Figure 3).

Figure 2
Freight and transport volume of HCF per link in 2018

** and airport: transport from sea ports are the vast majority in tonnes and tonne-km*

Note
14 mln ton transit by road of foreign vehicles are not included in the analysis

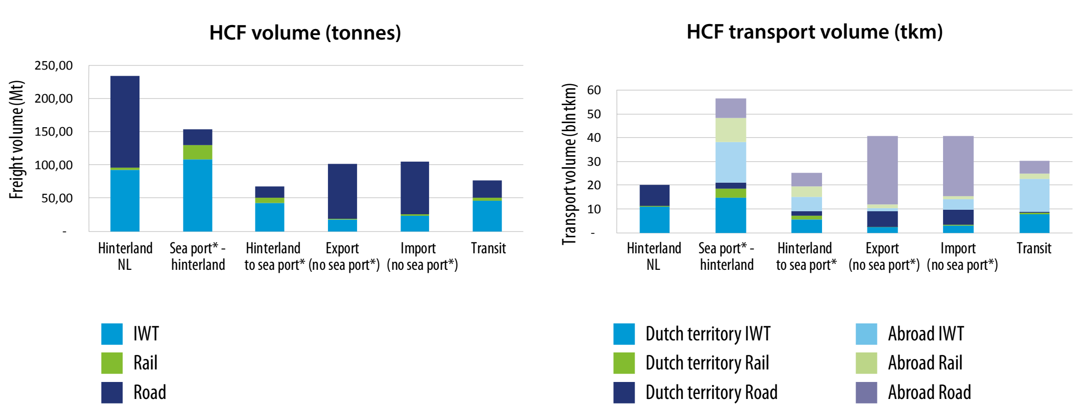
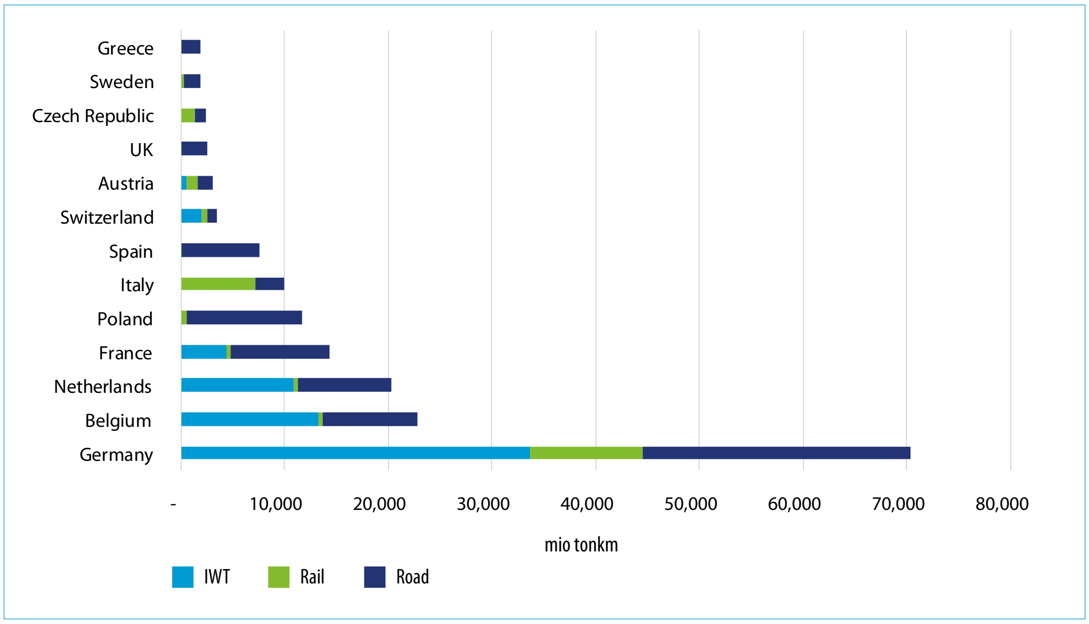


Figure 3 shows the top 13 countries in transport volume (including hinterland transport in the Netherlands), making up 94% of the total tonne-kilometres of HCF transport to and from the Netherlands.

Figure 3
Transport volume (mio tkm) and modal share on relations to and from the Netherlands

** Transit transport (transport going through the Netherlands, but not loaded or unloaded in the Netherlands) is not included in this graph*



Modal split figures show relatively low shares of road transport (<50%) to countries along the Schelde, Maas and Rhine (Germany, Belgium, Switzerland) and countries with a good rail connection (Italy, Austria and Czech Republic). Very high shares of road transport (>80%) are found for Poland, Spain, Greece, Sweden and UK[1]. Generally, rail transport to and from the Netherlands is particularly strong on long distances on the corridor to Italy. Thus use of rail towards Central and Eastern Europe and the Iberian peninsula is very limited, due to the high degree of competitive advantages of road transport (flexibility, costs, reliability) on these corridors. Particularly the connection with Spain is hindered by the French railway system which (according to industry experts) is hampered by relatively high costs and lower reliability of arrival times.

1 *Short sea transport is not part of HCF, but does play a role in the modal split to Sweden and UK, the latter being mostly road transport using ferries.*

2.2 Transport volumes per freight segment

Logistics characteristics such as choice of mode, need for time constraints and last but not least origin-destination relations very much depend on the type of freight. Coal and oil for example are bulk flows that require transport modes that can handle large weights and large volumes at low cost, such as IWT and rail. These flows are not time critical and are mainly shipped between large industrial plants and ports. Rail cargo carriers are used as rolling stock, which reduces handling costs. Flowers and plants on the other hand are time critical goods with high value per tonne, transported from greenhouse areas such as the Westland to distribution centres and retailers. Volumes between origin and destination are much smaller, weights per order are much less. Road transport is the favoured transport mode for its flexibility and response time. The starting point and decarbonization options for these kind of goods are very different. In the Outlook HCF we therefore distinguish between the 5 logistical HCF segments in Table 1.

Table 1
Logistical HCF segments Outlook HCF and characteristics

** Lower figure excluding empty containers, higher figure including empty containers*

Logistical segment	Characteristics
Liquid bulk	• high volumes on H-B relation • dedicated vehicles (tanks) • not time critical • between ports and industries • Low containerisation degree (3%)
Dry bulk (including neo-bulk)	• high volumes on H-B relation • not time critical • between ports and industries • low containerisation degree (11%)
Perishables	• small/medium volumes on H-B relation • time critical • between port/production areas and distribution/retail • high containerisation degree (32%) • often climatized conditions (reefers)
Non-Perishables (non-perishable consumer goods)	• small/medium volumes on H-B relation • can be time critical • between port/production areas and distribution/retail • medium containerisation degree (23%)
Industrial goods (semi-finished products, machines, transport and industrial equipment, including empty containers)	• high/medium volumes on H-B relation • not time critical • between port areas and industries • medium/high containerisation degree (24% -34%)*

Figure 4 shows the freight and transport volume per segment in HCF transport. The bulk segments (dry bulk: 51% and liquid bulk: 12%) account for over 60% of the tonnes, and have an even higher share in tonne-kilometres on Dutch territory (dry bulk: 55%, liquid bulk: 13%). The other segments (non-perishables:17%, industrial goods:13% and perishables: 7%) make up 37% of the tonnes and only 32% of the tonne-kilometres on Dutch territory. In the total tonne-kilometres (including abroad), however, their share is higher (41%), because of longer transport distances abroad than for bulk.

Figure 4
Freight and transport volume of the HCF segments

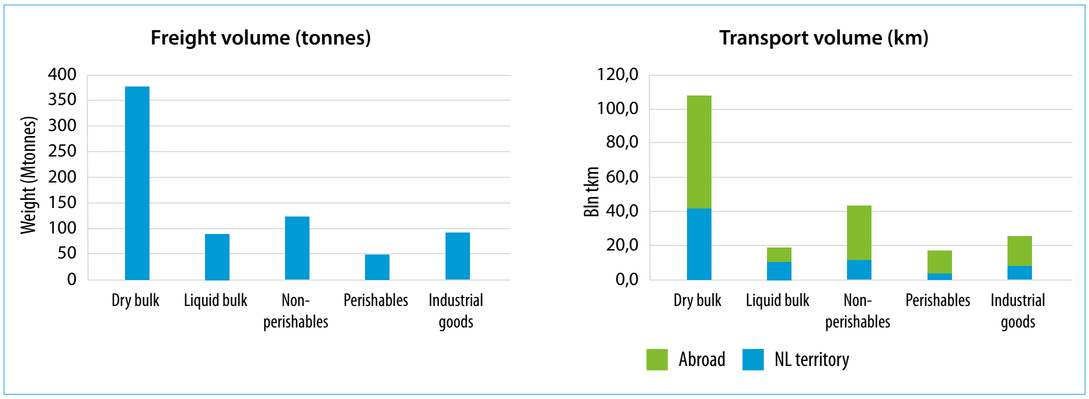


Figure 5 gives more detail on the modal split of the HCF segments. For an important share dry and liquid bulk is transported by IWT (62%) and rail (6%). For the other freight segments road transport is dominant, especially for perishables (90% share).

Figure 5
Modal split (tonnes) per freight segment and total HCF (right)

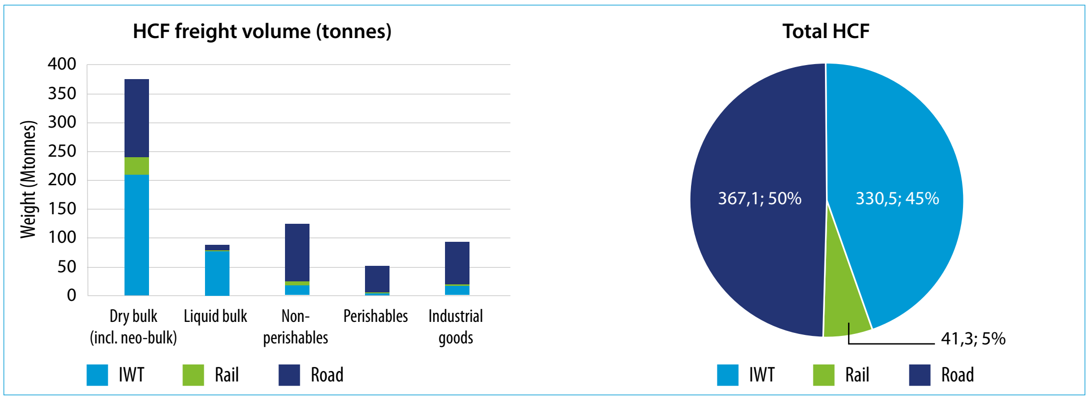
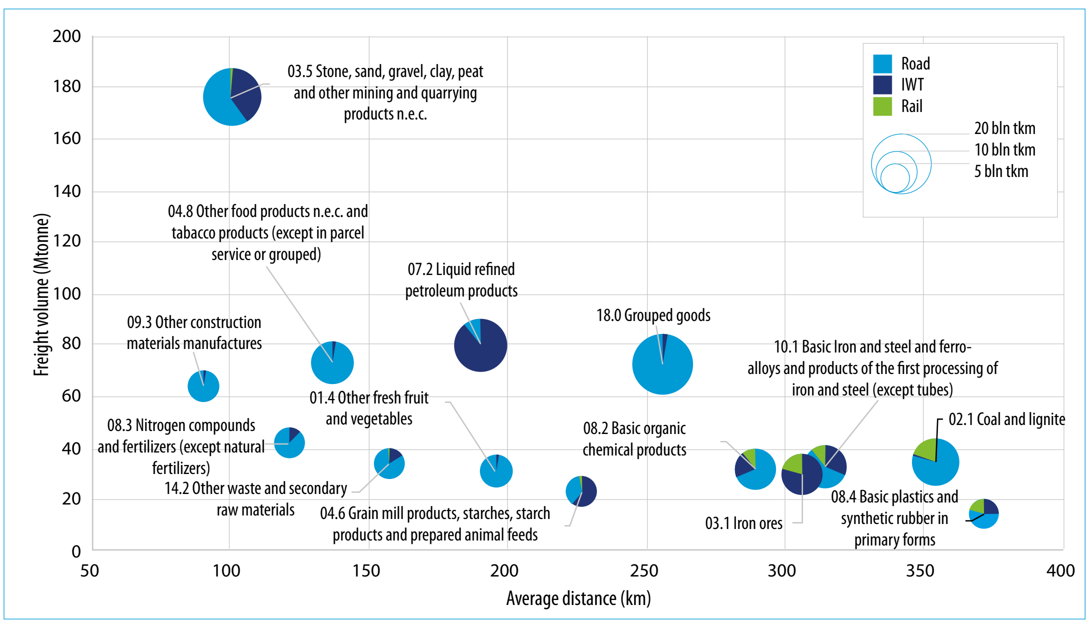


Figure 6 gives more detail on freight categories underlying the 5 freight segments. The figure shows the transport volume (bubble size in tkm) of the top 14 most transported freight categories out of 80 NST 2007 freight categories making up over 60% of the tonne-kilometres. Per freight category the average distance (x-axis), the freight volume (y-axis) and the modal split (pie chart) are shown.
The dry bulk categories i) stone and sand, and ii) coal and lignite both have high transport volumes, however, whereas the high transport volume of stone and sand is mainly driven by the high freight volume, the high transport volume of coal and lignite is driven by the large transport distances.

Figure 6
Transport volumes (bubble size: tkm), average distance and freight volume of freight categories of 14 most transported freight types



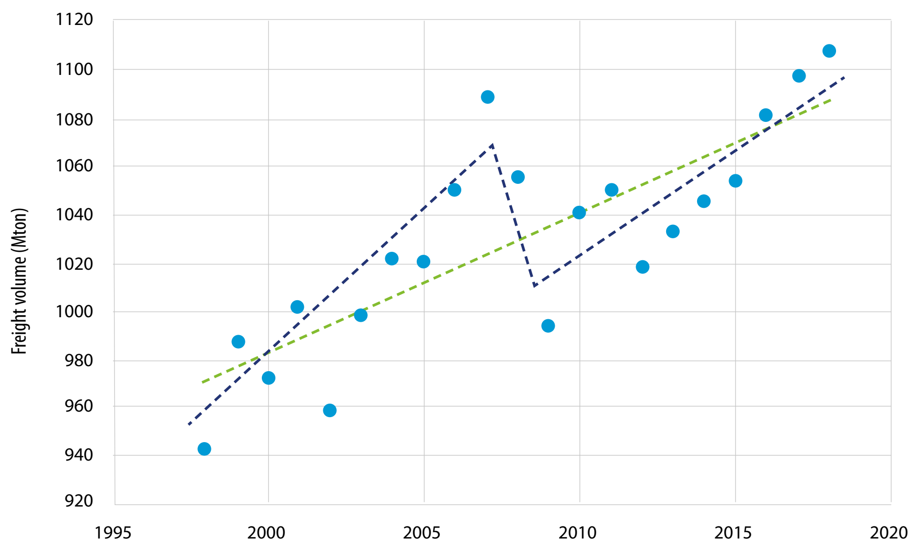
The freight categories with an average distance below 200 km are mainly transported by road, except for the heavy bulk categories stone and sand, and liquefied petroleum products. The freight categories with an average distance above 200 km show more IWT and rail transport, except for grouped goods. The higher average distance is mainly due to rail transport, with an average (tonne-weighted) transport distance of 650 km in HCF transport (see also Annex 2.2 for modal shares per distance classes and segment). Overall we conclude that road transport focusses on short distances, food products and grouped goods, whereas IWT focusses on bulk goods, and rail transport on long distances.

2.3 Developments towards 2030 in logistics segments

Freight volumes (HCF and national) have been growing the past years in the Netherlands (see Figure 7). The average annual growth in freight volume in the period 1998-2018 amounts 0.6%. In the period before (1998-2007) and after (2009-2018) the decline in demand (2007-2009) during the financial crisis, the growth is about 1% per year.

__Figure 7__
Historic freight volumes of IWT, Rail and heavy freight road transport (HCF + inland transport)

Source
CBS staline
- *historic data*
-- *average trend*
-- *trend including crisis*



It is hard to predict the growth towards the future, especially in times like this, where we are faced with the Corona crisis. Although the Corona crisis will likely have an important impact on freight and transport demand coming years, we assume that on the long term the effect can be negligible, having currently no data to estimate differently. On the longer run the effects of such a crisis might fade out, however, this crisis might also cause a drastic change in transport flows around the world (see textbox).

Possible effect of corona crisis

The consequences of this crisis for the economy and logistics are now incalculable. A deep recession is expected, which will have major consequences for the volume of production and consumption, costs, employment, etc. In addition, there may be a shift in production locations, for example by withdrawing production from China and the local production and distribution of goods again. This will have major consequences for the flow of goods to, from and within Europe. Also the relative costs between the various modalities and the progress in transition to sustainable economy might be affected as a result of the crisis. It is too early to determine the concrete consequences for the forecast figures in this Outlook, based on the WLO scenarios and Basgoed projections. The figures presented in this study are of course without any 'corona effects'. Depending on the way in which economic development resume after the crisis, there will in any case be a slowdown in growth, just like after the financial 2008-2010 crisis.

According to the WLO scenario (high) the average freight demand will grow about 1% per year towards 2030 with a somewhat smaller growth rate for dry and liquid bulk (0.7% - 0.8% per year) and a somewhat higher growth rate for non-perishables (2%), perishables and industrial goods (1.5%). To estimate freight volumes towards 2030, we have applied detailed growth rates from BASGOED (WLO-high) on the 2018 data of CBS. For 3 freight categories, however, we assumed a different growth rate, being:

- **Coal and lignite:** To reduce climate emissions, the Netherlands and Germany have plans to close coal fired energy plants in the coming years. This will have a big impact on the transport demand of coal and lignite. Some plants have already been closed, leading to a decrease in freight volume from 48 Mton in 2014 to 34 Mton in 2018. Instead of a 1-2% annual growth according to WLO, we assume a 43% decline in freight volume between 2018 and 2030. The 43% decline is in line with prediction by BP (BP, 2019) and the plans for the goals set in Germany to reduce energy from coal fired plants of 42.6 GW in 2017 to 16.7 GW in 2030 (Zeit online, 2019), knowing that coal fired plants are responsible for 2/3 of the coal consumption in Germany.
- **Liquid refined petroleum products:** The demand for diesel and gasoline is likely to reduce because of EU target on CO_2 emissions for cars trucks and because of national targets to increase the number of electric vehicles and the amount of zero emission fuels by 2030. Instead of an annual growth of 1% according to WLO, we assume a 22% decline between 2018 and 2030 which is in line with prediction for the EU by BP (BP, 2019).
- **Animal feed:** The stricter compliance to the EU nitrogen deposition rules are expected to result in a reduction in the total volume of Dutch livestock, according to shippers. This in turn will lead to a reduction in demand for animal feed. We estimated a 15% reduction between 2018 and 2030 (based on (RH-DHV, 2019)).

Some freight flows, like biomass and biofuels, might increase to replace coal and petroleum products to some extent. It is, however, not expected that this increase will be of the same magnitude as the declines. Other alternatives for energy production demand less transport (like wind and sun energy). Also for biomass and biofuels it is unsure whether the transport demand is similar as they might (partly) also be resourced more locally and not via sea ports.

Figure 8
Freight volume projections towards 2030 (million tonnes)

** 2030(BG) is the 2030 scenario with growth rated from BASGOED only*

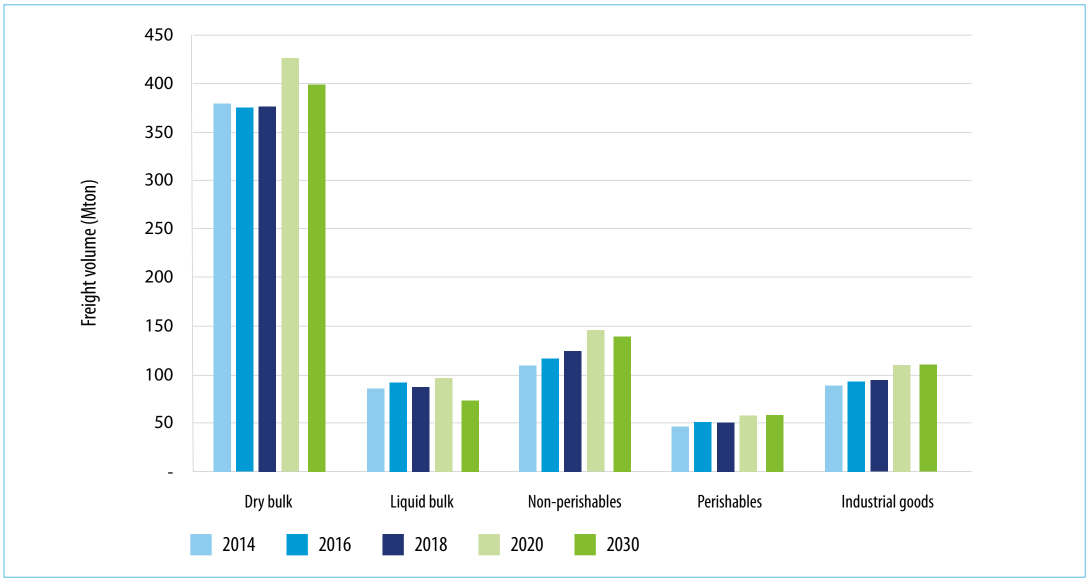
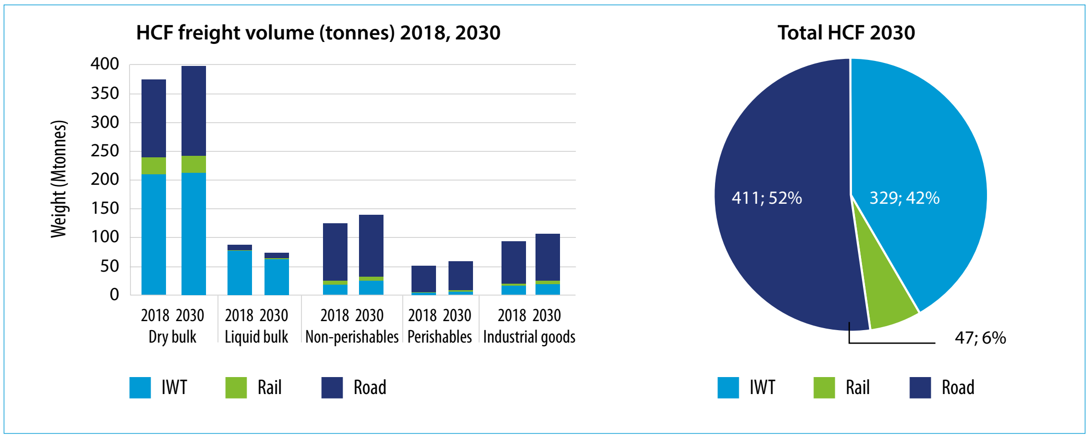


Figure 8 shows a growth towards 2030 for all freight segments, except for liquid bulk (-17%, 2018-2030) because of the expected decline in the transport volume of liquid refined petroleum products, which makes up 85% of liquid bulk. With a limited share of 9% in dry bulk, we expect that the relatively large decline in transport volume of coal and lignite will be cancelled out by the growth of the other bulk flows, resulting in a net growth of +2% between 2018 and 2030. For Non-perishables (+17%), perishables (+14%), and industrial goods (+12%), we expect the growth to be more substantial.

The limited growth in bulk as compared to the other freight segments, also affects the modal split (See Figure 9). Whereas we expect rail and road freight volumes to grow by ca. 15% and 12% respectively, the freight volume of IWT is expected to remain roughly the same, resulting in a lower share of IWT in the modal split (45% in 2018 -> 42% in 2030). The reduction in liquid bulk volume (-14 Mtonne) affects IWT strongly. The decline in liquid bulk is nearly compensated by a small growth in dry bulk (+3 Mtonne, despite the decrease in coal and lignite) and the other freight segments (+9 Mtonne) keeping total IWT at roughly the same level. This does not mean that ships active in liquid bulk will not be hit by the decline in the liquid bulk market as tank ships are not able to switch to dry bulk freight.

Figure 9
Modal split (tonnes) per freight segment in2030 and total HCF (right)

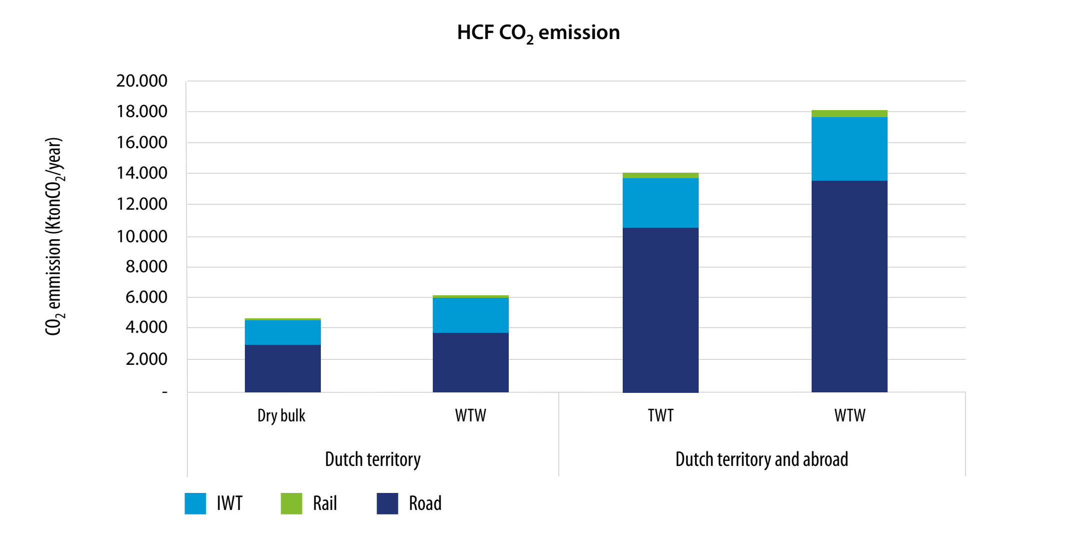


2.4 The challenge of decarbonizing HCF

Historic CO_2 emission of HCF transport

The total Carbon footprint of HCF transport in 2018 amounted 4.6 Mt CO_2 tank-to-wheel (TTW) and 6.0 Mt CO_2 well- to-wheel (WTW) on Dutch territory. When transport abroad is included TTW emission are 14 Mtonne CO_2 and 18 Mtonne CO_2 WTW (see Figure 10).

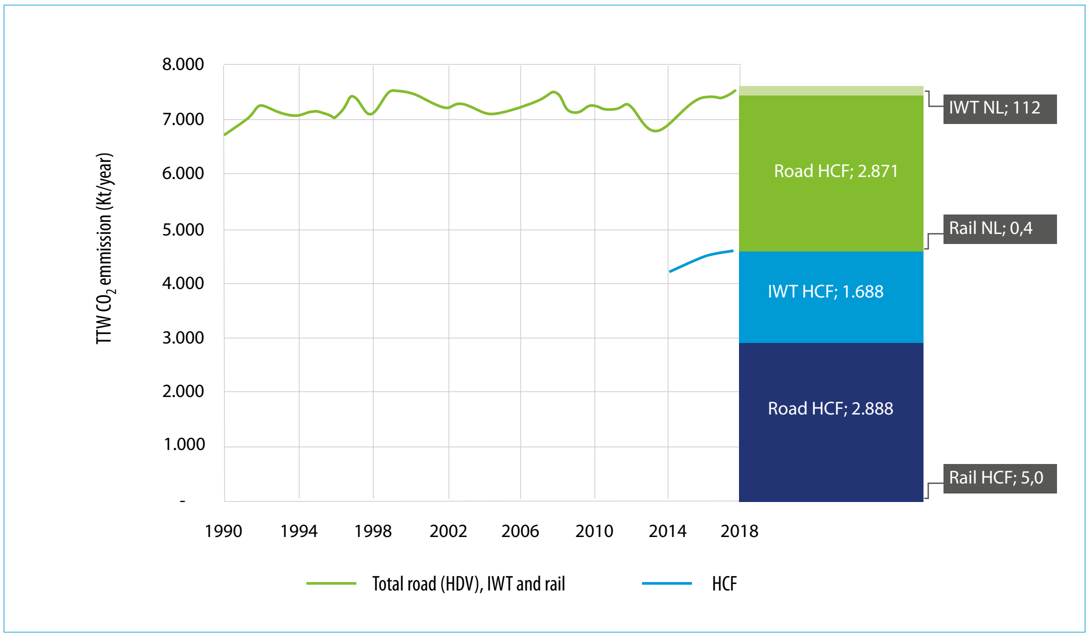
Figure 10
CO_2 emission of HCF transport in different scopes (2018)



Policy measures for CO_2 reduction in the transport sector mainly focus on the TTW emission on national territory, as the well-to tank (WTT) emissions are subject to policies in other sectors (industry) and emissions abroad are the responsibility of foreign countries. However, any policy on the TTW emission on Dutch territory is likely to effect the WTT emission and the emission abroad and these effects should be considered as well. In the following paragraphs the challenges to lower CO_2 emissions will be described based on the TTW emissions, as these are subject to Dutch policy.

Figure 11 shows for the period 1990-2018, the CO_2 emission of total road (heavy duty vehicles), IWT and rail freight transport on Dutch territory (green line) and the CO_2 emission of HCF transport for the more recent years (blue line). The total TTW Carbon footprint of HCF (4.6 Mt CO_2 in 2018) amounts 60% of the total CO_2 emissions of freight transport on Dutch territory (7.6 Mt CO_2, excluding vans). Throughout the period 1990-2018 the total CO_2 emissions of freight transport have been quite constant and even so the share of road transport (75%), inland waterway transport (24%) and rail transport (1%) in the total of CO_2 emission of freight transport. Rail and IWT transport are almost solely HCF transport, whereas half of road transport is HCF and half is national transport (see Figure 11). So far, climate policy and higher transport efficiency did not result in a reduction of the carbon footprint of freight transport. It only has prevented the growth of CO_2 emission as the total freight volume grew in this period (18% growth between 1998 and 2018, see Figure 7).

Figure 11
TTW CO_2 emissions of total freight and HCF transport (road, IWT and rail excluding vans)



Goals for HCF transport per mode

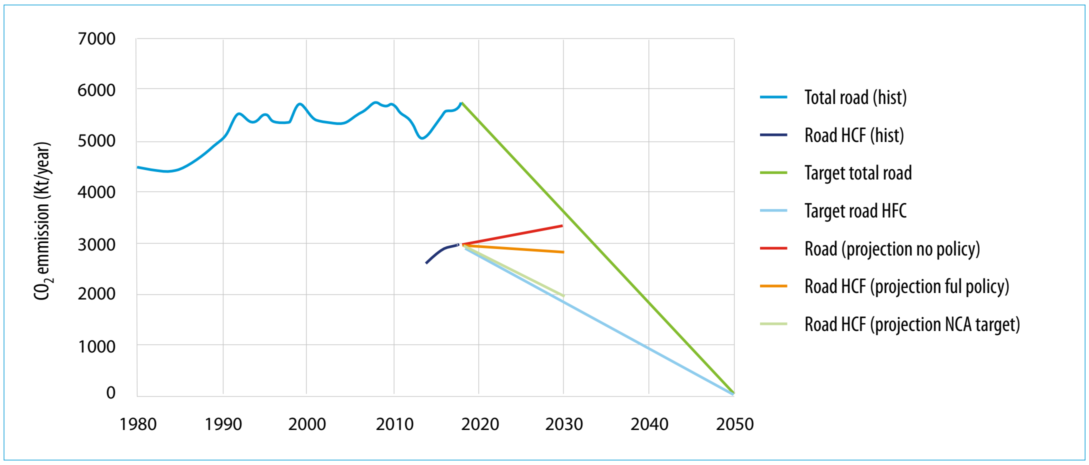
Road

The total CO_2 emission of HGVs (heavy good vehicles, GVW>3.5 tonne) on Dutch territory is fluctuating around 5.5 Mt CO_2 per year for the last two decades. With 2.8 Mt CO_2 emissions in 2018, HCF transport represents over 50% of the total HGV emissions on Dutch territory.
At the moment there is little standing policy that assures a drastic reduction in the CO_2 emission of HCF transport: EU CO_2 emissions standards for 2025 and 2030 require average new trucks to have 15% (in 2025) and 30% (in 2030) lower CO_2 emissions as compared to new trucks in 2020[2]. This reduction can be partly achieved with super-credits for the production of ZE vehicles. In addition, Directive 2009/28/EC gives a binding target of 10% share of renewable energy in transport by 2020. In the European Green Deal presented by the European Commission a substantial modal shift from road to rail and IWT is targeted, but this goal is not yet implemented in any policy instrumentation. Taking into account the expected growth in transport, CO_2 emissions are expected to hardly decrease the coming years based on EU legislation only (see Figure 12, red line).

2 Regulation (EU) 2019/1242

Figure 12
Historic, projected, and targeted CO_2 emissions of road transport: total and HCF on Dutch territory

Note
NCA is National Climate Agreement



In the National Climate Agreement (Klimaatakkoord) a target is set of -30% in 2030 for HCF transport (1.4 Mt CO_2 for road, IWT and rail). Road transport should significantly contribute to this target. The reduction is expected to mainly come from EU HGV emission standard regulations (0.8 Mt CO_2), logistical efficiency improvements (0.4 Mt CO_2) and HGV km-charges that will be implemented in 2023 (0.2 Mt CO_2). The -30% target in 2030 is a serious challenge as no emission reduction has been accomplished so far by the sector. Moreover the challenge is even bigger than projected in the Climate agreement as the EU regulation is less stringent than assumed[3].

In the period 2030-2050 the challenge will be to reach zero emission in HCF transport. It is of importance to prepare in the coming years for the unroll of zero emission infrastructure to allow for such a drastic change. Moreover there are several developments in road transport that might give road transport in the long term a relative cost advantage, resulting in a modal shift towards road, such as:

- lower fuel costs (e.g. more fuel efficient vehicles and electric vehicles);
- autonomous driving and or drone assisted driving.

From a perspective of road infrastructure demand, congestion and traffic safety such modal shift is detrimental.

IWT

The total CO_2 emission of IWT on Dutch territory is fluctuating around 1.7 Mt CO_2 per year for the last two decades. With 1.7 Mt CO_2 emissions in 2018, HCF transport represents over 90% of the total IWT emissions on Dutch territory (see Figure 5).

At the moment there are only EU emission standards to reduce air polluting emission, but none to reduce greenhouse gas (GHG) emissions of IWT. Without any policy, emission IWT are expected to slowly grow coming years (see orange line Figure 5). In the European Green Deal presented by the European Commission, however, modal shift from road to IWT is indicated as an important measure to reduce GHG emissions. A modal shift towards IWT can help to reduce emission of freight transport in general, but will also put extra pressure on the IWT sector to reduce its CO_2 emission.

3 The 0.8 Mt CO_2 reduction is based on plans of the Europarlement to set target for new trucks to have 20% lower emisisons in 2025 and 35% lower emission in 2030. The targets are actually set at -15% (2025) and -30% (2030).

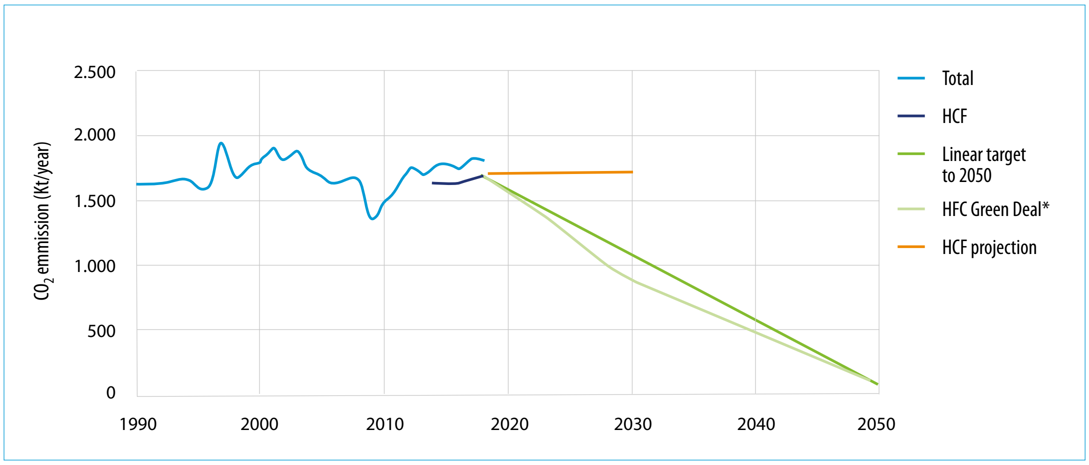


Figure 13
Historic, projected, and targeted CO_2 emissions of IWT transport: total and HCF on Dutch territory

** 40-50% reduction is set for the Dutch inland fleet, a 45% reduction is depicted in the graph for all IWT (including foreign ships) in the Netherlands*

As a result of the Dutch national climate agreement[4], the Dutch government, sectoral organisations and market parties have set climate ambitions and goals in the Green Deal on Maritime and Inland Shipping and Ports. The ambition is to reduce carbon emissions of Dutch inland vessels by 40-50% in 2030, with an intermediate goal to reduce carbon emission by 20% in 2024 relative to 2015 (see Figure 5, grey line). By 2030 at least 150 inland vessels (2-3%) should have a zero emission power train. The main GHG reduction should come from the use of biofuels according to the Green Deal.
It is an enormous challenge to achieve zero emission IWT, in particular when biofuels are not considered as final solution. Electrification of IWT is still being piloted and is not yet a proven concept. Also other zero emission drivelines, such as fuel cells, have not been demonstrated on freight ships. Some ships, however, have diesel-electric drivelines, and can switch to zero emission propulsion when zero emission techniques become available.

Rail

The CO_2 emission of rail transport is very limited as compared to the other modes. Last two decades, the total CO_2 emission of rail on Dutch territory is fluctuating between 0.05 and 0.08 Mt CO_2 per year, with 0.05 Mt CO_2 emissions in 2018. Almost all rail transport CO_2 emissions are from HCF transport (99%). The 0.05 Mt CO_2 emission are from diesel trains only, as CO_2 emissions from electricity production are not included in the TTW scope.

The National Climate Agreement expresses ambitions to further electrify rail transport and to make rail transport more attractive (lower costs, higher efficiency, better interoperability). Both EU (Green Deal) and national policies target on a higher share of rail in freight transport. When the 2050 climate goals for zero emission electricity generation are met, electric rail can be considered climate neutral. It is, however, worth to also focus on the minimisation of electricity consumption by electric trains as this will put less pressure on the electricity sector to reach their CO_2 targets. Energy reduction is also part of the goals rail in the National Climate Agreement. A 10% energy reduction is expected from the installation of energy meters in locomotives. Also the Betuwe-route will be made more competitive to attract more transport to this route, as the energy efficiency on the Betuwe route (25 kV) is better than the alternative routes. A shift from road to rail, however, is much more efficient in reaching the reduction objectives when compared to the impact of the abovementioned measures for rail.

4 Elaborated in the measures rail freight transport 'maatregelenpakket-spoorgoederenvervoer'

Implication of climate agreement target on HCF segments

Figure 14 shows the share of the logistics segments in the freight volume and the CO_2 emission on Dutch territory and in total transport. The figure makes clear that the CO_2 impact per tonne bulk is lower than for the other segments, resulting in a lower share of bulk in CO_2 emissions than in freight volume. On Dutch territory this is mainly due to the large share of IWT in bulk transport, with IWT having a relatively low climate impact. The even lower share of bulk in the CO_2 emission of the total transport is due to the limited distances abroad for bulk as compared to the other segments.

Figure 14
Share of logistics segments (2018) in freight volume (734 Mt), CO_2 emissions on Dutch territory (4.6 Mt) and total CO_2 emissions (14 Mt)

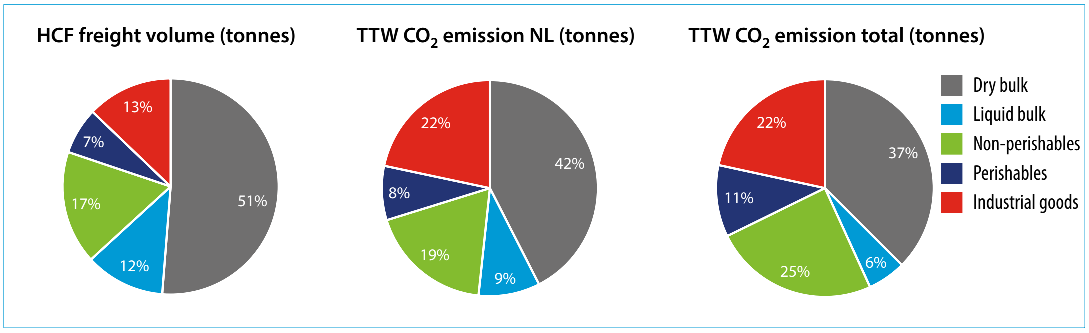
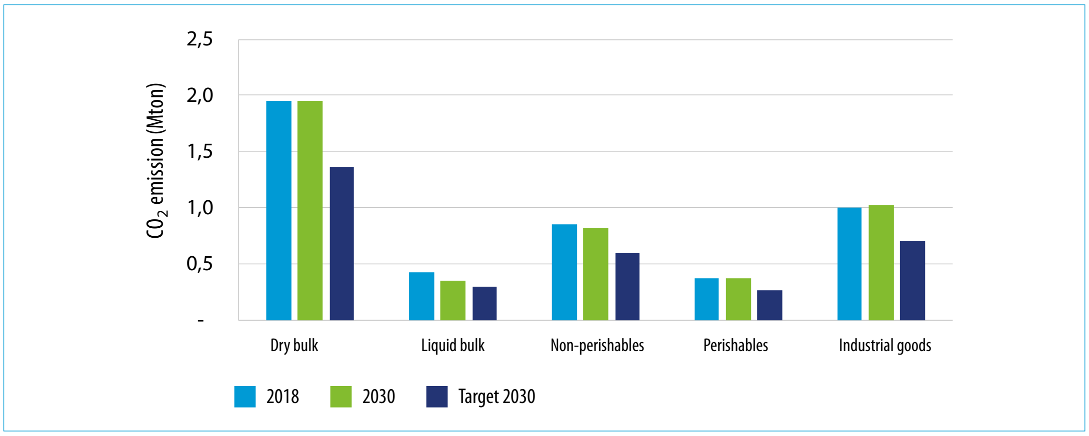


Figure 15 shows the CO_2 emissions per segment in 2030 compared to 2018, taking into account the change in freight volume as described in the previous section, a 15% improved fuel efficiency of road transport and a small increase in biofuels (2%) because of EU legislation. Next to this, the 2030 target levels per segment are shown, assuming a 30% CO_2 emission reduction target for each segment following the overall 30% reduction target according to the national climate agreement.

Figure 15 shows that setting a 30% reduction for all segment gives different challenges per segment. Whereas liquid bulk, in terms of CO_2 target, benefits from the expected decline in volume, the expected growth in freight volume of industrial goods is imposing an extra challenge to reach the CO_2 target in 2030.

Figure 15
CO_2 emission per freight segment in 2018, 2030 and the CO_2 emission target for 2030 (Dutch territory)



This is also illustrated in Figure 16 in which we have depicted the CO_2 emission per tonne of freight in each segment in 2018, the expected values in 2030 (EU policy) and the target values derived from a 30% decrease in CO_2 emission for each segment. The CO_2 emission per tonne dry bulk needs to be lowered by 30% as compared to the expected emission per tonne in 2030 based on EU policy only (affecting road only). For liquid bulk, only a 15% decrease of CO_2 emission per tonne is needed, because of the expected decrease in volume. For non-perishables, perishables an industrial goods the emission per tonne need to be around 30% lower than autonomously expected. For the non-perishables segment this is a bit lower (-27%) due to the expected improved fuel efficiency of road transport in 2030 and the relatively large share of road transport in the modal split of non-perishables. For industrial goods it is a bit higher (-32%) due to the lower share of road transport in the modal split.

Figure 16
TTW CO_2 emission per tonne freight in 2018, 2030 and 2030 target per logistics segment (total transport)

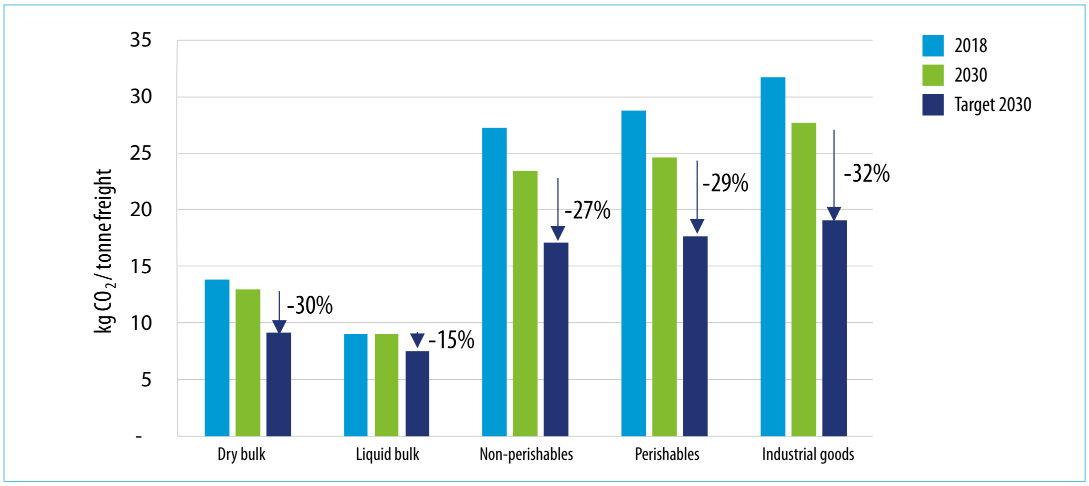


Figure 16 makes clear that extra policy is needed on top of the standing EU and national policy to reach the 2030 targets. The EU Green Deal and particularly the national climate agreement have the ambition to overcome the existing gap between the business as usual development in CO_2 emission and the 2030 targets. In the following chapter we will discuss the several options to reduce emissions.

2.5 Interpretation of results

In the previous sections we discussed the freight volumes, transport volumes and CO_2 emissions of HCF transport in 2018 and the expectations and challenges towards 2030. In HCF transport, bulk has a large share in the total freight volume. It is expected, however, that the growth of bulk freight will be tempered by the decrease in freight volumes of fossil fuels such as coal, ignite and liquid refined petroleum products. The latter decline has a relatively large impact on the total volume of liquid bulk in HCF transport, and especially on IWT where an overcapacity of tankers in the fleet is a serious risk for the market position and decarbonisation potential of this sector.

We expect the freight volumes of non-perishables, perishables and industrial goods to grow faster towards 2030. Per tonne freight the impact on CO_2 emissions of these HCF segment is larger, as the share of road transport (the mode with in general the highest CO_2 impact per tkm) is larger. Especially to countries that are not well connected to the Netherlands by inland waterways and rail, the modal split figures for these segments show high shares of road transport. Italy, Austria and Czech Republic and are good exceptions with a relatively high share of rail. Development of a rail corridor to Poland, Spain, and France and extending the corridors to Germany and Belgium can have a huge contribution to lower the CO_2 emission of HCF. The corridors towards Spain and Eastern Europe are particularly interesting for perishables, whereas rail transport has not yet been able to offer sufficient services for reefer containers and trailers.

Modal shift to IWT can also contribute to lower CO_2 emission of HCF transport. The modal shift should come from road transport along IWT corridors for freight types that are not too time-critical. It is important, however, that IWT also finds a pathway to zero emission solutions. Road transport realises a faster emission reduction compared to IWT, due to a/o EU regulation. IWT, however, does have the advantage that energy demand per tonne-kilometre is much lower.

Besides applying zero emission technologies and fuels, CO_2 emission can be reduced by logistics optimization. Higher load factors, reduction in kilometres will help to reduce the CO_2 impact per tonne freight. Logistical optimisation, however, can have also result in lower transport prices and therewith an increase in transport volume. To reach CO_2 reduction this should be circumvented.

The different carbon reduction strategies are further discussed in the following chapters.

3 Logistics efficiency: challenges and improvement potential

3.1 Introduction

By optimizing processes in the logistics sector, the same load can be transported between the same origins and destinations with less actual mileages. Therefore, such higher logistics efficiency will also result in lower CO_2 emissions. This chapter explores the ways the logistics efficiency can be improved in the on hinterland transport of containers, using the data on the contents and load factors of containers as provided by CBS. The potential for modal shift is dealt with in the chapters 5 and 6. In the first Outlook (2018) the potential of measures such as ICT innovations in planning and execution of transport, ecodriving, vehicle platooning, autonomous driving etcetera have been explored. This chapter in this Outlook zooms in on the specifics of containerised hinterland transport and shows how better data can help to identify the potential for improvement.

Possible ways to improve this logistics efficiency are:

- Lower actual mileages between the same origins and destinations, for example less detour miles to a warehouse;
- Increase of the (average) load factor;
- Reducing bidirectional transport of the same (or similar) product between regions.

The first of the abovementioned possible efficiency improvements are explored in the previous Outlook (2018). Increase of load factor and reduction of 'unnecessary' transport are explored in the next paragraphs, taking a/o the new data on container contents as a starting point.

Although a more efficient logistics system lowers transportation costs, shippers and carriers do not necessarily strive for the highest possible efficiency for the whole logistics system, because

- (Alleged) competitive advantage (e.g. packaging) deemed more important than logistics costs resulting from lower load factor;
- Timing (e.g. perishables and express deliveries) outweighs additional logistics costs resulting from lower load factor;
- Willingness or permission to collaborate with other transport companies is limited for competitiveness reasons;
- Freight bundling or collaboration between companies to reduce mileages increases dependency and complexity, reduces flexibility which might not be in the interest of the transport company;
- Trade: offering goods at the right location and time can be profitable.

In this chapter the potential of several possible logistics efficiency improvements are analysed.

3.2 Distance and volume reduction

Bidirectional transport of the same or similar goods

As mentioned in section 3.1, certain products are transported from one region to another while the same types of products are shipped in the opposite direction. Reasons for such bidirectional freight transport are the same as the reasons mentioned in section 3.1, i.e. competitive advantage, timing, limited collaboration or trade.

In this section, such bidirectional trade flows of similar products are analysed. In the data used in this study, product categories are available on NST2007 group level (NST2007 with one decimal). For the analysis, a number of products groups are selected that are relatively homogeneous in terms of their use. For instance, the product category 'potatoes' is deemed homogenous as, although potatoes come in different types and forms, (close to all) can be used in a similar way. It could therefore be argued that potatoes could be used close to the origin, rather than transporting them bidirectionally. This product group is therefore taken into account. On the other hand, certain product groups are so diverse that it cannot be determined whether the goods that are transported bidirectionally are similar or rather different. Therefore such more heterogeneous product groups are not analysed in this study.

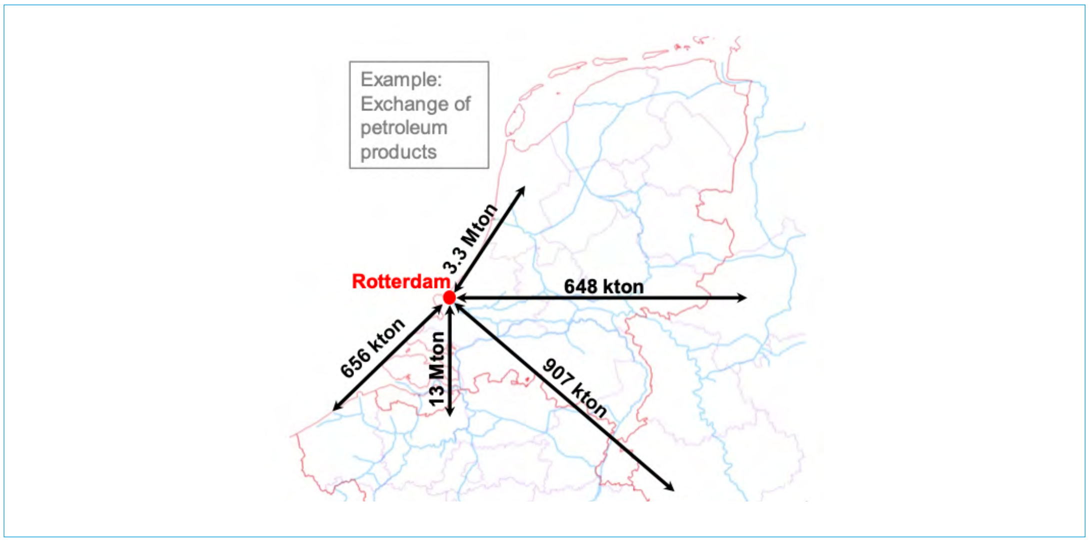
Table 2
Products transported in both directions (cumulative) in relation to the total amount of products transported to hinterland from or to The Netherlands

	from / to	from / to	01.2 Potatoes	02.1 Coal and lignite	03.5 Stone, sand, gravel, clay, peat and other mining and quarrying products n.e.c.	04.4 Animal and vegetable oils and fats	04.5 Dairy products and ice cream	06.2 Pulp, paper and paper products	07.1 Coke oven products; briquettes, ovoids and similar solid fuels	07.2 Liquid refined petroleum products	08.2 Basic organic chemical products	08.3 Nitrogen compounds and fertilizers (except natural fertilizers)	09.2 Cement, lime and plaster	10.1 Basic iron and steel and ferro-alloys and products of the first processing of iron and	14.1 Household and municipal waste
Total			22%	6%	27%	28%	14%	22%	26%	40%	43%	27%	13%	29%	13%
Examples	Zuid-Holland	Noord-Holland	0%	0%	2%	3%	1%	1%	0%	4%	2%	2%	1%	1%	6%
	Zuid-Holland	Zeeland	1%	0%	1%	3%	0%	0%	0%	3%	3%	1%	0%	1%	1%
	Zuid-Holland	Prov. Antwerpen	1%	0%	1%	1%	0%	4%	0%	18%	11%	1%	1%	1%	0%
	Noord-Braban	Prov. Limburg (BE)	3%	0%	0%	0%	1%	0%	0%	0%	0%	1%	0%	0%	0%
	Zuid-Holland	Düsseldorf	0%	2%	1%	4%	1%	2%	12%	0%	4%	1%	0%	7%	0%
	Zuid-Holland	Rheinhessen-Pfalz	0%	0%	0%	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%
	Limburg (NL)	Prov. Limburg (BE)	0%	0%	1%	0%	0%	0%	0%	0%	0%	1%	0%	0%	0%
	Zuid-Holland	Prov. Oost-Vlaande	0%	1%	0%	1%	0%	0%	6%	1%	3%	0%	0%	0%	0%
	Flevoland	Prov. West-Vlaand	2%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Zuid-Holland	Koblenz	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Zuid-Holland	Köln	0%	0%	0%	0%	0%	0%	0%	1%	2%	0%	0%	0%	0%
	Zuid-Holland	Münster	0%	0%	0%	0%	0%	0%	2%	1%	2%	0%	0%	0%	0%

From Table 2 can be concluded that 40% of liquid petroleum (related to Dutch HCF transport) is the result of exchange between regions. 18% of all petroleum products are transported bidirectionally between Zuid-Holland and Antwerp (Province). The bidirectional transport of this product category is also depicted in the figure below.

It seems that especially on the corridors Rotterdam from/to Antwerp and Rotterdam from/to Düsseldorf the same or similar products are transported in both directions. On the first corridor this is especially true for 'liquid petroleum' and 'basic chemical products' while on the second corridor significant shares of the transportation of 'cokes' and ' basic iron' is done in both directions. It must be noted that these flows are related to the three main (petro-)chemical and industrial clusters in the Rhine-Scheldt-Ruhr delta and an exchange of raw materials and semi-finished products between the clusters is leading to massive transport flows. A more detailed insight in the type and balance of the product and flows is needed before statements about the necessity and efficiency can be made. Factors such as the quality of the product, availability and seasonal patterns can play a role in the bidirectional transport flows.

Figure 17
Bidirectional transportation of petroleum products between Rotterdam and five other locations. The number shown are the cumulative masses of transportation of petroleum products in two directions



Overall, the bidirectional exchange of the product categories analysed, is responsible for approximately 5% of all CO_2 emissions related to Dutch HCF. Although the product categories analysed are selected based on homogeneousness, some categories include various product types. The CO_2 reductions due to the exchange of really similar products cannot be determined, as there are no more detailed data on product types available.

Since the selected and analysed categories are only a limited share of the overall Dutch HCF transport, the total exchange of products and therefore also the resulting CO_2 emissions are likely to be higher. However, due to the aggregated level of the analysis, it's not possible to determine the potential of reducing bidirectional 'unnecessary' transport flows. A further analyses on more detailed data would be required to determine to which extent a reduction of these flows is possible.

3.3 Load factor of containers

Increasing the load factor could result in lower actual mileages, as stated in section 3.1. In this section the load factor is analysed in various ways to determine where logistics efficiency could potentially be improved.

The use of containers

Containers are available in various shapes and sizes. 91% of containers used for transport related to Dutch continental freight, are either 20 ft standard (20%), 40 ft standard (47%) and 40 ft high cube (24%). The share of 40 ft containers has increased significantly over de last years.

Containers as we know them today were introduced in 1961, when the International Organization for Standardization (ISO) set standard sizes. Because of these standards, they can be (un)loaded, stacked and transported, and transferred between different modes without being opened. For all modes, systems are available to carry containers, i.e. container ships, rail transport flatcars, and semi-trailer trucks. The handling of containers is fully mechanised and is done using cranes and special forklift trucks. All containers are numbered and tracked using computerised systems.

Because the handling of containers is very efficient, it is also relatively low cost. Therefore generally containers are used whenever this is an option. Due to the low cost of shipping containers it can be beneficial to ship them while they are not completely full in terms of volume or weight.

Load factor of containers

Container weights are measured at for instance sea ports. In order to accurately assess the load factor of containers based on this measured weight, requires detailed information on the density of the product including the packaging. However, the product description is many times not available in enough detail for all included products to determine the product density. Therefore in this study another approach is used to assess the load factor of containers.

First, product categories have been selected from the CBS-Basgoed dataset (on NST2007 group level[5]) that are quite homogeneous in terms of density. Per homogeneous product category, the average mass is determined for 20 ft or 1 TEU containers. The mass per TEU was also determined for 40 ft (or 2 TEU) containers and for high cubes. Hereafter, the mass per TEU was compared for the various container types. Also the share of the different container types is determined per product category. All of this is shown in Figure 18.

Figure 18
Mass per TEU for 2TEU and high cube containers relative to that of 1TEU containers for a number of homogeneous product categories

5 www.unece.org/fileadmin/DAM/trans/doc/2008/wp6/ECE-TRANS-WP6-155a1e.pdf

Figure 18 shows that the average mass per TEU is lower for large containers (2TEU and high cube) for most product categories selected. This is shown in the figure as the green dots (2TEU containers) and blue dots (high cubes) are in many cases below the blue ones (1TEU containers). For the products categories to the right, the average mass per TEU for the large containers is only half of that of 1TEU containers. As 1TEU containers are half the size of 2TEU containers and since the 1TEU containers on average are not fully loaded, this means in theory that the amount of goods in the large containers would also have fit in a small container. In practice, the choice for a 2TEU container is made more often because of availability, imbalance in freight flows and trade-offs between transport and handling costs.

The product categories for which the load factor of large containers is low, the share of large containers is smaller than for the product categories for which the load factors of small and large containers are closer together. Nevertheless, for categories like ' fruit and vegetables', 'beverages' and 'stone, sand etc', the load factor of large containers are more than 40% lower than that of small containers while up to 65% of containers used are large.

The most extreme product categories are 'dairy products' and 'other fruits and vegetables'. For these categories, the average load factor of large containers is about 40% lower than for small containers. Nonetheless, 95% of the containers used for transporting these goods are large. The limited availability of 20' reefer containers (compared to 40' and 45' reefers) is probably the main reason for this apparent inefficiency.

A possible reason for using large containers while the load is limited, is that the large containers are more easily available as these have become the standard. Moreover, the additional cost for transporting a large container compared to a smaller 1TEU container are limited. For instance, the handling cost are usually independent of the container size.

Increasing the load factor of large containers (2TEU of HC) or increasing the share of 1TEU containers with a higher load factor, could result in less trips and therefore less distance covered to transport the same amount of goods over these same distance. This would lead to lower CO_2 emissions. Potential disadvantages of the system changes required to achieve such reductions are:

- Longer lead times due to a lower trip frequency;
- The need for a new fleet of smaller ships or trucks with the same frequency.

In general the first option, lower trip frequencies would lead to higher CO_2 reductions as the CO_2 emissions per TEU-km or per tonne-km are lower for larger trucks or ships.

In case the load factor would be increased by using 1TEU containers or by increasing the load factor of large containers to the same level of the average 1TEU container, 5% less containers transport would be required.

Empty container transport

Reasons for empty container transportation

Containers without any load are transported for various reasons:

- Structural imbalance in trading of containerised goods between regions. In this case, not returning empty containers would lead to the build-up of containers on one end of a corridor;
- The container owner sets the maximum time the container can be used, which limits the time to find another load for the return trip;
- Shippers use different shipping lines to transport their goods, so even if there are import and export flows in a region, it could still be that empty containers are moved to and from the region due to the fact that different shipping lines are used which require the use of their equipment.

Reducing structural trading imbalances is very complex or sometimes even impossible as they can be the result of phenomena like:

- The availability of natural resources, such as a warm climate (required for growing certain fruits or vegetables) or mining products. Regions with such circumstances may export products while there may not be a flow of containerised goods in the opposite direction;
- Wages: labour intensive products are usually produced in regions with relatively low wages.

Although the issues resulting from the timeframe in which containers have to be returned to the owner are not easy to resolve either, there are ways to reduce the amount of empty containers transported. Possibilities are:

- Lengthening the timeframe;
- The use of white label containers;
- The use of a digital platform at which shippers put up a request for freight transportation, increasing the chance of utilising a container that otherwise would be transported empty[6].

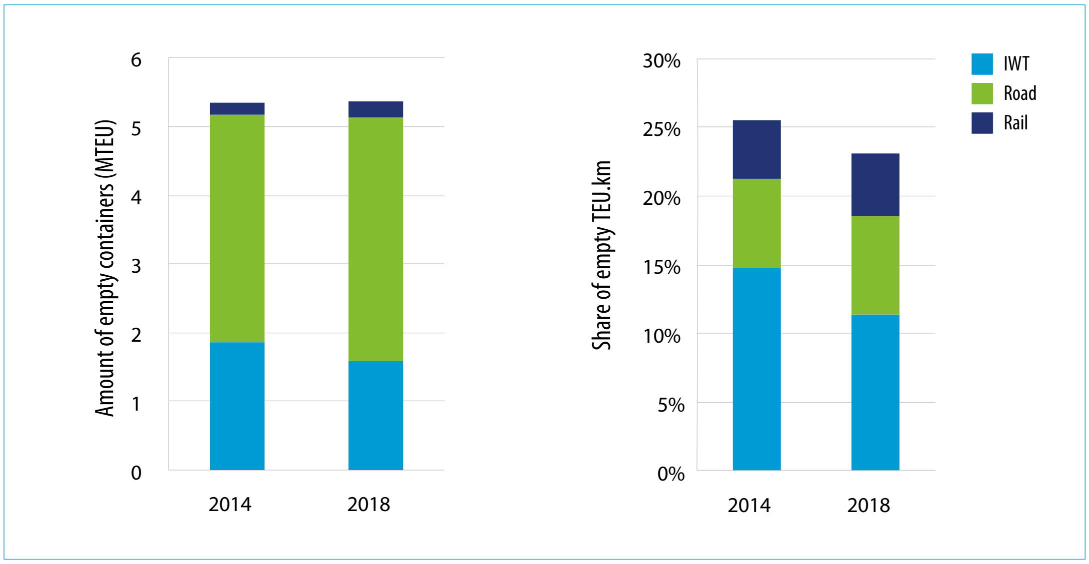
In this paragraph we will analyse the transport of empty containers and assess the reduction potential in terms of transport activity and CO_2 emissions.

Development of empty container transportation

Between 2014 and 2018, the number of transported empty containers related to Dutch HCF was more or less constant, i.e. approximately 5.4 million per year. At the same time, the average distance over which the empty containers were transported, decreased 7%, according to the CBS-Basgoed dataset. Therefore the amount of empty TEU-km also decreased by 7%.

Empty containers make up approximately 23% of the total TEU-km related to Dutch HCF transport. In 2014 this was 26%. This decrease is also the result of the lower average distance over which empty containers are transported.

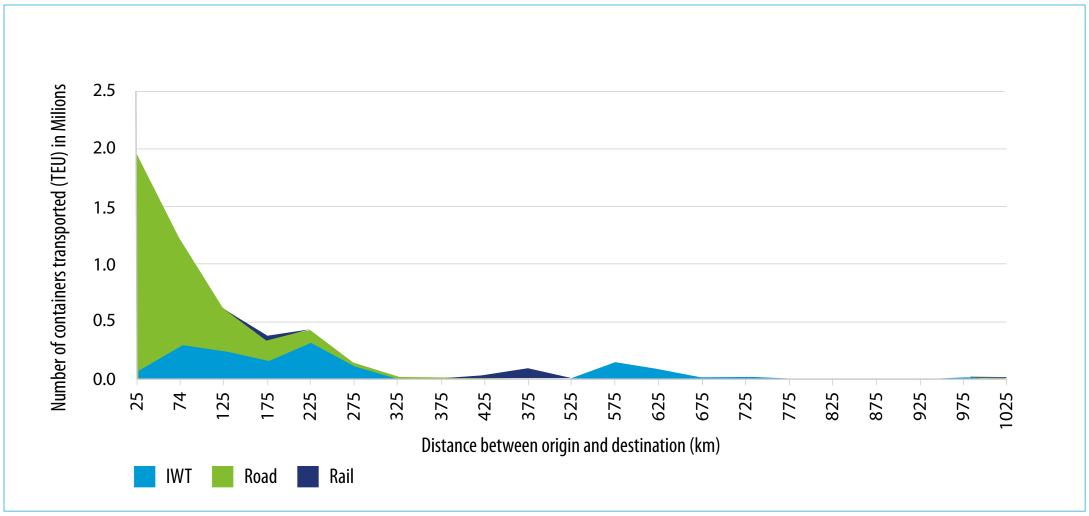
Figure 19
Absolute and relative amount of empty containers



Approximately 66% of empty containers are transported by trucks. As these trucks cover relatively low distances, the share of empty TEU-km with trucks is only 21%. On the other hand, inland ships and trains carrying empty containers travel relatively long distances. Therefore the share of empty TEU-km of these modalities (respectively 49% and 20%) is much larger than their share in the amount of transported empty containers (respectively 30% and 4%).

6 The Avantida platform is an existing initiative that tries to improve the efficiency and reduce empty container transport

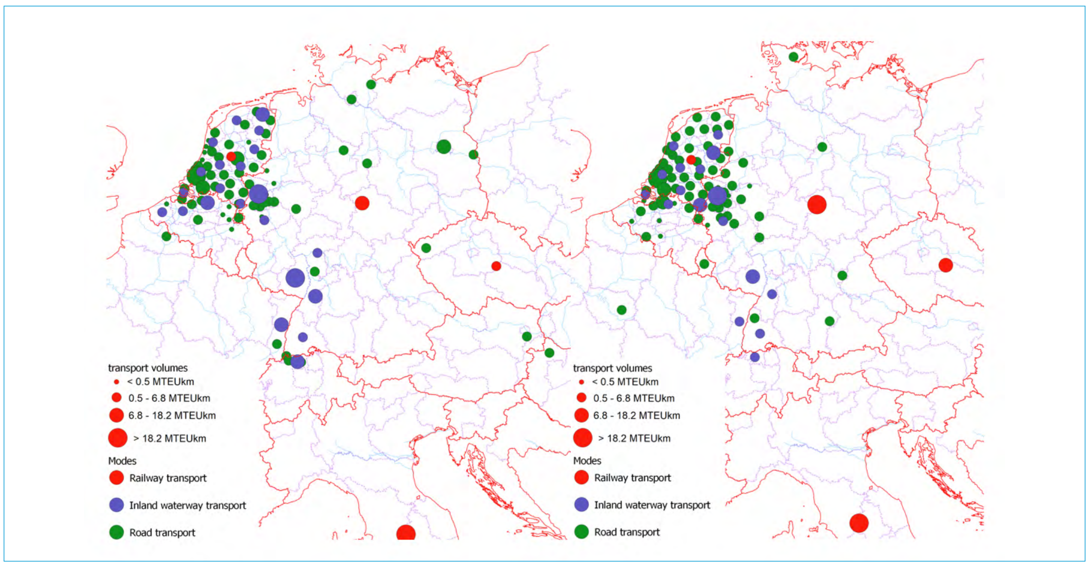
Figure 20
Number of empty containers transported per modality over a certain distance in 2018 (CBS 2019)



In 2018 approximately 63% of empty containers related to Dutch HCF transport, had Rotterdam as origin or destination. As empty containers from or to Rotterdam travel slightly longer than average distances, approximately 68% of empty TEU-km have Rotterdam as origin or destination.

Of all empty TEU-km, 39% is due to the bidirectional exchange of empty containers between regions. In other words, for 20% (20% per direction is 39% in total) of all empty containers transported, the same amount of empty containers are transported in the exact opposite direction. This is the same phenomenon as discussed in the previous section, but then specifically for empty containers. Such exchange of empty containers accounts for 9% of all container transportation. Economical and technical constraints and requirements, such as demurrage and detention agreements, quality and type of containers, can play an important role in the explanation of the apparent inefficiency.

Figure 21
Transport of empty containers (in million TEUkm) from the Port of Rotterdam (left) and to the Port of Rotterdam (right). Transport by road shown on NUTS-3 level, inland shipping on NUTS-2 and rail on NUTS-1 level



Reduction potential

It is likely that a large share of the empty containers exchanged between regions are transported because of limited timeframes for which containers are available. In case measures would be applied to avoid such exchange, a potential maximum amount of 125 tonnes of CO_2 (TTW) can be reduced. This is approximately 1.3% of all CO_2 emissions resulting from Dutch HCF transportation.

3.4 Conclusions

Significant reduction potential exists within the logistics sector to further optimise processes in order to reduce the CO_2 emissions per tonne-km. This means that the same amount of goods can be transported between the same origins and destinations while CO_2 emissions are reduced. Some ways to achieve this potential are described in this chapter. The common element of all of these ways is that systematic changes are required within the logistics sector. One important change is enhanced cooperation within the supply chain, both vertically and horizontally. Vertical cooperation between for instance the container supplier and the user could result in more case specific timeframe for the container use. Because of this increased flexibility, the user may be able to arrange another load to be transported in the opposite direction rather than returning an empty container, lowering the amount of empty containers transported. Horizontal cooperation requires parties to share more information. This way a shipper may be able to know when a vehicle with available cargo space will be traveling from close by to the required destination.

An important lever to increase the logistics efficiency is cost. Logistics inefficiencies partly exist because transportation is relatively cheap. Many times the additional costs for realising and maintaining extra warehouses outweigh the additional transportation cost. As a result a system with less warehouses is realised, resulting in additional distance driven. Similarly, storing empty containers to wait for a shipment can result in higher costs than transporting an empty container. This also results in more CO_2 emissions. Panelising low load factors or additional mileages or rewarding the opposite is a way to increase logistics efficiency. A change of the entire logistics ecosystem is needed, overcoming individual interests and associated suboptimal solutions.

4 Road transport

4.1 Introduction

According to the climate agreement, HCF road transport needs to reduce its emission by 30% in 2030 and 95-100% in 2050 as compared to 1990. Under business as usual circumstances HCF Road transport is expected to grow towards 2030 and 2050 (see section 2.4). There are, however, developments that might lead to disruptive growth paths for road transport. On the one hand, there are potential technological developments that can increase the attractiveness of truck transport as compared to the other modes. The introduction of eco-combi trucks, (drone assisted) autonomous driving, and in the longer term zero emission trucks, might lower the costs of road transport significantly. These developments will make road transport more attractive when relatively similar costs reductions cannot be achieved by the other modes of transport. In addition, congestion in the seaports that is particularly hindering inland navigation, might also lead to a (further) shift towards road transport. On the other hand, a substantial modal shift from road to rail and IWT is targeted in the Green Deal proposed by the European Commission. One of the actions in the roadmap of the Green Deal is referring to initiatives to increase and better manage the capacity of railways and inland waterways.

Whether the modal share of road transport will grow because of technological/economic developments or decline because of EU policy measures is unsure. To reach the 2030 and 2050 climate targets, however, HCF road transport needs to reduce CO_2 emission drastically, Emission reduction in HCF road transport up to 2030 may for a large part be fulfilled by the introduction of more efficient combustion drivelines in trucks, a development that can be expected as a result of the new EU CO_2 emission standards for HDVs (heavy duty vehicles). In addition biofuels will play a role in emission reduction on the short and medium term. On the longer term, however, there will be need of zero emission trucks.

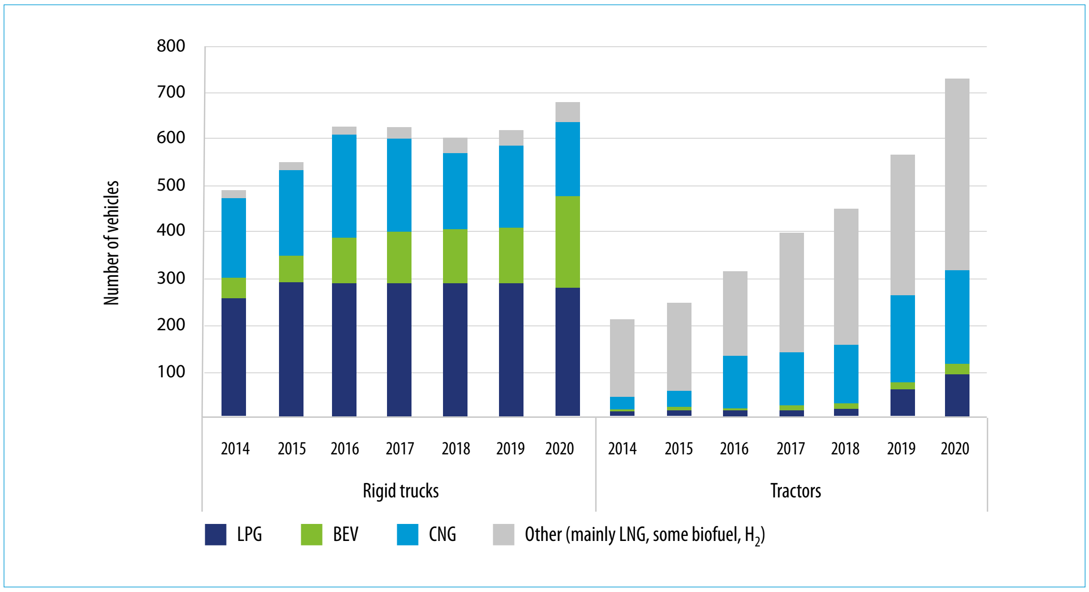
In this chapter we sketch for HCF road transport, routes towards zero emission transport. We focus on in this chapter on technological changes that are needed to reach zero emission road transport. We do not address efficiency related measures that can also contribute to CO_2 emission reduction, such as super-ecocombis, autonomous vehicles, and other ITS developments, that in the end also will rely on zero emission HDVs to become completely zero emission. First in paragraph 4.2, we start with an overview of the current situation of alternative techniques in (HCF) road transport and the current CO_2 reduction potential. In paragraph 4.3 we continue with expected developments of zero emission trucks towards 2030. In paragraph 4.4 we explore the potential for CO_2 reduction technologies up to 2030 in HCF transport. In paragraph 2.5 different scenarios are assessed on infrastructure requirement and feasibility regarding costs, environment and implementation after 2030.

4.2 Current situation on alternative fuel and zero emission trucks

Fleet

The vast majority of the current HDV fleet (98%) is still running on diesel. From the 144,634 registered HDVs on January 2020 in the Netherlands, only 1,406 were not running on diesel or gasoline (893 gasoline HDVs). The HDVs with alternative fuels and driveline, however, are increasing in number last years (see Figure 22). In the rigid truck segment, incremental innovations such as LNG, CNG and biofuels have a steady share in the period 2014-2020. Most of these alternative trucks are based on already existing models. The number of battery electric trucks (BET) have been growing in the period 2014-2020 with a factor 5, but the absolute numbers are still very limited. The growth is attributed to small and medium battery electric trucks active in city logistics with no need for a high range. There are only 2 fuel cell electric trucks (FCET) currently.
In the tractor segment CNG and LNG trucks have gained market share in the last 6 years. The number of electric trucks has also been growing, but, the absolute numbers are much smaller. Electric tractors for heavy transport are hardly available yet (see next paragraph). Technologies such as BET and FCET have just come on the market or are in still in the development phase.

Figure 22
Trucks in the Netherlands according to fuel/driveline type on 1 January 2020 (CBS, 2020)



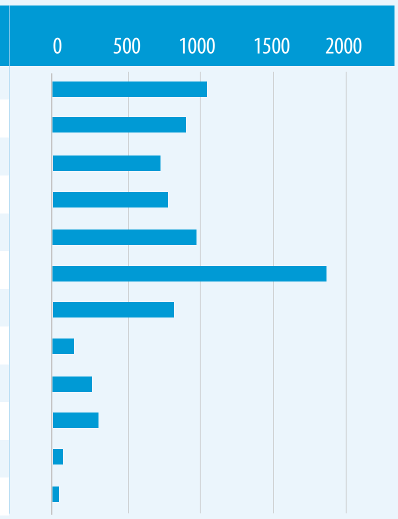
CO_2 emissions

The different fuels and technologies described above to some extent all can help to reduce CO_2 emissions. Figure 23 shows the well-to-wheel (WTW) CO_2 emissions per km per fuel and driveline, according to the average situation in 2018. HDVs running on LPG, CNG, LNG, hydrogen (from gas) and battery electric HDVs reduce WTW CO_2 emission by 8% (LPG) to 31% (CNG). With the emission form the current electric energy mix in the Netherlands of 480 g/kWh (CE Delft, 2020) the CO_2 emission reduction for electric tractors is around 23% compared to conventional diesel tractors. Hydrogen produced with the average electricity mix will have higher CO_2 emission than diesel, due to the relatively high energy demand for hydrogen production[7]. For fuel-cell (PEM) tractors using hydrogen produced from methane an 8% CO_2 reduction is estimated. Clearly larger CO_2 emission reductions are reached with the current mix of biofuels that fulfil the EU Renewable Energy Directive (RED II) requirements, with diesel and biogas (bio-CNG/bio-LNG) almost solely produced from waste streams. Biodiesel (FAME[8] nd HVO[9]) is currently mainly used in a blend with conventional diesel. Hauliers that can claim to use electricity or hydrogen produced from wind energy can reach the highest CO_2 emissions reduction of 95% (H_2) to 98% (electricity). Currently only a small percentage of the total energy supply to HDVs can be addressed to solar or wind energy.

Figure 23
Well-to-wheel emissions of truck trailer (GVW 40 tonne) with different fuels and drivelines

** MJ/km based on TNO, 2019, CO_2/MJ based on NEA 2019, JRC 2014 (for H_2) and CE Delft 2020 (Electricity)*

	MJ/km	WTW g CO_2-eq/Mj	WTW CO_2-eq/km
Diesel	11.1	95	1,051
LPG	12.0	74	886
CNG	10.5	69	728
LNG	10.5	75	783
FCEV-PEM (H_2-gas)	9.2	105	964
FCEV-PEM (H_2-average electricity)	9.2	205	1,880
BEV (electricity-average mix)	6.1	133	811
Biodiesel (FAME, HVO)	11,1	14	149
Bio-CNG	10.5	24	252
Bio-LNG	10,5	29	307
FCEV-PEM (H_2-wind energy)	9.2	6	54
BEV (electricity-wind enery)	6.1	4	23



At the moment the CO_2 reduction from the use of biodiesel is by far the most significant of the options in Figure 23. Due to the blending of biodiesel in diesel (5.8% (MJ/MJ) in 2018), to fulfil the renewable energy targets for transport (Annual obligation energy for transport), the CO_2 emission of diesel are lowered by 5% (NEA, 2019). It is important, however, that biofuels are not made from feedstock with a high risk of indirect land-use change (ILUC) and therefore high indirect CO_2 emissions. The RED II therefore implements limits on the contribution of food-based biofuels. Advance biofuels from lignocellulosic energy crops, wastes, and residues can be used in any quantity according to RED II, but the feedstock is not unlimited (ICCT, 2020). Biofuels will play an important role in CO_2 reduction on the short and medium term in road transport. On the longer term biofuels will not be the absolute zero emission option and biofuels are also expected to be needed for other purposes for which alternatives are harder to find, such as aviation and shipping (Klimaatakkoord, 2019).

7 *However, the electric energy generation mix in the Netherlands will change significantly in this decade, pivoting towards solar and wind. The result will be a reduction in emission per kWh of 50-75% in 2030 compared to 2020, which changes the relative emission of BEV of Hydrogen trucks accordingly.*
8 *Fatty Acid Methyl Esters*
9 *Hydrotreated Vegetable Oil*

4.3 Development towards 2030

Technologies

To reach climate goals in 2030 and beyond a stronger focus on CO_2 emission reduction technologies is needed. In this paragraph we describe the development of technologies that can contribute to CO_2 reduction in HFC road transport.

Biofuels

Figure 24
Volvo LNG (Volvo, 2020)

Alternative fuels for internal combustion engine vehicles (ICEV) can provide an intermediate solution to reduce CO_2 emissions, due to the relatively incremental change of drive technology, such as for bio-LNG. LNG trucks are being produced for the last couple of years. Volvo, Scania and IVECO are all producing LNG trucks that are fitted for long hauls. LNG fuelling infrastructure is present in The Netherlands with around 25 fuel stations. LNG trucks are around 30% more expensive in purchasing price (Nationaal Platform LNG, 2019), but can be earned back due to lower fuel costs.

Also biodiesel is an option to reduce CO_2 emissions on the short term. FAME can be mixed with diesel but only up to 7% due to contaminants being drawn to the fuel. HVO is a synthetic fuel that is formed by hydro processing of oils and fats. It is a cleaner fuel than FAME and can be mixed or used as 100% HVO. Where with FAME engine alterations are needed, HVO is a drop-in fuel, and no changes are needed to run HVO in modern EURO VI diesel engines. For example, MAN's, Scania's and DAF's EURO VI trucks allow the use of HVO. Biofuels and biogas will be a CO_2 reduction option for road freight transport in the short and medium term. The amount of biofuel, fulfilling the requirements in the RED II regulation, however, is not unlimited (ICCT, 2020) and other ZE alternatives are needed as well. On the longer term it is expected these fuels are also needed by other modes, such as aviation and sea shipping, to become (nearly) climate neutral. Application of advanced biofuels in road transport can also be important to develop the biofuel technology for future application in other modes.

E-fuels

An alternative to the use of biofuels in combustion engines could be e-fuels, like e-diesel, e-methane and e-methanol. Carbon based E-fuels are produced from water and (renewable) electricity. To be carbon neutral, CO_2 for the production is supposed to be captured from industrial processes that rely on carbon-fuels or it needs to be extracted from air. At the moment E-fuels are only produced in pilot plants. Sunfire is running the first e-fuel pilot plant worldwide in Dresden, Germany producing 57 m3 fuel a year. In 2021 Sunfire is planning to scale up production to 10.000 m^3 per year in a plant in Norway (Concawe, 2020). A much higher scale up, however, is needed for E-fuel to become a serious option. The big drawback for E-fuels is the low energy efficiency well-to-wheel.

Battery and fuel cell electric trucks (BET and FCET)

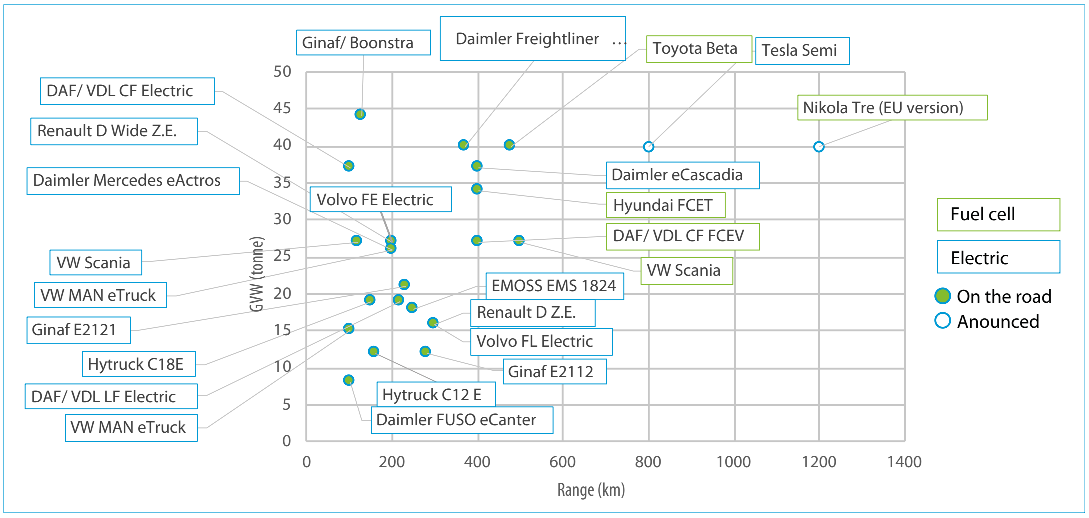
The most attention to lower the CO_2 emission of HCF road transport is given to battery (BET) and fuel cell electric trucks FCETs). BETs and FCETs can be considered zero emission when it concerns the tank-to-wheel emission, but not well-to-tank. The well-to-tank emissions depend on the CO_2-footprint of the electricity used. According to PBL CO_2 emission of electricity generation in 2030 might be 80% lower than in 2017 (PBL, 2019) and thus CO_2 emission of BETs and FCET in 2030 can be 80% lower than depicted in Figure 23. The current fuel cell technology for trucks is mainly based on Proton-exchange membrane fuel cells (PEM) using hydrogen as a fuel. On the longer term SOCF fuel cell technology that are also able to convert other (more dense) fuels (like methanol) might become also an option. These cells are being researched by Nissan (Nissan, 2020) for application in the automotive industry.

Currently transport companies in HCF transport hardly use zero emission HDVs. In city logistics, however, some front runners do have zero emission HDVs in their fleet. Since a few years, supermarket chains Jumbo (Jumbo, 2018) and Albert Heijn (AH, 2017), and shipping company Breytner (Breytner, 2019) are testing and using battery-electric trucks (BET) for urban distribution. Boonstra transport (Greendealzes, 2019) introduced a retrofitted 44 ton electric tractor to its fleet. In total, in January 2020, there were 193 rigid electric trucks (mainly box trucks) and 20 electric tractors in use (See also Figure 22). The number of fuel cell electric trucks (FCET) is still very limited, and amounts 14 registrations according to RDW[10].
A fast development in the adoption of zero emission technology is expected, as several cities in the The Netherlands will introduce zero emission zones in 2025 and more zero emission city trucks are needed. HCF transport can benefit from the experience in city logistics and from expected developments in zero emission technology. It is, however, important that more zero emission HDVs become available. Figure 25 shows an overview of zero emission HDV models that have been introduced on the market or have been announced. The figure shows models by Hytruck, EMOSS and Ginaf, companies that at an early stage introduced electric power trains on existing HDV models. Most of the larger OEMS are now also testing their new BET models with customers and are preparing for serial production within 1 one or 2 years. Most models are below a GVW of 27 tonne and with a range below 300km. In the US, Daimler is testing 2 BET models (e Cascadia and Freightliner eM2 106) of 37 and 40 tonne GVW with a range up to 400 km. The Tesla Semi is supposed to reach 800 km with a GVW of 40 tonne but has not been tested with customers yet and it is unclear when the truck will become available on the market.

10 RDW open data

__Figure 25__
Electric truck models in on the road and announced

__Source__
(ICCT, 2019), (Middelweerd, 2018), Company websites



There are also developments on the introduction of fuel cell electric trucks (FCET). Although not produced in series for the market yet, a couple of FCET concepts are being developed and tested. Hyundai, Toyota, VDL and Scania all have introduced FCET models with ranges of 400 km or higher. The Nikola Tre is supposed to even reach a range of 1200 km, but like the Tesla Semi, has not been tested with customers yet. Daimler Truck and Volvo also see hydrogen as the solution for heavy duty long distance transport and recently announced a 50/50 joint venture for development and large-scale production of fuel cells for applications in heavy-duty vehicles. It can be concluded that in the short term there will be no good operational solutions for long distance transport yet. Existing BETs have too little range and FCET with a higher range are not ready for market introduction yet. However, OEMS are investing more than before in zero emission technology and developments in battery and fuel cell technology might enable the production of trucks with a higher range.

An infrastructural innovation that could minimize or mitigate range problems of zero emission trucks are electric road systems (ERS) such as overhead wires. Since 2010 Siemens has been working on the development of an electric road system (ERS) for road freight transportation. Siemens has developed a prototype pantograph to extract electricity from a catenary system. The system has been applied on several test locations with hybrid Scania trucks (Siemens, 2019). By using overhead lines electricity is provided to hybrid trucks, which use BET, ICEV or conventional ICEV hybrid systems to cover the distances between the ERS routes. If large stretches of highway are electrified by ERS the need for large batteries will become lower. According to Siemens, 89% of truck movements after highway driving are less than 50km. Besides using ERS to power trucks on that particular stretch of road, trucks can charge their batteries during this period. The first iterations of ERS will probably be implemented in shuttle services, such as in Schlegswig-Holstein where trucks hail containers from ship to train terminal. The network will be further developed starting with stretches of highway with the highest intensities of truck traffic.

StratON project on ERS in Germany

Figure 26
Overhead catenary infrastructure in Germany: selected dense routes (grey) and gap closures (red). (Öko-Institut, 2020)

Within the framework of the research project 'StratON - Evaluation and Implementation Strategies for Overhead Catenary Heavy Duty Vehicles' funded by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, the potential of the ERS system has been analysed in depth over the past three and a half years (Öko-Institut, 2020). The project results show that the OC-truck system could significantly reduce GHG emissions from long-distance road haulage with heavy trucks.
If an overhead line network is set up very rapidly, the GHG reduction contribution in 2030 can be up to 3-6 Mt (tank to wheel) or 2-4 Mt (well to wheel, i.e. including the additional emissions in the electricity sector). In the longer term, the contribution to GHG reduction will be significantly higher. The electrification of a core motorway network of around 4,300 kilometers (90 % electrified, 3,800 kilometers) covers a large volume of traffic. At around 12 billion euros, the costs of setting up the network are moderate, especially in comparison with other decarbonization options for road freight transport such as electricity-based fuels. (Text from; (Öko-Institut, 2020)

Figure 27
ERS (Siemens, 2019)

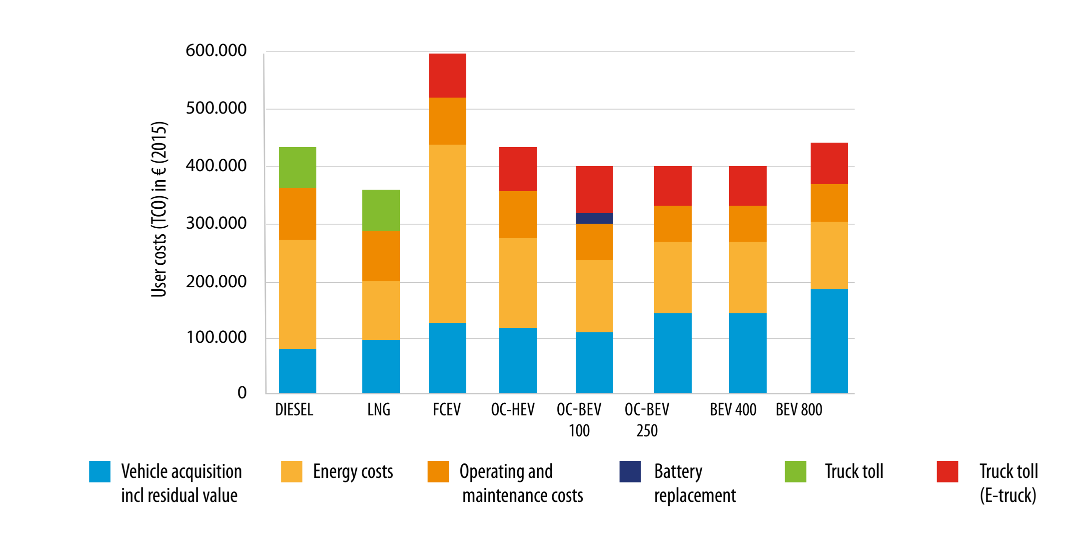
Also according to German Industry Association BDI (https://bdi.eu/publikation/news/klimapfade-fuer-deutschland/), 4000 to 8000 of overhead catenary lines have to be used as a cost-effective climate action for heavy duty vehicles (HDV) to reach German climate goals. This study states that the first investments in ERS have to be made by 2025, with the first 400km operational in 2028. The study also highlights the costs per km to be the lowest for ERS while also having the highest efficiency well-to-wheel (WTW). Large scale use of ERS is proposed after 2030. According to Siemens, the infrastructure costs of overhead lines are € 2.2 million per km, including all the necessary equipment and installations.
Maintenance equates to 2.5% per year of investment per year. Allocating 11% of the next 10 years of annual Maut-LKW (truck toll revenue, >€ 7.2 billion per year) to the eHighway would cover the investment in the 4.000 km network.

Costs of zero emission technologies

Several studies have assessed the costs of zero emission trucks. Earl et al. (T&E, 2018) made a comparison between a theoretical long haul heavy duty battery-electric truck and diesel truck. In the comparison they considered wages, maintenance, insurance, fuel and electricity prices, and road charging. The TCO results (see also the figure in the Annex on Section 4.3), based on a 5-year TCO, show that under current prices, the TCO of the BET might lower or higher than the diesel truck depending on the size of the battery pack (and range) and the use of supercharging. The electricity price and level of road charges are uncertain and can be an important factor for the BET to become cost competitive or not.
Also a recent German study (Öko-Institut, 2020) calculates lower or similar TCO costs for electric truck-trailers and diesel trucks in 2025 (see Figure 28). The BETs with a larger battery (800 km range) have a higher TCO than the BET with a smaller battery due to the higher battery costs[11]. The costs for electric trucks with overhead are a bit lower than for the BET (400km). According to the study the TCO for FCETs will still be much higher than for diesel.

Figure 28
TCO of semitrailer tractors in the year 2025 for different technologies over a 5 year utilization period

Source
(Öko-Institut, 2020); OC = overhead catenary, HEV = hybrid electric vehicle, the numbers, like in BEV 800, reflect the range in km



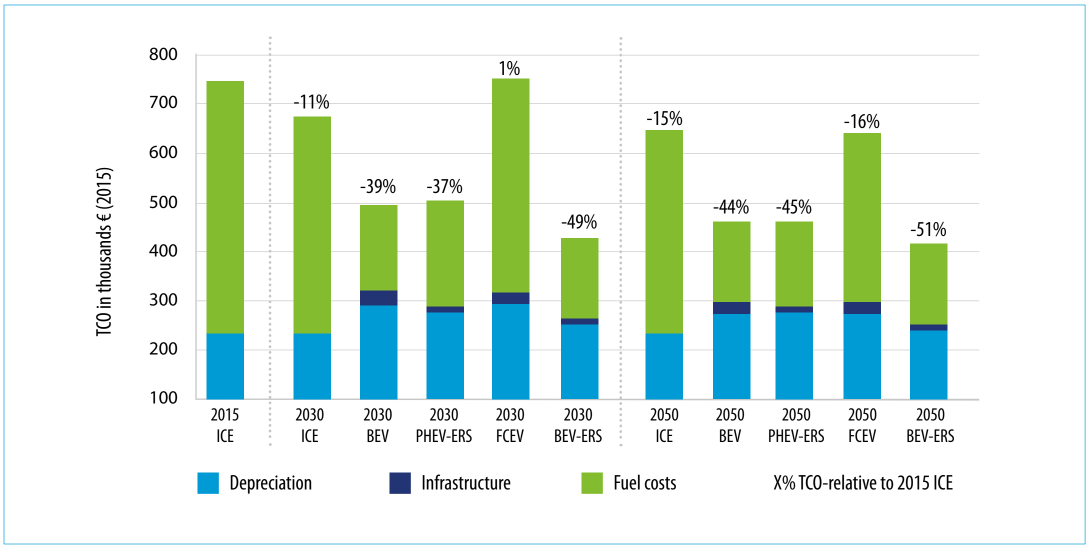
A study for ICF (Cambridge econometrics, 2018) also assessed the costs of BETs, BETs using electric road system (BET-ERS) and FCETs for the year 2030 and 2050. The TCO of the BETs and BET-ERS are becoming more favourable as compared to diesel, but the FCET is expected to have higher TCO than diesel in 2030 and a bit lower in 2050 (see figure 28).

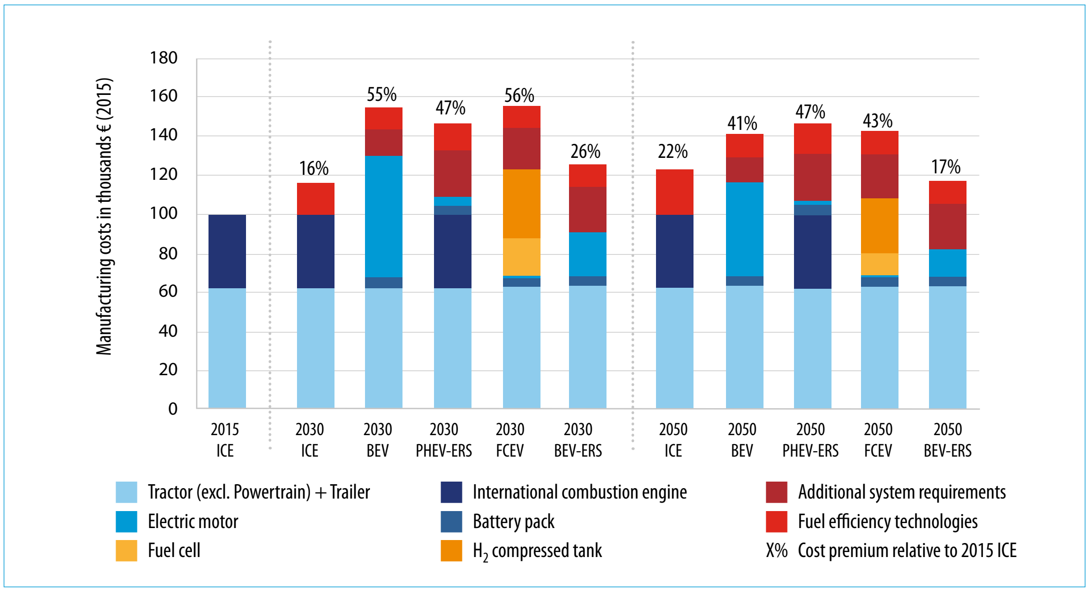
Although a favourable TCO would entail a better business case, the high purchase price of ZE trucks creates a barrier for transport companies to switch from conventional vehicles. Especially battery costs have a major share in the price premium over conventional trucks (see figure 29 on the bottom). Future battery improvements with costs reductions will make BEV truck prices lower. From 2030 onwards, according to the study the purchasing price would become more competitive in combination with an already lower TCO. According to the projections, FCEV trucks will remain more expensive than BET's. It should also be noted that currently prices for BETs on the market, with a smaller range, are still about double in price than projected in the three referenced studies for the year 2025 and 2030. The BET market, however, is developing quickly. On FCETs, there are also several studies reporting 2-3 times higher investment costs (e.g. Ronald Berger, 2017).

11 Costs as a result of different profiles, due to limited range seem not to be included.

Figure 29
TCO (over 5 years) and manufacturing cost of heavy HGV in 2030 and 2050 (ECF, 2018)

BEV= Battery Electric Vehicle (700 kWh battery), PHEV -ERS = Plug-In Hybrid Electric Vehicle using Electric Road System.(50 kWH battery), BEV-ERS is BEV using ERS (200 kWh battery)





According to (Concawe, 2020), E-fuels are more expensive than gasoline up to 2050. The fuel costs are about 2-5 times higher in 2022, 50% to 3 times higher in 2030, and 20-80% higher in 2050. The infrastructure and vehicle costs will be the same as for the diesel truck.

An important cost item which is not included in the previous studies are the cost for changes in logistical profiles due to changes in range or due to needed charging time. A recent study for the Topsector Logistics showed that (Connekt, 2019) the benefits from a larger range, resulting in lower electricity costs and less stops for charging, can outweigh the costs of a larger battery.

Energy efficiency and CO_2 reduction potential of techologies

Table 3 shows the well-to-wheel energy efficiency of the three main technologies for CO_2 reduction after 2030. Clearly electric trucks are most efficient in energy conversion. The use of green hydrogen or E-Diesel in trucks requires well- tot-wheel a factor 2-6 more energy than the direct use of electricity in BEVs or ERS-BEVs. The pathway to use electricity in trucks is relatively short and has relatively little energy losses, due to the relatively efficient electric engine. The use of hydrogen in trucks requires an electrolysis step, liquifying and transport and finally a conversion to electricity to drive the engine. These are all steps with relatively high energy losses. For E-diesel the conversion of hydrogen to a fuel comes on top of that.

Table 3
WTW Energy efficiency of a truck trailer (GVW 40 tonne) electric (BET/BET-ERS), FCET and on E-Diesel

** According to (Ivan Mareev, 2018) the overall efficiency of BET an BET-ERS are similar*

*** Internal combustion engine truck*

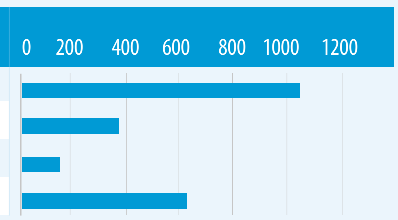
Source
Values from different sources: (T&E, 2020), (Concawe, 2020), (Öko-Institut, 2020). Ranges are given when values differ between the sources

	Stage	Electricity (BEV, BET-ERS)*	Hydrogen (FCET)	E-Diesel (ICET**)
(Sustainable) electricity		**100%**	**100%**	**100%**
WTT efficiency loss	Electricity transmission	-5%	-5%	-5%
	Electrolysis	-	-30% to -24%	-30% to -24%
	CO_2 capture and fuel synthesis	-	-	-37% to -30%
	Transport and distribution (incl. liquefying H_2)		-20%	-5%
Overall WTT efficiency		**95%**	**53%-58%**	**44% -49%**
TTW efficiency loss	Charge battery	-10%	-	-
	H_2 to electricity	-	-40% to -18%	-
	Engine efficiency	-15% to -10%	-15% to -10%	-70% to -58%
Overall WTW efficiency		**73%-77%**	**22 -38%**	**11-19%**

The higher energy requirement for H_2 and E-Diesel also means that the CO_2 emission of the hydrogen and E-fuel pathway are higher than for electricity. Figure 30 shows the WTW CO_2 emissions per km of a based on the average CO_2 emission of electricity in 2030 according to (PBL, 2019).

Figure 30
Well-to-wheel (WTW) emissions in 2030 (CE Delft, based on table 1, and average electricity mix in 2030 of 27 g/MJ))

	MJ/km	WTW g CO_2-eq/MJ	WTW g CO_2-eq/km
Diesel	11.1	95	1,051
FCEV-PEM (H_2- from average electricity)	9.2	41	376
BET (electricity-average mix)	6.1	27	162
E-Diesel	11.1	57	633



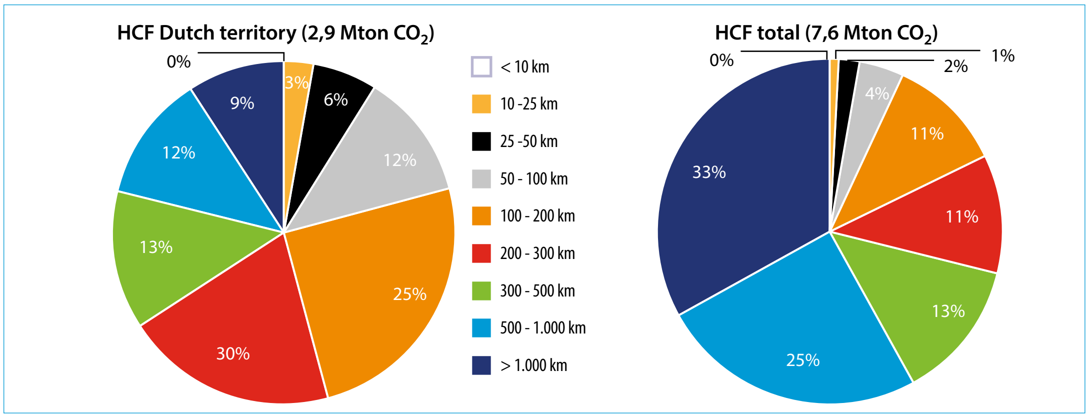
Note
BET and BET-ERS are assumed to have the same energy efficiency and CO_2 emissions per vkm

4.4 Zero emission towards 2030

Until 2030 we expect that CO_2 reduction in HFC road transport can mainly be realized on shorter distances by the introduction of electric vehicles in the fleet. As shown in the previous paragraph OEMS are having already models on the market are expecting to produce them in series within 1-2 years. They have battery capacities allowing ranges up to 400 km. In addition (advanced) biofuels will play role in CO_2 reduction. FCETs are not expected to be produced in series before 2030. Also E-fuels are not expected to be produced on large scale before 2030. An electric road system (ERS) could be piloted before 2030, but needs is also expected to contribute significantly after 2030 is such a system would be developed.
As currently BETs still have a limited range of up to 400 km, they cannot easily be deployed on heavy duty long distance transport. Before 2030, however, they might play a role in HCF transport on distances up to 200 km. The prerequisite is that after the introduction of lighter BET models, also models like the Daimler freightliner are introduced and produced in series as the majority of transport-km in HCF (>60%)[12] are made by 40-44 tonne trucks trailers. Figure 31 shows for the 2.9 Mton CO_2 of HCF on Dutch territory (TTW) and the 7.6 Mton of total HCF, the distribution over distance classes. From the total CO_2 emissions on Dutch territory, 46% of the CO_2 emission (1.34 Mton) is from transport over distances below 200km. In the total HCF transport the share is 19% of the CO_2 emissions (2.0 Mton).
Not all trucks will operate exclusively on short distances or long distances only. If we assume that half of the trips are in a specific market where trips can be operated by BETs, in 2030 this would reduce HCF CO_2 emission with 0.7 Mton CO_2 TTW on Dutch territory (scope Dutch Climate agreement) and 0.6 Mton WTW. We estimate that it required 15,000 to 20,000 HDVs to be electrified.

12 In total transport the share of the truck trailer is 64%. In HCF it has a larger share (CBS, 2019))

Figure 31
Share of HCF distance categories in the HCF CO_2 emissions on Dutch territory and total HCF CO_2 emissions (TTW)



4.5 Scenarios after 2030

After 2030 there are several options for HCF road transport to reduce CO_2 emission drastically. For the technologies to be successful it is important that governments, OEMS, hauliers and the energy sector prepare for the required changes. Governments have to take care of the implementation of required infrastructure as do fleet owners in case of charging installation on depots. OEMS need to supply the vehicles and the energy sector needs to supply the fuels (H_2, E-Diesel) or power grid connections.

In the first section of this paragraph we describe different zero emission scenarios after 2030 and give an impression of the required infrastructure and vehicle investment costs if we assume that all HCF road transport, that is not yet zero emission before 2030, will become zero emission. This is done for the following scenarios:

- Battery electric trucks (BET);
- Battery electric trucks with electric road system (BET-ERS);
- Fuell cell electric trucks using E-H_2 (FCET);
- ICET on E-Diesel.

The targeted HCF transport volume after 2030 concerns 2.85 billion km on Dutch territory from about 35,500 HDVs. They are responsible for 2.2 Mtonne CO_2 emissions TTW and 2.8 Mtonne CO_2 emissions WTW. In the second section we discuss the pros and cons of the scenarios.

Infrastructure and vehicle investments

BET-scenario

For the BET scenario we assume that from 2030 on heavy HGVs will be on the market with a 700-800 kWh battery package having a range over 400km[13]. The BETs are supported by a network of ultra-fast chargers (350kW) at highways and depots supplying the average electricity mix. For long distance transport the HGVs need to stop for one or 2 hours to recharge. This can partly be done during regular stops.
The 2.85 billion km corresponds to about 4,812 GWh electricity demand (1.69 kWh/km). We estimate that for this transport 488 public charging points are needed and 5.385 charging point at depots[14]. The depot charging point will be mainly used overnight and can charge more than one vehicle during the night (note: 150 kW charges might also be feasible at depot, but would not give a very different result). With an estimated cost of € 350,000, per charging point for installation an connection (Connekt et al., 2019), the total investment costs are estimated at € 2.05 billion for charging infrastructure.

13 Scenario based on (ECF, 2018) and (TNO, 2019)
14 Based on (TNO, 2019), we assume 6% of the energy demand on public charging station and 94% at depot or customer sites The average charging point delivers 1620 kWh per day 365 days a year. For the depot we assumed 2800 kWh per day, 300 days a year.

The extra costs for the BET in 2030 are estimated at € 50,000 per vehicle (ECF, 2018), resulting in 1.8 billion euros investments for the vehicle. The total investment costs for the BET HCF scenario than amounts € 3.85 billion. As the TCO figures in paragraph 4.3 show, the investment cost can be recovered by the lower fuel costs as compared to diesel. In this scenario most of the investments , for both infrastructure (mainly at depot) and vehicle, need to be made by the carriers.

BET-ERS scenario

For the BET-ERS scenario we assume an ERS network of 1150 km (37% of the national road network) on the highways that are most densely populated by HDVs. The roads have been selected by analysing the trucks kilometres against the road kilometres (see Figure 32). The 37% road or the national road length corresponds to about 56% of the total truck-km on the national road network. The selected roads are depicted in blue in Figure 33 (map on the left). As HCF transport is mainly active on these corridors (see O-D relations on map in the middle) we assume that 70% of the HCF-kilometres will be powered by the ERS (average electricity mix). The assumption is that abroad the ERS-HDVs can also make use of ERS and therefore they need a smaller battery pack of 200 kWh. The following investment costs apply:

- The need for charging facilities will be 30% of the BEV scenario, and amounts €0.62 billion.
- The investments in 1150 km road with ERS amounts € 2.2 million per km highway (Siemens, 2019) (ECF, 2018) (both ways) and 2.5 billion in total.
- The extra costs for a BETs equipped with a pantograph amount € 10,000 per vehicle according to (ECF, 2018) resulting in total in cost of € 0.35 billion for the total HCF fleet.

The total investment costs for the BET-ERS scenario than amounts 3.5 billion. As the TCO figures in paragraph 4.3 show, the investment cost can be recovered by the lower fuel costs as compared to diesel. In this scenario the largest part of the investments, for infrastructure (74% of total), will end up with government and energy network companies. The vehicle and charging infrastructure at depots with the carriers.

Figure 32
Relation between national road length (per segment) and vkm of HDVs (length > 12 metre) in NL when ordered from high to low intensity

Source
Analysis based on INWEVA data

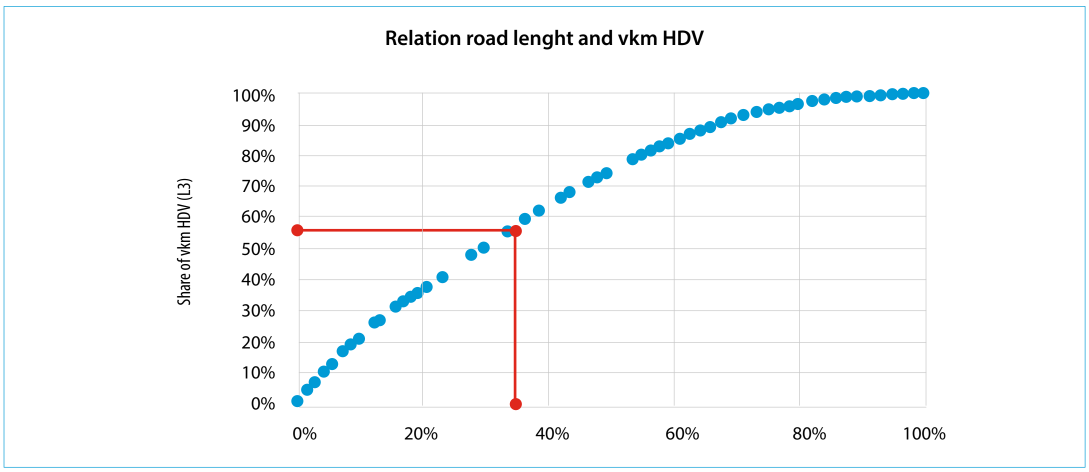
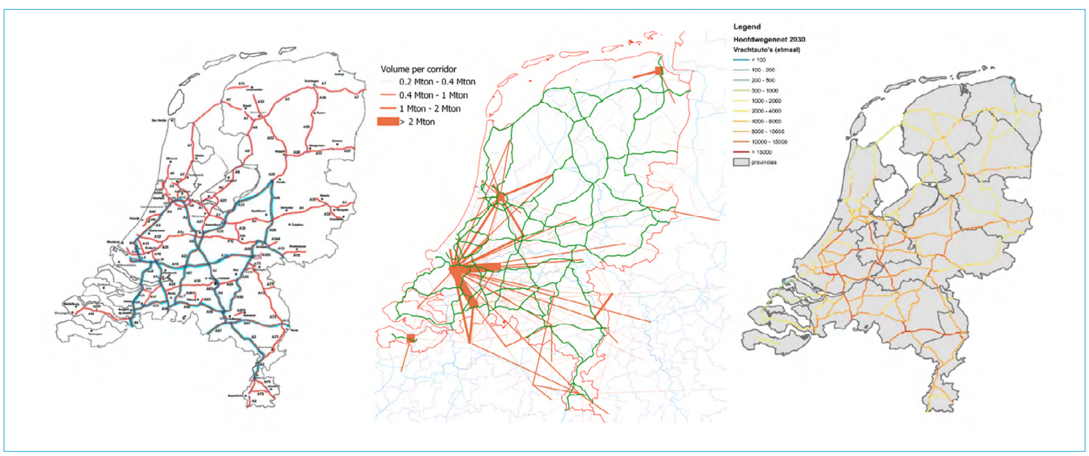


Figure 33
On the left: proposed ERS corridors (blue), based on INWEVA road intensity truck data. In the middle : HCF O-D relations of road freight movements in Mton with highways on background in green. On the right: (TNO, 2019), trucks per day on Dutch highways in 2030.



FCET (E-H_2) scenario

For the FCET we assume that from 2030 on heave HGVs will be on the market with a 60 kg hydrogen tank having an range of about 800 km. The FCET are supported by a network of H_2-fuel points that deliver 1600 kg H_2 daily per fuel point at 7 kg per minute. Refuelling takes only 10 minutes and has no impact on the current logistical profile (Scenario based on (TNO, 2019)). The H_2 is produced with the average electricity mix (E-H_2).

The 2.85 billion km corresponds to about 217 kton (7,260 GWh) hydrogen demand (1.55 kWh/km). We estimate that for this transport 372 public fuel points are needed. With an estimated cost of € 42,000,000 per fuel point[15], the total investment costs are estimated at € 1.58 billion for H_2 fuel infrastructure.

The extra costs for the FCET in 2030 are estimated at € 50,000 per vehicle (ECF, 2018), resulting in 1.8 billion euros investments for the vehicle. The total investment costs for the FCET HCF scenario than amounts € 3.36 billion. The extra costs for the vehicle, however, could also be much higher than for BETs, according to other sources (Ronald Berger, 2017), resulting in similar or even higher investment costs than for BETs. As the TCO figures in paragraph 4.3 show, the investment cost will not be completely recovered by the lower fuel costs as compared to the diesel case. In this scenario the investments for infrastructure (47% of total) will end up with government and H_2 suppliers, the vehicle investment (53%) with the carriers.

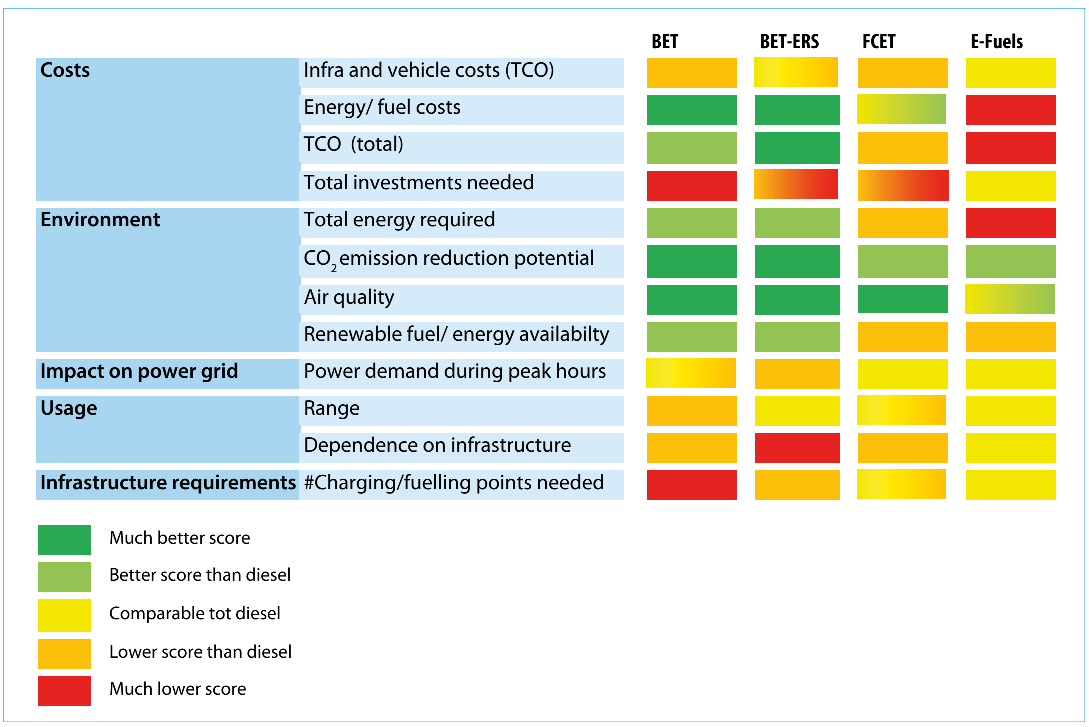
E-Diesel scenario

For E-diesel we assume that no extra infrastructure investments are needed, as the diesel infrastructure is already in place. The Fuel prices, however, will be about 1.5-3 times higher than for Diesel. The E-Diesel is produced using from electricity (average mix).

Pros and cons of zero emission HCF scenarios

Figure 34 shows how the different scenarios qualitatively score on several selected aspect as compared to diesel and mutually from 2030 on. The colour yellow in the table indicates that the score of the scenario is similar as to keeping diesel ICE vehicles, green indicates and improvement and orange and red a downturn.

Figure 34
qualitative scores of scenarios on selection of criteria (year 2030)



15 Based on (ECF, 2018), assuming total costs for installation of compressor and installation units of € 2,640 /kg daily capacity (26 mln for 10,000 kg/day unit).

Comparing the 4 options on costs, the E-diesel scores best when it concerns infrastructure and vehicle costs. No changes are expected in comparison to the future diesel option, whereas for the other options there will be extra depreciation costs/fees for infrastructure (Charging station, ERS , H_2 fuelling station) and vehicles (batteries, pantograph, fuel cells and E-engine). The fuels costs in the E-diesel scenario, on the other hand, are the highest resulting also in an overall TCO for E-diesel that is higher than for diesel. The other 3 options are expected to have much lower energy/fuel costs, also resulting in a more favourable TCO than diesel, especially the 2 BET scenarios.

Although the TCO results for BET, BET-ERS an FCET are lower than for diesel, the total investments that are required are high for all 3 options. In the BET scenario investments need to come mainly from the carriers. They need to invest in electric trucks with large battery packs and also in charging infrastructure. In the BET-ERS case these investments are lower, as smaller battery packages are needed for the trucks. The government and/or energy network companies, however, need to invest in an ERS system. In the FCET case carriers need to invest in trucks, government and H_2 supply companies in H_2 fuelling infrastructure.

Looking at environment aspects, all scenarios show benefits on CO_2 reduction and air quality improvement. On TTW basis, the scenarios, per definition, all reduce 100% of the CO_2 emissions. On WTW basis the emission reduction in the BEV scenarios in 2030 is 85%, in the fuel-cell H_2 scenario 64% and in the E-diesel scenario 40% based on the 2030 average electricity mix. The air quality improvement in the E-diesel scenario is limited, as the combustion engine, although probably to a lesser extent as compared to conventional diesel (for PM) will still produce exhaust emissions. The 2 BET options are most favourable which originates from the highest energy conversion efficiency of these 2 pathways as compared to the fuel cell and E-diesel pathway. The pathways from electricity to E-diesel and E-H_2 comprise many steps in which energy is lost. The availability of renewable electricity is expected to grow according to national plans to increase the share of renewable electricity in the electricity mix. The availability of E-fuels (E-H_2 and E-diesel), however, depends on the production of H_2 from (renewable) electricity. To have the fuels available for HCF transport in 2030 requires a large scale up of production capacity. At the moment the availability of renewable H_2 is very limited and the large majority (>99%) of H_2 is produced from fossil sources. The production will likely be scaled up at location where renewable energy (sun and wind) is available at low cost. However, there will be competition for the use of E-H_2 with other processes that need high quantities of E-H_2 to become sustainable, like for the production of ammonia, methanol and steel (IEA, 2019).

Related to the environmental impact is the impact of the scenarios on the power grid. Whether the power grid needs to be extended depends on the impact the extra electricity demand has on the peak demand during the day. When the peak demand is raised it also means that more electricity production capacity or buffer capacity is needed. The challenge to green the electricity production will be more challenging. In the BET case most of the charging of the vehicles is expected during off-peak hours, in the night at depots. In het FCET and E-diesel scenario, production of the E- fuels can also be planned off-peak. For the BET-ERS scenario the impact on the peak demand is expected to be the largest as the energy demand of the BET-ERS vehicles is real-time during transport.

Important usage aspects are range and infrastructure dependence. The range in the FCET, but mostly in the BET scenario will be lower than for the diesel default scenario, but might increase over time with technological developments. For E-diesel the range will be the same. In the BET-ERS the range can be longer than for diesel when the ERS is available on the track, but also lower when it isn't. In this scenario, the trucks depends most heavily on the infrastructure. Also BET and FCET depend more on the charging/fuelling infrastructure than default diesel does as they need to refuel more often. BET and BET-ERS need the most energy infrastructure, and thus space, to realize the scenarios.
A limited range will have effect on the logistics. Whether the impact is high or not depends on the way recharging or refuelling can be embedded in the current profile of driving an resting and to what extent it will cost extra time and money.

All scenarios have pros and cons and also mixed scenarios are possible. To make fast progress on the reduction of CO_2 from 2030 on, the BET scenario and the BET-ERS scenario seem most promising. To have green H_2 and E-diesel available at the required scale is challenging and also other industries and transport modes are in competition. On the other hand, long distance transport over 500 km distance might still be hard to realize with BETS, although scenarios to deploy BETs (with a limited range) in long distance transport have not been fully researched to our knowledge . With BET-ERS it might be possible to cover long distances, if a network of ERS is developed, not only in the Netherland, but also other countries, especially Germany and Belgium. A good collaboration will be needed. Long distance transport can also be the focus market for FCET of E-diesel fuelled trucks. Alternatively, rail and IWT might be given a specific role in long distance transport (see next chapters).

Although there are large uncertainties in the scenarios discussed above, it is clear that in all cases large investments are required from market parties and governments. It is therefore important that, based on information on pros and cons, politics and industry outline a clear pathway towards sustainable transport after 2030, on which all involved parties can anticipate their investments.
The list of pros and cons ca be further completed and certain effects, such as the effect of the scenarios on the costs for the carriers and the effect on the electricity grid deserve a more detailed analysis.

5 New inland waterway concepts for container transport

In the previous Outlook it became clear that the traditional inland navigation sector in the Netherlands will face an enormous challenge in coping with the decline freight flows -particularly fossil flows- in one hand and the decarbonisation task on the other hand. It was concluded that the container segment in inland navigation has the best growth potential, and can contribute to the overall CO_2 reduction task in hinterland and continental freight transport. The energy consumption per tonkilometre is much lower than that of road transport. A modal shift towards inland waterway transport will therefore help achieving the objectives of the Paris climate agreement, also on the long term, if the propulsion of barges is based on non-fossil technologies. However, the technical and economic challenges for decarbonizing the inland waterway sector are great.

Growth of container transport will put more pressure on the organisation of container handling in the deepsea ports. The peaks in demand for quay capacity, both for large deep-sea-vessels, feeders and inland container ships are growing due to the increase in size of dee-sea container vessels. More container transport will increase the peaks and the subsequent waiting lines of barges in the port. Innovations in the organization of container transport per barge to and from the deepsea terminals are needed to keep a predictable handling time and enable an increase of market share. Several solutions to improve container handling in the port are developed, such as Nextlogic, the integral planning tool for container transport in the port, and the Container Exchange Route (CER) that should reposition containers to decrease the calls per barge in the port. This chapter describes how new network systems can also contribute to an economically viable IWT sector that contributes to the decarbonisation task in hinterland and continental transport.

5.1 Basic principle of the concepts

Present situation

The largest part of container transport by barge in the Netherlands consists of import and export flows to and from the deepsea terminals in the port of Rotterdam. In total 5.3 million TEU is transported by barge annually, of which 3.6 million in relation to Rotterdam. Of these 3.6 million, approximately 2.6 million TEU is transported to and from the Rotterdam region, app. 1.0 million TEU is transported within the region. The remaining 1.7 million TEU is mainly between the other seaports in the Netherlands and Belgium and the hinterland.

In total there are 48 inland waterway container terminals in the Netherland, of which 44 are situated in the hinterland. The figure below shows the location of these hinterland terminals. The figure also shows the total freight flows on the inland waterway network.

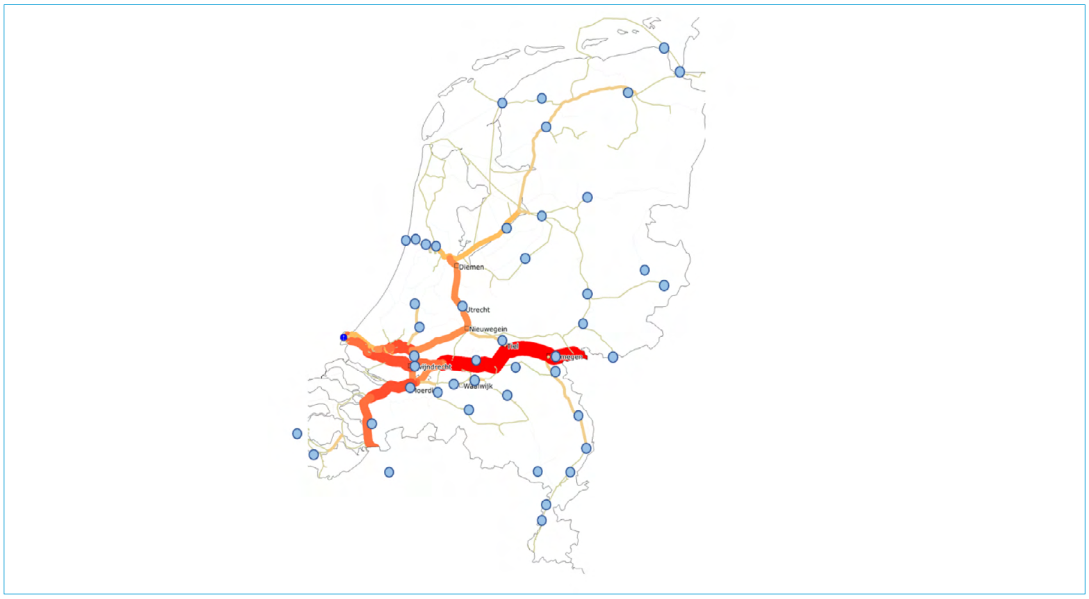


Figure 35
Inland waterway container terminals and flows (based on Panteia[16])

Three main corridors can be identified:

1. East (towards Germany),
2. South (towards Antwerp) and
3. North (towards Amsterdam-Groningen).

Due to the great number of inland terminals along these corridors, the flows are quite dispersed. All inland terminals provide dedicated container shuttle services to and from the various deepsea terminals in the mainport. The containers for an inland terminal need to be collected from several different terminals in the port. The challenge for the barges is to minimize the number of vessel movements and to effectively use the scarce quay capacity. The increase of scale in vessels and operations in the deepsea terminals creates large peaks in demand for handling capacity, leading to waiting lines for barges.

16 Panteia 2018, Drietrapsraket containerbinnenvaart

Description of the concepts

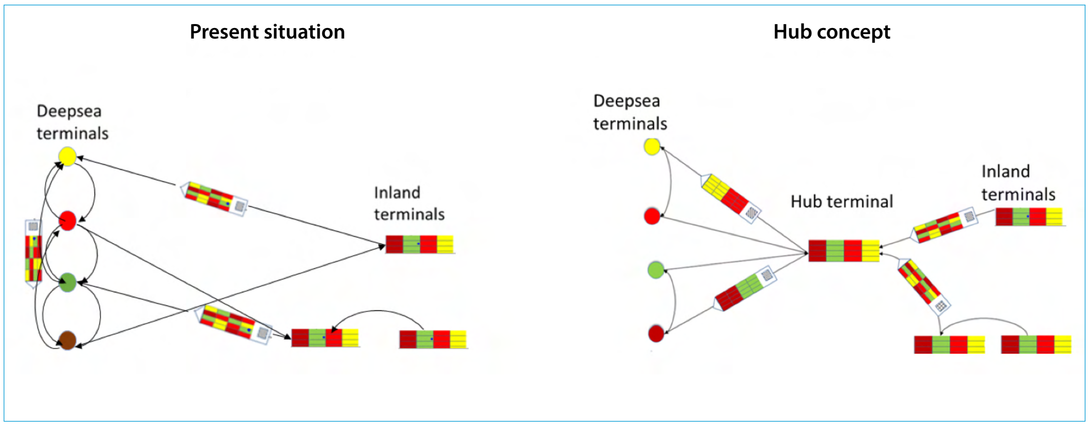
For the new transport concepts described, a system-based approach is required, which implies new organization and co-operation models for the parties in the supply chain (shippers, barge and terminal operators, shipping lines).

There are different concepts that have been developed which have one or more of the following elements::

- Combining and bundling container flows;
- Funneling container flows using transhipment hubs;
- Decoupling loading and unloading using push barges;
- Introduction of new drive lines/electrification.

When smaller flows are combined in the hinterland terminals, the call sizes in the deep sea terminals can increase and fixed windows can be applied for. Combining flows for a single deepsea terminal will have the highest impact on efficiency in the port area. Funnelling the flows at the inland side using a hub that enables the decoupling of the deepsea flows from the hinterland terminals. At the transhipment hub the container flows from the hinterland terminals are rearranged per deepsea terminal, which enables a more efficient handling at the deepsea terminal. Shuttle services with dedicated containers per deepsea terminal provide the link between hub and deepsea terminal.

Figure 36
IWT hub concept



The advantages of this concept can be summarised as follows:

- One ship serves one or two deepsea terminals instead of visiting several terminals in one trip;
- The call size of barges in the deepsea terminals can increase;
- Faster handling in deepsea terminal;
- Higher reliability;
- Kilometre reduction, depending on the location of the hub terminal;
- Lower costs due to reduction of dwell (retention) time in the port;
- Increased possibilities for battery-electric powered ships due to a reduction in trip kilometres.

There are also some disadvantages:

- Extra handling (transhipment) at the hub terminal, resulting in
  - extra transhipment costs
  - possible extra travel time
- Reduction of flexibility on some specific relations.

When loading and unloading are being decoupled by using push barges, the quay capacity can be optimised and waiting costs are drastically reduced.

The abovementioned concepts are being developed, tested and applied in different combinations and contexts. The next section describes the West-Brabant Corridor initiative, where the principle of funnelling and reshuffling container barges to the deepsea terminals is already being applied. A specific application is a system where containers are transported to and from the deepsea terminal in push barges that can be called whenever there is quay capacity available. This so-called 'Lego-barge system' is currently being investigated by the Topsector Logistics. Finally, a European initiative with small push barges called Watertruck is shortly described.

5.2 Practices and initiatives

West Brabant Corridor

In the province of Noord-Brabant there is a large concentration of European distribution centres and logistics and production activities for national and international supply chains. Inland terminals are providing regular services to the ports of Rotterdam and Antwerp. Due to the congestion in the deepsea terminals restrictions have been imposed on small and irregular services. The inland ports of Moerdijk, Oosterhout and Tilburg have developed a joined service, where large push-barge convoys provide services between Rotterdam and Moerdijk, where the push barge is released and the inland ship continues its journey towards Tilburg, which accessibility is limited. Due to the relatively large size of the vessels (CEMT Class V) and frequent and shuttle services, the handling at the port can be efficient and reliable, using fixed windows at the deepsea terminals.

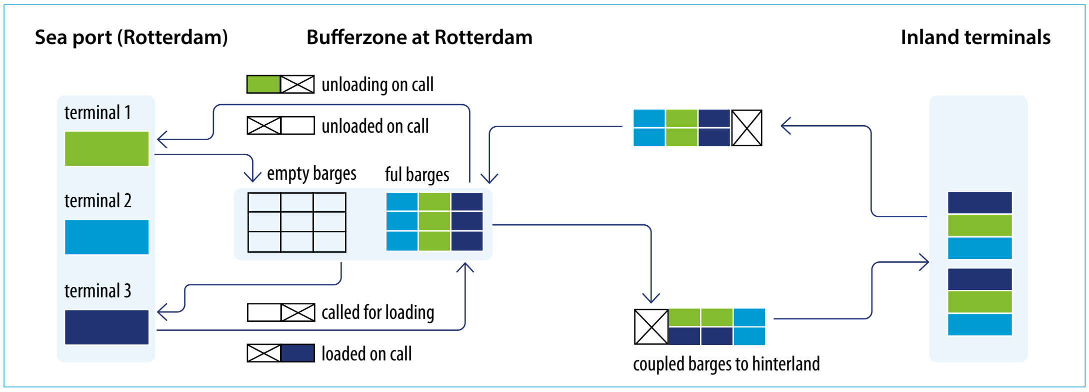
This concept has been in service for over a year now and has already proven its value in reducing costs and facilitating a modal shift from road to inland waterway transport. At present there are 22 timeslots per week (and thus services) in Rotterdam, transporting 480,000 TEU between West-Brabant and Rotterdam. The overall CO_2 reduction is estimated to be 28 Kton, over 23 million road transport kilometres have been avoided[17], compared to unimodal road transport. Without this concept, the shift potential would have been substantially lower.

17 *Source: www.topcorridors.com*

Push barge 'Lego' system

The concept of funnelling can be combined with decoupling the loading and unloading process at the terminal, in order to optimise the utilisation rate of the deepsea terminal quays. The system that is nicknamed 'Lego-barge system' is based on the use of unmanned push barges that are buffered in the port area and called for (un-)loading whenever capacity is available. This system is also based on the concept of funnelling and combining flows from the hinterland. The figure below gives a schematic overview of the concept.

Figure 37
'Lego' push barge system

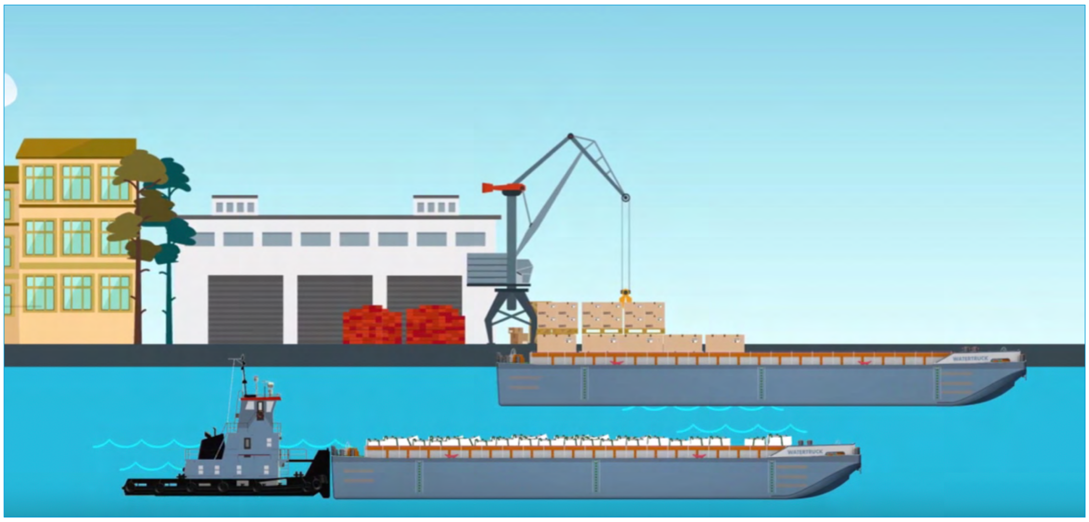


Watertruck

Between 2010 and 2014 the Belgian Smart Mobility expertise centre conducted research on a new concept to optimize the transport of goods via small waterways (up to and including CEMT-class IV).
The concept consists of smaller push tugs with small barges, adapted to the size of the waterway. On larger waterways, the barges can be coupled and continue in convoys. The main characteristics of the project are, on the one hand, the separation of the actual transport and (un)loading activities and, on the other, that staff no longer needs to live on board.

Although the system is mainly designed in order to preserve transport options per barge on small waterways, it also uses the concept of decoupling the (un)loading activities like the 'Lego' push barge system does with containers. The economic viability of this system however is rather limited, as the costs for equipment and staff per ton/TEU transported are relatively high compared to road transport.

Figure 38
Impression Watertruck



5.3 Potential impact on transport flows and modal split

The total transport volume by road between the mainport and the hinterland regions on the inland waterway corridors is 160 million ton, of which 36 million ton in containers. Of this 36 million ton, 17 million ton is transported over a distance larger than 50 km. At present, approximately 16 million ton (1.5 million TEU) is transported in containers by barge to and from the mainport terminals.

In theory, the potential for new inland waterway concepts to increase the market share is large: more than 100% increase is possible (from 16 to 33 million ton) when all road container transport on the corridors with a distance larger than 50 km is shifted to barge. Moreover, for distances smaller than 50 km some shift towards barge is also likely, depending on the service levels and costs. In the Rotterdam port area, there are a few examples of container services on short distances, mostly between terminals and in order to reallocate empty containers.

It is therefore likely that new concepts as described above can lead to an extra modal shift ranging from 8 million ton (presuming 50% of the longer-distance potential is addressed) to 12 million ton (with some short distance transport included as well). Expressed in TEU, the potential is between 700,000 and 1.1 million TEU. Expressed in tonkilometres, the shift will be between 1.25 and 1.40 billion per year. A crucial prerequisite for this shift is the cost competitiveness of IWT transport, as well as a higher level of reliability in the port.

Incentives in the field of costs (e/g road taxation) or legislation support the modal shift potential. When road transport costs increase, e/g due to road pricing and/or CO_2 taxation, the new concepts become more competitive. The same applies for policies that restrict the use of certain vessels and vehicles, for instance in zero-emission zones in urban and port areas.

5.4 CO_2 emission reduction and revenue

The current CO_2 emission of the container transport by barge in the Netherlands is 330 kiloton (TTW) on Dutch territory. The container transport to inland terminals in the Netherlands is 60 kiloton, 270 kiloton is related to flows to Germany and Belgium. With the international part of the transport leg included, the total emission in container transport mounts up to 620 kiloton. The total carbon emission of inland navigation on Dutch territory is 2,160 kiloton in 2018.

The decarbonization potential for the new concepts described in the previous section consists of three different elements:
1. The contribution to the modal shift from road to water
2. The reduction of transport distance in hub systems
3. The use of alternative propulsion and/or motor fuels

Re. 1: Modal shift impact

The maximum modal shift potential has been estimated in the section above to be between 700,000 and 1.1 million TEU, or between 1.3 and 1.4 billion tonkilometres. The impact of this shift is roughly estimated to be between 64 and 69 kiloton. See the table below for the calculation and assumptions.

Table 4
CO_2 calculation hub concept

Modal shift impact	Min	Max	Assumptions
TEU shifted	700,000	1,100,000	
Containers shifted	440,000	690,000	1.6 TEU per container
Tonkilometers (million)	1,280	1,390	Average distance 160 km overall, 27 km for short distance (within port region) services
CO_2 road (Kton)	116	128	Same distance and tonkm as IWT, based on average emission (WTW) of 90 gr/tonkm.
CO_2 IWT (Kton)	50	55	Based on average emission (TTW) of 39 gr/tonkm.
CO_2 pre-/endhaulage (Kton)	14	21	Average distance 20 km
Total CO_2 IWT (Kton)	64	76	Main leg by barge plus pre- and endhaulage
Savings CO_2 (Kton)	52	52	Unimodal road compared to IWT plus pre- and endhaulage

Re. 2: Reduction of transport distance

Panteia has argued in its report 'Drietrapsraket containerbinnenvaart' that a hub system can lead to a reduction of the total transport distance compared to point-to-point traditional container services. An average reduction of 30 kilometres is mentioned. This reduction depends not only on the location of the hub(s), but also on the size of the ships that are deployed in the transport between the hubs and the mainport and hinterland terminals. A very rough estimation can be made of the overall savings potential when it is assumed that on an average trip length of 160 km (the average of hinterland container transport outside the port region) a reduction of 10% is possible. Assuming that maximum 50% of all hinterland container transport can benefit from 10% trip length reduction, the total reduction will be app. 24 million tonkilometers. This will lead to a reduction of app. 950 ton (1 kiloton) of CO_2 per year.

Re. 3: The use of alternative propulsion

One the greatest challenges for the transport sector in general and the IWT sector in particular is the need to turn away from fossil fuels. Electrification is probably the most likely path towards decarbonization, which is particularly difficult in heavy transport segments such as inland navigation and long-distance road transport. However, the introduction of hub-systems opens up new chances for battery-electric propulsion, as the transport distances between hub and terminals become small enough for electrification. With the extra modal shift envisaged, pre- and endhaulage will also be far easier to electrify compared to long-distance road haulage, as the average trip length of pre- and endhaulage is in general between 25 and 50 km, which is the first segment of heavy road haulage that can be electrified. A quantification of the impact of electrification is difficult to make, at this stage it's also unclear to what extent and at what speed the electrification will take place in the competing transport modes (road transport in particular, see also chapter 4).

Resuming, the overall decarbonization potential of the new IWT concepts can mount up to 70 kiloton per year, with an additional potential for electrification and hence much bigger CO_2 reduction potential.

The system costs will consist of the following:
- Extra transhipment costs at the hub;
- Hub terminal investment;
- Extra equipment: investment in push barges;
- Electrification inland navigation vessels.

A rough estimation of these costs is indicated in the table below:

Table 5
Cost calculation hub concept

Cost	Value	Assumptions
Number of containers via hub	1,000,000	30% of all inland containers (3.4 million in total).
Extra transhipment costs (euro/year)	30 million	15 euro per move, 2 moves per container.
Cost reduction due to lower dwell time in port	-10 million	Depending on corridor and hub location, savings calculated by Panteia vary between 0 and 5 million per corridor. Note that the sharing of costs and benefits needs to be arranged for and requires new organizational concepts as well.
Hub terminal investment (euro)	80 million 4 million/year	4 hubs, 20 million investment per hub (including cranes and systems) , 20 years depreciation.
Extra equipment	PM	The hub system can be served with conventional ships, the 'Lego' system requires substantial investment in barges.

These costs can be compared to the CO_2 reduction of 70 Kton, which is presented in the overview below:

Table 6
Costs compared to CO_2 reduction

Concept	Ton-kilometers (million)	Total costs/year	CO_2-reduction	Ratio euro/CO_2 ton
Hub-system IWT	1,390	24 million	52 kton	460

The costs per ton CO_2 reduction are relatively high for the inland shipping hub concept when compared to other decarbonization options (sea also the next paragraph). The reason for this is the poor CO_2 emission performance of fossil fuel powered vessels compared to a/o electric rail transport. When the IWT sector is capable of electrifying its fleet, the CO_2 performance will improve significantly. The hub-concept facilitates and helps accelerating the electrification of inland shipping. First full-electric container vessels, using ISO container battery packs, are currently being developed and will be deployed for the transport of Heineken export lager from the terminal in Alphen a/d Rijn towards Moerdijk. The first vessel will be introduced in 2020, in 2021 another 5 electric vessels will be deployed.

With the maximum estimated shift potential of 1.1 million TEU being transported by electric barges, the CO_2 savings can increase with an additional 54 kiloton to 61 kiloton in total. Panteia estimates that the investment costs for electric propulsion are 2.5 million Euro per kiloton CO_2. The annual costs for electrification mount up to 13.5 million euro.

Table 7
Costs compared to CO_2 reduction including electrification

Concept	Ton-kilometers (million)	Total costs/year	CO_2-reduction	Ratio euro/CO_2 ton
Electrified hub-system IWT	1,390	24 + 13,5 = 37.5 million euro	52+54 = 106 kton	354

Of course the calculations above are very rough and the outcome strongly depends on the assumptions on costs and the way these can be attributed to the actors in the chain. As stated before, a new system approach will be required to introduce such a concept successfully.

6 Fast and flexible rail transport

The development of rail freight transport in Europe in the past four to five decades is characterised by a steep decline in traditional wagonload transport, waning bulk flows and a moderate growth of container shuttles. The overall modal split has been relatively stable the past 20 years, despite ambitions of government and port to increase the share or rail in the modal split. When the Paris reduction targets are taken seriously, however, rail needs to increase its competitive position and market share substantially.

The first Outlook on HCF in 2018 showed that an approach on system level is required, similar to inland waterway transport. A new conceptual approach on innovative rail transport systems can help to show how this modality can gain market share and contribute to the required decarbonisation of transport. The traditional, long distance bulk flow (coal and oil) segments are disappearing and the growth in international container flows reaches its limits. The main potential for rail must be found in segments that are nowadays served by road transport.

The objective of this case is to demonstrate how new rail concepts can increase market share, particularly for time-critical goods (fresh produce, dairy, meat, express freight and parcels) in hinterland and continental transport flows. The impact on modal shift, emission on CO_2 and competitive position will be illustrated.

Two different rail concepts have been distinguished, based on different innovative rail systems, logistics organisation and flow characteristics:

1. Short freight train network;
2. Long distance trailer trains.

6.1 Concept of short freight train network

Concept introduction

Traditional rail market innovation is focused on improving interoperability between the networks of different countries and lengthening trains in order to decrease the costs per unit transported. However, the competition with road transport is hardly won with these developments, as rail will still be ways behind on flexibility, frequency and reliability. Therefore, an opposite development towards shorter and faster trains might be able to regain market share in segments where road transport now practically has a monopoly. The idea of the first concept explored in this Outlook is to develop a network of short and fast freight trains, connecting the mainport regions with hinterland hubs in the Netherlands and across the border in Germany and Belgium. These short trains can serve the network with high frequency with the same characteristics as passenger trains. It is therefore also easier to integrate them in the current train schemes, providing that the overall capacity of the rail network is increased, a/o by using ERTMS[18] to its full potential in the near future, increasing the flexibility and amount of train paths.

The following attributes apply to the concept:

Based on passenger train setup and driving characteristics:
- Fixed configuration (fixed train sets/EMU)
- Electric/battery-electric traction
- Maximum speed 120-140 km/h
- Fast acceleration and deceleration
- Train length 90-160 m

Modular load concept:
- Containers/swap bodies
- Easy to handle load units (10’-containers)
- Train capacity 15 TEU (30 10’-containers)

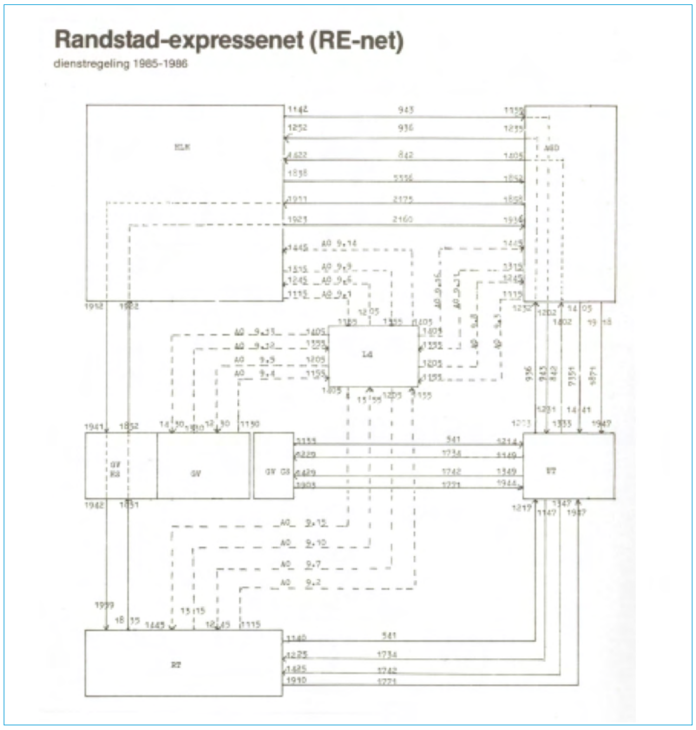
The concept of a short freight trains network is not new, neither is the idea of standard load units that are transported from door-to-door. The latter system was already introduced before WWII in the Netherlands, the so-called 'Autolaadkistensysteem from ATO/Van Gend & Loos'. The figure below give an impression of this system.

Figure 39
The Dutch door-to-door rail-road Laadkisten system

18 European Rail Transport Management System

With the upswing of the truck in the years after the war, the system was no longer competitive. From a more recent era is the network exploited for the postal services, the so-called 'PTT-posttreinen'. These electric motor units served a network connecting the post distribution and sorting centres on a frequent basis. The following figures show the motor units and the network deployed until the mid-eighties. The high costs of the exploitation of the network and trains was the main reason the PTT decided to shift to road transport.

Figure 40
The Dutch train post system



The latest attempt to develop short and fast freight trains was made in Germany, where at the end of the last century the 'CargoSprinter' concept was presented. The train consisted of a five-car permanently connected set of container-carrying vehicles (10TEU capacity), with a driving cab at each end and motorised with underfloor diesel engines. The trainsets could be connected easily and worked in multiple with other CargoSprinter trains. The CargoSprinter trains operated between the intermodal rail terminals of Frankfurt, Hamburg, Osnabrück, and Hanover and between 1997 and 1999, carrying two trains per day: the equivalent of 5000 truckloads per year. The service was initially successful with high reliability and full utilisation; work on the connecting railway line in the second year of operation disrupted the service, causing loss of customers, leading to the termination of the service.

Figure 41
The German CargoSprinter

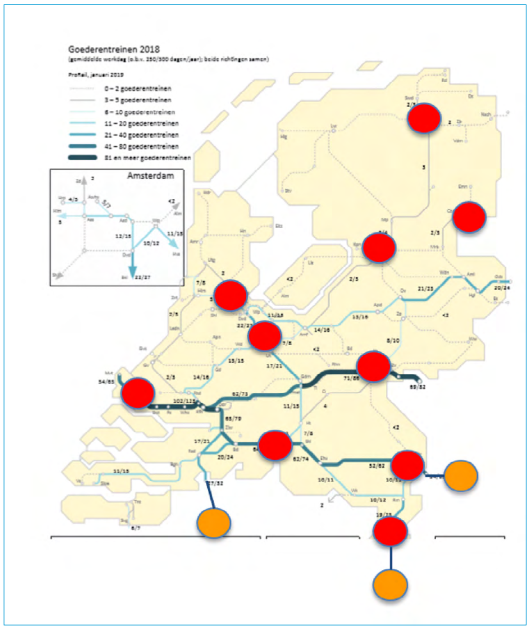
Set-up of the concept

The rise and fall of the concepts described above show that in segments where rail freight using short trains can be successfully exploited, but the low costs of road transport in combination with higher reliability and flexibility of road has led to the extinction of the concept.

However, in the light of the enormous CO_2 emission reduction task the sector is faced with, the need for zero-emission transport systems becomes more important than ever. In combination with the problems of congestion, safety and other environmental issues (air quality, nitrogen deposition, noise etc.), the societal cost-benefit ratio of such a 'new' transport can become positive. The system described is an illustration of what a new concepts could look like and what the potential impact could be in the long term. In the framework of this Outlook, it must be seen as a possible disruptive development that can support the immense decarbonization task that lies ahead in the transport sector. Of course further analysis of the feasibility, societal cost-benefit analyses, business case development and elaboration of technical and organisational aspects are still needed.

A potential network for the short trains could consist of the following network connection (hubs):

Figure 42
Proposed hubs for short freight trains



Network connection	Terminal infra availabale	Rail capacity available
Rotterdam	++	+
Amsterdam	+	-
Utrecht	-	-
Arnhem	-	+
Venlo	+	+
Duisburg (D)	+	+
Tilburg	+	-
Antwerpen (B)	+	+
Zwolle	-	-
Coevorden	+	+
Born	+	+
Luik (B)	+	+
Groningen	-	-

The table above presents a rough estimation of the railway and terminal capacity in the hubs selected. For each of the hub regions (NUTS3 level), the freight flows in the HCF database (CBS, Basgoed) have been used in order to determine the potential. The road transport flows as forecasted for 2030 have been selected as the basis for the potential between these hubs.

The next table shows these flows.

Table 8
Freight flows between selected hubs (road transport, Basgoed 2030)

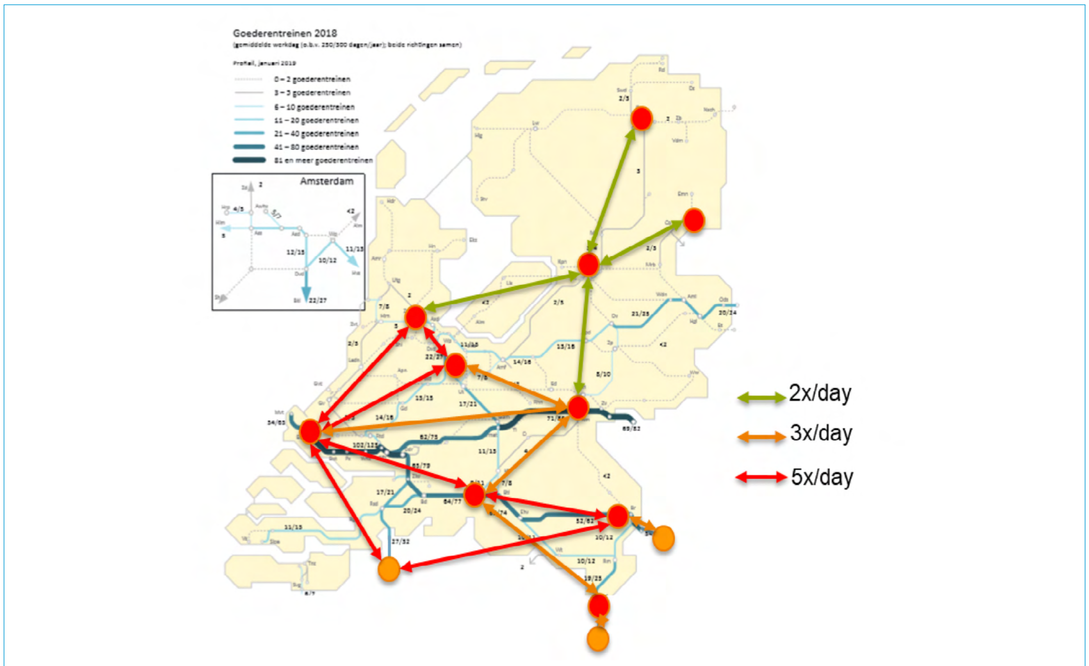
Network connection	Rotterdam	Amsterdam	Utrecht	Arnhem	Venlo	Duisburg	Tilburg	Antwerpen	Zwolle	Coevorden	Born	Luik	Groningen
Rotterdam		1,084,657	902,246	413,727	497,172	271,669	488,304	724,131	137,185	66,785	326,318	51,731	73,052
Amsterdam	670,229		554,355	159,540	106,061	22,577	164,513	202,804	118,285		70,765	44,601	18,445
Utrecht	720,338	653,640		702		17,623		144,055			959	17,798	
Arnhem	392,083	260,392	11,451		2,033	9,947		128,046			31,218	1,341	
Venlo	430,805	95,976		4,041		128,062		44,947			4,621	17,554	
Duisburg	111,511	37,219	29,521	55,427	114,386		15,878	25,396	9,480	9,240	98,988		8,529
Tilburg	647,700	196,147		454		10,101		245,040			1,620	19,697	
Antwerpen	922,046	282,825	91,436	52,341	66,418	6,812	231,602		59,834	15,183	483,753	11,777	8,663
Zwolle	121,556	106,935				2,371		141,625				16,974	
Coevorden	65,729	20,840				27,651		2,487					
Born	250,978	92,361	714	4,419	8,916	75,319	4,359	106,079				40,040	
Luik	39,828	95,839	3,751	10,890	4,946	5,248	64,962	12,654	6,509	4,034	35,297		5,741
Groningen	77,757	49.798				10,695		36,745					

With these hubs and volumes, the following network characteristics apply:

- 17 Links;
- Average link length 75 km;
- In total 122 trips per day (61 per direction): 73,000 trips per year;
- 2,3 Million train kilometres per year;
- Total number of trainsets required: 24;
- 5 Trips per day per train set.

The next figure presents a rough outline of the proposed network with an indication of the maximum frequencies per link. This is based on an balance of bi-directional flows, where combinations in the core of the network are foreseen, e/g between Rotterdam and Amsterdam/Utrecht with ongoing service toward the east and north.

Figure 43
Proposed connections short freight train network



Impact of the concept

In order to determine the modal shift and the impact on CO_2 emission and costs, a number of assumptions on the performance have been made, which are described in the text box on the next page. The impact of a system with the links and hubs proposed, served with a frequency of 2 to 5 trains per day per direction can mount up to 7 million ton transported per year, shifting 5,5 million truck kilometres and saving 40.000 ton of CO_2 emission compared to diesel trucks. The costs per ton CO_2 shifted are roughly estimated to be 340 Euro. It must be noted that the estimated shift potential will remain a theoretical maximum as long as additional policies in the field of pricing are not implemented in the meantime. The additional costs of the rail service (transhipment, infrastructure and equipment) will be high, even if all external costs are being internalised by means of road pricing. The system should compete with existing road transport market niches, whereas cannibalisation of existing IWT and rail services must be avoided.

Transport performance:

- Train capacity 30 containers (10'), average load factor 60% (bidirectional): 20 containers (or 10 TEU) per train.
- Average load per 10'-container: 5 ton, average load per train: 100 ton, compared to 10 ton per truck.
- Total tonkm transported daily: 0.9 million.
- Pre- and end haulage = 20% of average link distance (15 km).
- With 244 trains per day and an average load of 10 TEU (20 10'-units) per the number of TEU transported is 2.440 per day.
- With 5 ton average load per unit (10 ton/TEU), the total amount transported per day mounts up to 24,000 ton, expressed in ton-kilometre 1.8 million tkm.
- Annually this is 7 million ton resp. 550 million tkm.

Environmental performance:

- CO_2 emission (WTW):
  - Road: 100 gr/tkm
  - Rail (electric): 10 gr/tkm
- By road (10 ton/trip) the total amount of CO_2 emission is 180 ton daily, rail is 18+36=54 ton.
- The CO_2 reduction compared to road transport will be 40,000 ton/year.
- Other external impacts: congestion, NO_x, PM_{10}, safety: PM.

Costs:

- Investment in terminals: 10-20 million per hub, depending on infrastructure availability: 150 million in total.
- Investment in rail equipment: 5 million per train set, with 24 required sets.
- Number of trainsets required: 24, total investment: 120 million.
- Total investment costs: 270 million euro, 13.5 million annualy.
- Total annual revenue (based on road transport price of 2 euro/km and 5.5 million km/year): 11 million euro.

6.2 Concept of long-distance trailer train network

Concept introduction

The share of road transport in distances between 300 and 1000 km is relatively large, particularly for time-critical transport flows such as fresh produce, flowers, dairy and express and parcel freight in groupage. Traditionally, rail had a substantial share in these medium and long distance international transport flows. However, road transport has been extremely competitive in terms of costs, flexibility and reliability. With the increased pressure on this mode due to the decarbonization and other sustainability goals, rail transport will need to (re)gain its market share. As logistics chains are configured to road transport, new rail concepts will only be successful if they can adapt to the needs of the road transport users. A rail system that can transport non-craneable trailers in a cost-effective way with a high frequency and reliability could seduce shippers and transport operators to shift to rail. The transport of non-craneable semi-trailers by rail is presently only successful in a few specific corridors in Europe, particularly those overcoming natural barriers such as the Alps and the Channel between France and England. An exemption is the use of the LorryRail system in France, where semi-trailers are transported on dedicated shuttle trains between the south (Perpignan) and north (Bettembour and Calais).

Other systems comparable to LorryRail have been developed and tested on a small scale, particularly Megaswing and Cargobeamer. These systems slightly differ from LorryRail in terms of loading and unloading methods and the need for specific terminal infrastructure. The big advantage of all these systems is that they enable all road users to shift to rail without additional investments in craneable trailers. Fast loading and unloading speed is a prerequisite, as is relatively high operating speed (100+ km/h) and medium to long train length (500-700 meter). With a capacity of 40 to 60 semi-trailers, these trains can run on shuttle services between European links. As the concept will need to compete with road transport, the distance between the hubs will be between 500 and 1800 km, enabling A/B and A/C connections. A minimum frequency of one train per day is also required. The figure below illustrates the systems as they are now operated or in development.

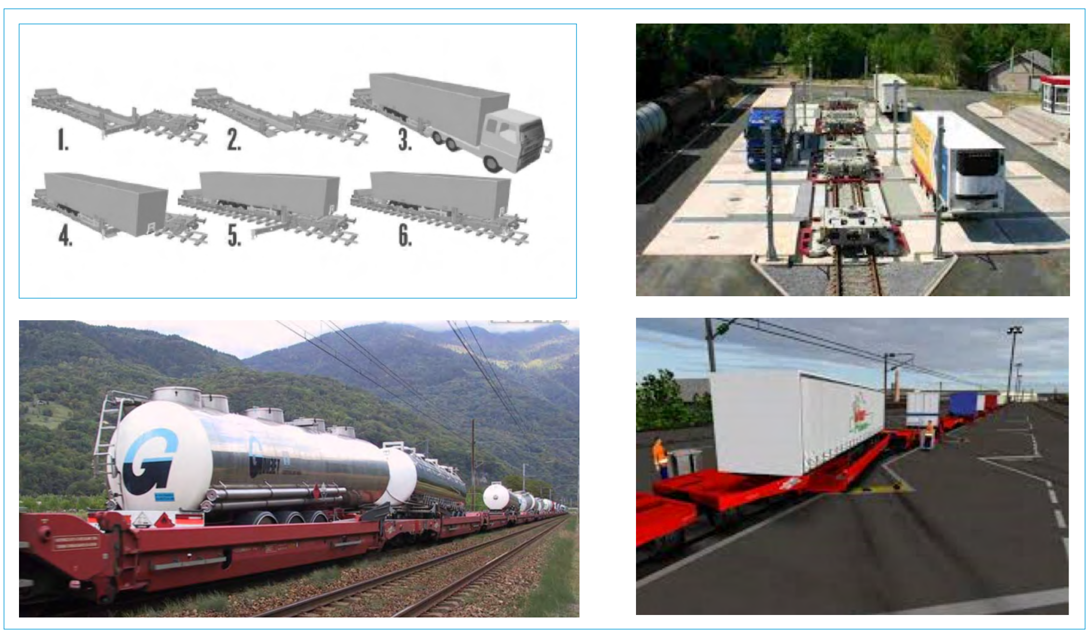


Figure 44
Innovative trailer-train systems (Megaswing, Modalohr)

Set-up of the concept

A selection of relevant hubs on such a network can be made based on the HCF flows of perishables and other time-critical goods. The following destinations and origins have been selected to elaborate the concept:

Figure 45
Proposed hubs long-distance trailer train network

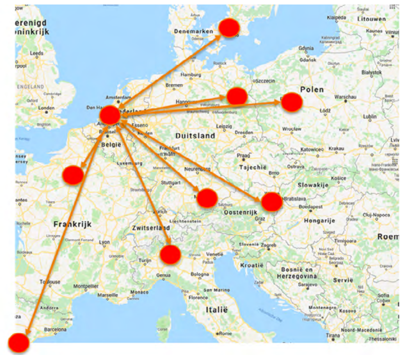
Netherlands:	Rotterdam-Rijnmond/Venlo
East:	D: Berlin, München
	CZ: Prague
	PL: Poznan
South-West:	F: Paris
	ES: Valencia-Alméria
South:	IT: Milano
South-East:	AU: Vienna
North:	SWE: Malmö

The next table presents the road transport flows (prognoses based on Basgoed data, 2030 in tonnes) between the hubs selected:

Table 9
Freight flows between selected hubs (road transport, Basgoed 2030)

Network connection	Flow to NL Tonnes 2030	Flow from NL Tonnes 2030
Berlin	142,348	488,225
München	122,202	203,910
Vienna	26,672	138,807
Poznan	210,971	362,195
Paris	67,026	204,371
Valencia/Almería	381,492	125,012
Milano	16,030	85,579
Malmö	218,295	390,249

For all the links selected, the flows are substantially enough to allow a daily service in both directions. With these hubs and volumes, the following network characteristics apply:



- Frequency (average) 5 trains per week;
- 16 (14+2 reserve) train sets required;
- Average load per train: 35 trailers;
- Average link lenght: 1,000 km;
- Number of trailers transported: 2,800/week;
- Number of tons: 33,600/week;
- Number of truck kms per year: 140 million;
- Number of train kms per year: 4 million;
- Number of tonkms per year: 1,680 million;
- System costs (total investment costs depending on system chosen, rough estimation):
  - 15 million euro per train set;
  - 25 million euro per terminal;
  - Total investment costs: 450 million euro, annualy (20 years).

Impact of the concept

The CO_2 reduction compared to (conventional) road transport will amount to 160 kton/year, whereas 140,000 trucks can be removed from the road annually. The ratio of the costs per ton for the CO_2 reduction is 140 euro/ton.

6.3 Summary of the impact and revenue

An overview of the impact of the two different innovative rail concepts described in the above is summarized in the table below. It must be noted that the concept elaboration and impact calculation is merely providing a rough first overview of the potential of these innovative rail systems. The potential success for implementation will be based on economic considerations first. In other words: the business case needs further elaboration. The cost element of the cost-benefit analysis is for rail freight transport generally already difficult, for new rail services on a conceptual level like described above it is only possible to look at the revenue side. In other words: what can be the income of the rail concept when the same costs of road transport are applied. Based on an average road price of 2 euro per TEU-km the revenue of the two systems is estimated, providing insight in the room to manoeuvre.

Table 10
Summary of costs and revenues rail concepts

Concept	Truck-km	Ton-km	Number of trips road	Number of trips rail	Investment costs/year	Revenue per year	CO_2 reduction	Ratio euro/ CO_2 ton
Short trains	5.5 million	550 million	730,000	73,000	13.5 million	11 million	40 kton	340
Trailer trains	140 million	1,680 million	140,000	4,000	22.5 million	280 million	160 kton	140

7

Integration and implementation strategies

7.1 Integration of modal developments

In order to realize the challenging goals for decarbonization, the previous Outlook on HCF (2018) already concluded that all transport modes need to be deployed and that a system approach is required. This new Outlook shows how innovative systems can be introduced to (re-)gain market share for the most sustainable transport modes and gives insight in the investments and infrastructure requirements to develop a sustainable hinterland transport system. Such a system can be based on the concept of ZE- (zero emission) corridors, with short range ZE-connections between the corridor and the destinations. The advantage of concentrating these investments in strategic high-volume-corridors is that their utilization factor will be relatively high, supporting the business case. This strategy can combine the advantages of the different transport modes and enables the HCF flows to decarbonize by in the meantime retaining the position of The Netherlands as gateway towards Europe.

Electric road transport on long distances (>500 km) will be challenging from a technical and economic point of view in the next decades, unless with an ERS system covering important EU corridors. Moreover, the relatively high energy consumption per tonkilometer and the negative impact on traffic safety, noise and spatial limitations of road transport are an important motivation to prevent a 'road transport only' solution in the future, even if full electrification is possible.
A combination of (battery-)electric road transport with intermodal transport systems, using rail and inland waterways for the main legs, is a promising route towards zero-emission HCF transport and provides the basis for the ZE-corridor concept.

The main advantage of the deployment of rail and inland navigation is the possibility to use electric road transport on short distances, where the economic[19] and technical deployment of battery-electric trucks is optimal. Other zero-emission solutions for road transport (like hydrogen and biofuels) are likely to be less promising, due to the expected shortage of supply, energy inefficiency and alternative applications with high demand in industry, maritime and air transport.

19 An optimal economic deployment of battery-electric trucks consist of a combination of high annual mileage with short/ medium sized trip lengths.

At present, the share of rail transport in hinterland and continental freight flows is limited when compared to road transport, even on distances exceeding 500 kilometre. Increase of the market share is possible when rail transport innovates in order to become more flexible and reliable, faster and less expensive. The development of a network for fast services for trailer trains can improve the share of rail substantially. When in the meantime long-distance road transport becomes more difficult due to the limitations of electrification and other restrictive and/or pricing measures, the potential for rail freight can increase significantly. However, the performance of rail transport in the past shows the enormous challenge for this transport mode to compete with road transport. For perishables and other time-critical goods, the present level of service in terms of speed, reliability and quality (lack of reefer-services for instance) is not sufficient.

For the shorter distances, a complete new rail system can be developed, but this will require more investments and the costs per ton CO_2 reduction will be higher than for long-distance concepts.

Growth in size and scale of maritime container transport in combination with the problems of congestion in the deep sea ports requires a system approach for inland shipping. The hub systems that are being developed and deployed can help the IWT sector to improve its market share, but this requires adaptation and introduction of new financial and organisational models from the market parties, with strong financial and flanking policies, including road pricing, restrictions and spatial measures (e/g geo-fencing, environmental zones), from the side of the government.

7.2 Implementation options and strategies

In order to accelerate the decarbonization in hinterland and continental freight transport, several strings need to be pulled by private and public parties. These strings are related to costs, policy development, infrastructure provision and the need for further research and development (R&D).

The main drivers in logistics will remain cost-based. The internalisation of external costs from CO_2 emissions is from an economic point of view the most effective approach for decarbonisation. Development of carbon taxation schemes, which need to be deployed on a European and/or global level, will effectively stimulate the development and use of transport modes and systems with the lowest emissions. Existing taxation instruments such as road pricing can be adapted in order to increase the costs of the most polluting transport modes, vehicles and vessels.

In addition, flanking policies can further enhance the use of the most energy efficient transport systems. Examples of supporting policies that are already being deployed in some European countries are:

- Vehicle weight exemptions for pre- and endhaulage;
- Exemptions of weekend driving bans for pre- and endhaulage.

More restrictive policy measures are envisaged by European, national and local authorities, such as:

- Discouragement of long-distance road transport;
- Environmental zoning, banning diesel-powered vehicles (and in the future possibly vessels).

In the field of infrastructure provision, public and private parties can support the development of the hubs and terminals, as well as missing links in the IWT and rail network and necessary load infrastructure for battery electric vehicles and vessels.

Finally, the support for R&D in the field of battery development, cooperation models and organisational issues can stimulate the transition towards zero-emission HCF transport.

Elaborating on the abovementioned elements, a number potential actions that support the decarbonisation of HCF per transport mode until 2030 can be distinguished, such as:

- development of battery-electric heavy trucks and loading systems (ERS, charging stations);
- development of financial (fiscal) system for speeding up the introduction of battery-electric trucks;
- implementation of heavy duty charging stations and locations.

Inland waterway transport:

- elaboration of new IWT hub system: proof of concept, pilots;
- stimulation hybrid barges and R&D on full electric vessels.

Rail transport:

- feasibility research on short train concepts;
- development of long-distance trailer train services, in combination with
- development of legislative actions to stimulate rail and discourage road transport on long distances.

8 Conclusions

It is hard to predict how global trade and transport will develop during and after the Corona crisis that started in the beginning of 2020. The impact of lock-downs and border closings has been immediate and huge, after reopening the economy it can be assumed that many trades will return to their 'business as usual' and freight volumes might recover, comparable to what happened after the financial crisis a decade ago. However, the crisis now also shows the risks of globalisation and 'dragging around' people and goods. Combined with a shift in economic and political power, growth scenarios for production and trade have to be redrawn completely. For instance, a return of production from the far-east to Europe is one of the potential developments that can apply for various segments. Supply chains will be redesigned accordingly.

The other main challenge for the logistics sector will remain the decarbonisation task as required by the Paris Climate Agreement. As both size and character of international flows are uncertain, it is also hard to predict whether the HCF sector in the Netherlands will be capable of meeting the challenge of achieving zero-emission by 2050. This Outlook is based on growth scenarios and trade developments before the current crises. However, the efficiency potential and options for improving sustainability on a system level as explored in this Outlook will hold their value and might even become more important in a changing global economy. As shown in this Outlook the challenge will be different for the different HCF segments. Whereas the freight volume of perishables, non-perishables and industrial goods are expected to grow much faster than of bulk and especially liquid bulk, the CO_2 reduction per volume needs to decline much more in these segments. The non-bulk segment relies more on the more carbon intensive road transport, but at the moment the decarbonisation strategies for road seem closer to implementation than for IWT.

Due to its geographic position, the Netherlands will remain to be a major gateway towards a densely populated hinterland of millions of people. The logistics chains will probably change due to the abovementioned developments, but the need for transport, distribution and value added services will remain. As will the negative impacts of road transport in terms of congestion, noise, safety and land use. Efficiency improvement within the road transport sector can lead towards a reverse modal shift, for instance when Super EcoCombis are competing with rail and barge transport.

The analysis carried out on the potential for logistics efficiency improvement raises questions about the logic and necessity of carrying similar cargo in two directions. More research on the details of these flows might provide new starting points for decreasing the carbon footprint of HCF transport. The same applies for the use of large 40' containers where smaller 20'containers can be used more efficiently. Further analysis behind the rationale of container selection can improve the insight in the potential. The imbalance in freight flows and the need for repositioning of containers are the main causes for the large amount of empty containers that are being transported. Optimisation on a system level - rather than on a company or supply chain level - can substantially improve the performance of road, rail and IWT transport of containers. Price incentives will be a major driver towards modal shift, as long as rail and IWT are capable of providing competitive quality and reliability.

Zero-emission road transport in HCF is challenging, due to the relatively long transport distances and heavy transport loads, particularly in bulk and container transport. Whereas in national and city distribution the battery-electric van and light truck are likely to be commonplace in the near future (before 2030), heavy trucks require high-capacity batteries and sufficient charging facilities. The supply of heavy battery-electric trucks is still insufficient, many OEMs are still in the development phase and investment costs are currently three to four times higher than conventional diesel trucks. The total costs of operation of battery-electric trucks are becoming more competitive in the next years. Financial incentives (subsidies, pricing and taxes) will help to accelerate the economic viability of electric trucks.

Zero emission heavy road transport on longer distances (>400 km) will be very challenging, but might be possible when the energy density of batteries will strongly improve or by introducing cross boarder electric road systems (ERS) . It is questionable, however, whether road transport on these long-distance relations is a sustainable business model for the long future. Other transport modes and systems are needed for a zero-emission HCF transport system and can serve as 'backbone' for the zero-emission corridors envisaged.

Inland navigation has the biggest challenge in obtaining a zero-emission fleet. Technological innovations are not mature, whereas the innovation speed is relatively low, due to the long technical lifespan of ships and limited economic power of its owners. Innovative hub concepts can speed-up the innovation of the sector, with better potential for zero-emission propulsion. These concepts are enabling the use of electric road transport for pre- and endhaulage, whereas in the meantime efficient transhipment in the deepsea terminals is enhanced.

Rail transport is by its nature the most energy-efficient transport mode with the lowest other external impacts in the field of air pollution, safety and congestion. The operational peculiarities, such as limited flexibility and difficult interaction with passenger rail transport, require an innovative approach in order to regain market share. For long-distance hinterland transport a substantial modal shift can be achieved when trailers are put in a European network of fast rail services. The decarbonization potential is substantial, as it also enables the use of electric trucks for pre- and endhaulage and decreases the need for expensive charging systems for road transport.

Large investments in infrastructure and vehicles for a transition to ZE emission HCF transport are needed, We envisage a HCF system with strategic high-volume ZE corridors, with (relatively short range) ZE-connections between the corridor and the destinations. Some corridors like pipelines and electrified railtracks are already nearly zero emission or will be so with renewable electricity. These corridors should be extended where possible and optimally used. New ZE-corridors based upon rail, road or inland waterway transport are needed. The advantage of concentrating these ZE investments in strategic high-volume-corridors is that their utilization factor will be relatively high, supporting the business case.

9

Bibliografie

Öko-Institut. (2020). *E-Fuels im Verkehrssektor*. Berlin: Öko-Institut.

ACI. (2019, 10 1). *https://aci.aero/.* Opgehaald van AC airoprts council international: https://aci.aero/about-aci/priorities/environment/acert/

ACM. (2019). *Post- en Pakkettenmonitor 2018.* Autoriteit consument & markt (ACM).

ADEME. (2016). *Base Carbone.* ADEME.

AEA, CE Delft, TNO. (2012). *EU Transport GHG: Routes to 2050.* UK: AEA.

BP. (2019). *BP Energy Outlook 2019; Insights from the Evolving transition scenario - European Union.* www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/energy-outlook/bp-energy-outlook-2019-region-insight-eu.pdf.

Breytner. (2019). *Zero Emission.* Opgeroepen op 10 10, 2019, van https://breytner.com/

CBS. (2019, 11 6). *Verkeersprestaties vrachtvoertuigen; kilometers, laadvermogen, grondgebied.* Retrieved from CBS Statline: https://opendata.cbs.nl/statline/#/CBS/nl/dataset/80392ned/table?ts=1575984318279

CBS. (2020, 2 5). *Bedrijfsvoertuigen; voertuigkenmerken, regio's, 1 januari.* Retrieved from CBS Statline: https://opendata.cbs.nl/statline/#/CBS/nl/dataset/71407ned/table?dl=8068

CE Delft. (2014). *STREAM personen.* Delft: CE Delft.

CE Delft. (2014). *STREAM personenvervoer 2014 versie 1.1.* Delft: CE Delft.

CE Delft. (2016). *STREAM Freight 2016.* Delft: CE Delft.

CE Delft. (2019). *Rapportage systeemstudie energie-infrastructuur Noord-Holland 2020-2050.* Delft: CE Delft.

Connekt. (2017). *Gebruikers en inzet van bestelauto's in Nederland.* Delft: Connekt.

Connekt et al. (2019). *Charging infrastructure for electric vehicles in city logistics.* Delft: Connekt et al.

Department for BEIS. (2017). *2017 GOVERNMENT GHG CONVERSION FACTORS FOR COMPANY REPORTING;* Methodology Paper for Emission Factors - Final Report. London: Department of Business Energy & Industrial Strategy.

Down to earth. (2019). *https://downtoearthmagazine.nl/elektrisch-vliegen-lowtech/.* Opgeroepen op oktober 3, 2019, van https://downtoearthmagazine.nl/elektrisch-vliegen-lowtech/

E. Keijzer, G. L.-E. (2015). Carbon footprint comparison of innovative techniques in the construction and maintenance of road infrastructure in The Netherlands. *Environmental Science & Policy, 218-225.*

Earl et al. (2018). *Analysis of long haul battery electric trucks in EU: Marketplace and technology, economic, environmental, and policy perspectives.* Graz: European Federation for Transport and Environment (T&E).

EC. (2020, 2 6). *Ten-T guidelines.* Retrieved from European Commission (EC): https://ec.europa.eu/transport/sites/transport/files/themes/infrastructure/ten-t-guidelines/doc/maps/be-lu-nl.pdf

ECF. (2018). *Trucking into a Greener Future (Summary Report).* Brussel: ECF.

ECN. (2010). *Raffinaderijen naar 2030.* ECN.

EEA. (2018, 5 7). *file EEA: END_DF4_DF8_Results_2012_170331.* Opgehaald van www.eea.europa.eu: www.eea.europa.eu/data-and-maps/data/data-on-noise-exposure-4

EERE. (2020, 2 7). *Comparison of Fuel Cell Technologies.* Opgehaald van Energy Efficiency & Renewable Energy (EERE): www.energy.gov/eere/fuelcells/comparison-fuel-cell-technologies

EIB. (2018). *EIB Group Carbon Footprint Report 2017; GHG emission resulting from EIB Group internal operations.* Luxembourg: EIB Group.

EMEP/EEA. (2013). *EMEP/EEA emission inventory guidebook 2013 1; 1.A.3.a, 1.A.5.b *Civil and military aviation; Guidebook 2013.* EMEP/EEA.

EMEP/EEA. (2017). EMEP/EEA air pollutant emission inventory guidebook 2016 - Last update June 2017. EMEP/EEA.

EMISIA SA. (2018). Copert, v5.2 2018; www.emisia.com/utilities/copert/.

ePure. (2016). *Overview of the biofuel policies and markets across the EU-28.* ePure.

Eurosai. (2019). *Joint report on air quality*. Eurosai.

EUROSAI. (2019). *Joint report on air quality.* EUROSAI Working group on Environmental Auditing.

Eurostat. (2018, 5 15). *Distribution of population by degree of urbanisation, dwelling type and income group - EU-SILC survey.* Opgehaald van Eurostat.

EZK. (2019). *Klimaatakkoord.* Den Haag: Economische Zaken en Klimaat (EZK).

Frischknecht, T. (2016). *Mobitool - Grundlagenbericht - Hintergrund, Methodik & emissionsfactoren.* Bern: Mobitool.

Green deal. (2019, mei 7). *www.greendeals.nl.* Opgehaald van www.greendeals.nl: www.greendeals.nl/nieuws/ontheffing-van-vrachtwagenrijbewijs-voor-elektrische-bestelautos

Greendealzes. (2019, 10 24). *Eerste 44 Tons elektrische vrachtwagen voor Boonstra Transport.* Opgehaald van Zero Emissie Stadslogistiek: www.greendealzes.nl/eerste-44-tons-elektrische-vrachtwagen-voor-boonstra-transport/

ICCT. (2019). *CO_2 emission standards for passenger cars and light-commercial vehicles in the european union.* ICCT.

IEA - ETSAP. (2011). *Technology Brief T14: Road Transport Infrastructure.* IEA-ETSAP.

IEA. (2017). *The Future of Trucks: Implications for Energy and the Environment.* Parijs: International Energy Agency.

IEA. (2019). *The future of Hydrogen.* IEA.

IFEU et al. (2018). *Ecological Transport Information Tool for Worldwide Transports Methodology and Data Update 2018.* Berne - Hannover - Heidelberg: IFEU, INFRAS, IVE.

IFEU -Institut, Öko-Institut. (2011). *Carbon Footprint and environmental impact of Railway Infrastructure.* Heidelberg/Berlin: IFEU.

IMO-UCL. (2015). *Further technical and operational measures for enhancing the energy efficiency of international shipping.* London: IMO.

INFRAS. (2007). *PM2.5-Emissionen verkehr : Teil Schienenverkehr.* INFRAS.

INFRAS. (2014). *Handbook Emission Factors for Road Transport.* Berne: INFRAS.

Inland links. (sd). Opgeroepen op 10 10, 2017, van www.inlandlinks.eu/nl/terminals/

IVL. (2001). *Life Cycle Assessment of Road: A Pilot Study for Inventory Analysis.* Gothenburg, Sweden: IVL.

IVL. (2016). *Port Infrastructures in a System Perspective.* Stockholm: IVL.

Jesús M. Barandica, G. F.-S. (2013). Applying life cycle thinking to reduce greenhouse gas emissions from road projects. *Journal of Cleaner Production,* 79-91.

Jumbo. (2018). *Jumbo breidt wagenpark uit met volledig elektrische vrachtwagen.* Opgeroepen op 10 10, 2019, van https://nieuws.jumbo.com/persbericht/jumbo-breidt-wagenpark-uit-met-volledig-elektrische-vrachtwagen/359/

Klimaatakkoord. (2019, juli 15). *Klimaatakkoord.* Opgehaald van www.klimaatakkoord.nl/: www.klimaatakkoord.nl/klimaatakkoord

Klimaatberaad. (2018). *Ontwerp van het Klimaatakkoord.* Den Haag: Klimaatberaad.

Martins, e. a. (2013). *'Grid Electrified Vehicles: Performance, Design and Environmental Impacts,* Chapter: Chapter 10: real-life comparison between diesel and electric car energy consumption. Minho, Portugal: University of Minho.

Nationaal Platform LNG. (2019, 10 24). *Waarom overstappen op LNG.* Retrieved from Nationaal Platform LNG: www.nationaallngplatform.nl/waarom-overstappen-lng-trucks/

Nissan. (2020, 2 5). *e-Bio Fuel-Cell.* Retrieved from Nissan Motor Corporation: www.nissan-global.com/EN/technology/overview/e_bio_fuel_cell.html

Öko-Institut. (2010). *Treibhausgasemissionen durch die Schieneninfrastruktur und Schienenfahrzeuge in Deutschland.* Berlin: Öko-Institut.

Öko-Institut. (2020). *StratON Bewertung und Einführungsstrategien für oberleitungsgebundene schwere Nutzfahrzeuge*. Berlin: Öko-Institut.

PBL. (2019). *Klimaat en Energieverkenning 2019.* Den Haag: PBL.

PostNL. (2019). *Annual report 2018: Driving transition.* PostNL.

Radiocommunications Agency Netherlands. (sd). *AIS: volgsysteem voor de scheepvaart*. Opgeroepen op 10 10, 2017, van www.agentschaptelecom.nl/onderwerpen/scheepvaart/maritieme-radiozendapparatuur/ais-volgsysteem-voor-de-scheepvaart

RH-DHV. (2019). *Gevolgen grote transities en wereldhandel voor de binnenvaart 2020-2040.* Royal Haskoning DHV.

SER. (2014). *Deelrapport Brandstofvisie Duurzame Luchtvaart; Reductie van emissies en kosten door daadwerkelijke groene groei.* SER.

Siemens. (2019, 10 23). *eHighway.* Opgehaald van Siemens: https://new.siemens.com/global/en/products/mobility/road-solutions/electromobility/ehighway.html

Sturgus Carbon Profiling LLP. (2013). A proposal to identify the benefits from networked solution to meeting London airport capacity shortage. Sturgus Carbon Profiling LLP.

T&E. (2019). *EU target to cut truck CO_2 and boost zero-emission truck sales must only be the start.* $E.

TLN. (2019, 1 11). *nieuws.* Opgehaald van Vrijstellingsregeling C-rijbewijs elektrische bestelauto's in mei van start: www.tln.nl/actueel/nieuws/Paginas/vrijstellingsregeling-crijbewijs-elektrische-bestelautos-mei-van-start.aspx

TNO. (2008). *Fijnstofemissies als gevolg van slijtage bij de spoorwegen*. TNO.

TNO. (2019). *Behoefte aan infrastructuur voor alternatieve energiedragers voor mobiliteit in Nederland.* Den Haag: TNO.

Topsector Logistiek. (2017). *Gebruikers en inzet van bestelauto's in Nederland.* Delft: Topsector Logistiek.

Treeze Ltd. (2016). *Mobitool Grundlagenbericht v2.0.* Bern: Treeze Ltd.

UIC. (2016). *Carbon Footprint of Railway Infrastructure.* UIC.

UIC. (2016). *Comparing existing methodologies on typcial corridors - Recommendation for Harmonized apporach.* Paris: UIC.

UIC. (2016). U*IC CO2 and Energy Database; Paris 2016*. Opgehaald van www.uic.org/Energy-and-CO2-emissions#Environment-Strategy-Reporting-System-ESRS

UIC. (2018). *Annual Energy consumption figures EU average (in Excel)*. UIC.

University of Bath. (2011). *Inventory of Carbon and Energy (ICE).* Bath: University of Bath.

Volvo. (2020, 2 5). *Volvo FH LNG.* Retrieved from Volvo Trucks Nederland: www.volvotrucks.nl/nl-nl/trucks/volvo-fh/volvo-fh-lng.html

World Bank. (2010). *Greenhouse Gas Emissions Mitigation in Road Construction and Rehabilitation; A Toolkit for Developing Countries.* World Bank.

Zeit online. (2019, Januari 26). Viele Milliarden für den Kohleausstieg. *Zeit online,* pp. www.zeit.de/wirtschaft/2019-01/kohlekommission-kohleausstieg-bundesregierung-plan-kraftwerke-braunkohle#der-ausstiegsplan.

Annex Chapter 2

Description of CBS Dataset

For this report CBS has created a tailored dataset on freight Statistics for the year 2014, 2016 and 2018. The dataset contains information on the amount of i) freight (tonnes), ii) transport volume (tkm) on Dutch territory and iii) transport volume in total from transport with an origin and/or destination in the Netherlands or with a passage through the Netherlands (transit). The data differentiates between containerized and non-containerized transport.
Origin and destination are known at NUTS 3 level for locations in the Netherlands. For locations abroad they are known on NUTS levels depending on the mode : Road NUTS3, IWT NUTS 2, Rail NUTS1. An origin is defined as the location where goods are loaded and the destination as the location of unloading. These location are not necessarily the origin and destination of the goods, but can also be part of a transport chain. For the locations it is indicated whether it is a sea or airport in the Netherlands. The latter information has been used to create a subset from the database for HCF transport.

CO_2 emissions per mode and freight type have been calculated from the tkm data by using emission factors per tkm of light medium and heavy goods from (CE Delft, 2016). The emission factors per mode are weighted averages of different vehicle types based on information on vehicle utilisation per freight type from CBS (road) and BIVAS (IWT). For rail, emission factor are based on 70% electric and 30% diesel traction. The resulting emission factors per NST 2007 class are depicted in Table 11.
The emission factors have been scaled-up to match the CO_2 emission on Dutch territory with the total CO_2 emission reported on Dutch territory by CBS (CBS Statline). This means that a correction factor has been applied of 1.9 for IWT, 1.3 for Road and 1.14 for Rail.
Especially the correction factor for IWT is high. At the moment the CO_2 calculation method for IWT at CBS is updated, which is expected to lead to lower CO_2 emissions. For this report, however, the CO_2 emission have been scaled to the current CBS total.

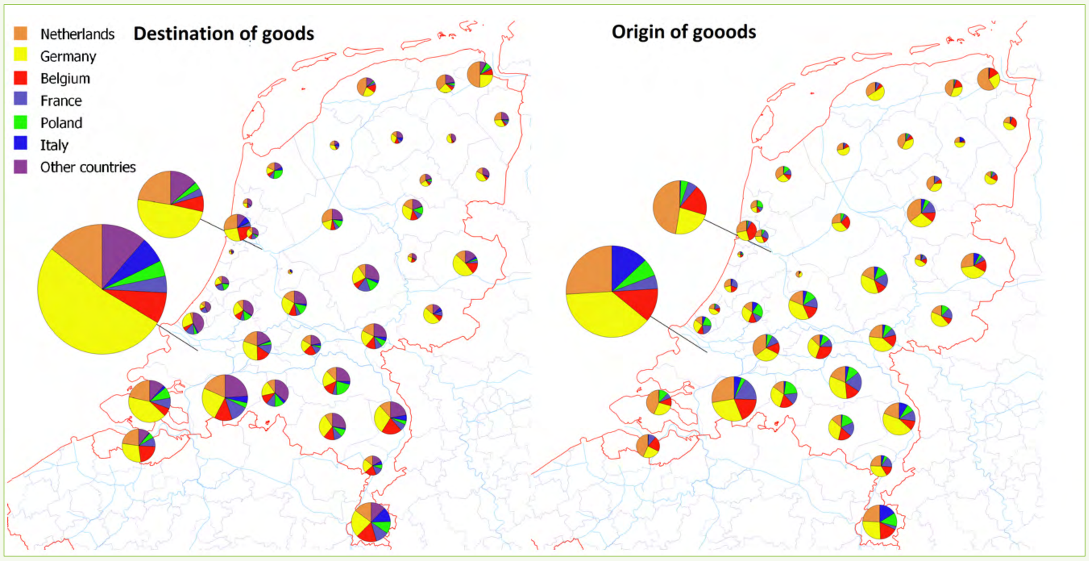
Table 11
CO_2 emission factors (g/tkm) applied on CBS dataset (without scaling factor)

NST2007		IWT		Road		Rail
	TTW	WTW	TTW	WTW	TTW	WTW
01.x Products of agriculture, hunting, and forestry; fish and other fishing products	25	32.6	71	91	7.13	20.03
02.1 Coal and lignite	17	21.7	88	112	4.03	11.48
02.2 Crude petroleum	19	24.3		112	4.03	11.48
02.3 Natural gas			88			
03.1 Iron ores, 03.2 Non ferrous metal ores (except uranium and thorium ores), 03.4 Salt 03.6 Uranium and thorium ores	13	17.1	89	114	4.03	11.48
03.3 Chemical and (natural) fertilizer minerals	25	32.4	89	114	4.03	11.48
03.5 Stone, sand, gravel, clay, peat and other mining and quarrying products n.e.c.	22	28.8	89	114	4.03	11.48
04.x Food products, beverages and tobacco	26	33.2	68	87	7.13	20.03
05.x Textiles and textile products; leather and leather products	17	22.4	83	106	7.13	20.03
06.x Wood and products of wood and cork (except furniture); articles of straw and plaiting materials; pulp, paper and paper products; printed matter and recorded media	17	22.4	73	94	7.13	20.03
07.1 Coke oven products; briquettes, ovoids and similar solid fuels	17	21.7	71	91	4.03	11.48
07.2 Liquid refined petroleum products 07.3 Gaseous, liquefied or compressed petroleum products 07.4 Solid or waxy refined petroleum products	19	24.3	71	91	4.03	11.48
08.1 Basic mineral chemical products	22	28.8	69	88	7.13	20.03
08.3 Nitrogen compounds and fertilizers (except natural fertilizers)	25	32.4	69	88	7.13	20.03
08.2, 8.4-7 Other Chemicals, chemical products, and man-made fibers; rubber and plastic products; nuclear fuel	19	24.4	69	88	7.13	20.03
09.1 Glass and glass products, ceramic and porcelain products	17	22.4	78	99	7.13	20.03
09.2 Cement, lime and plaster	22	28.8	78	99	7.13	20.03
09.3 Other construction materials, manufactures	22	28.8	78	99	7.13	20.03
10.1 Basic iron and steel and ferro-alloys and products of the first processing of iron and steel (except tubes)	13	17.1	72	92	4.03	11.48
10.2 Non ferrous metals and products thereof	13	17.1	72	92	4.03	11.48
10.3 Tubes, pipes, hollow profiles and related fittings	22	28.8	72	92	4.03	11.48
10.4 Structural metal products	17	22.4	72	92	4.03	11.48
10.5 Boilers, hardware, weapons and other fabricated metal products	17	22.4	72	92	4.03	11.48
11.x Machinery and equipment n.e.c.	17	22.4	80	103	7.13	20.03
12.x Transport equipment	17	22.4	110	141	7.13	20.03
13.x Furniture; other manufactured goods n.e.c.	17	22.4	95	122	7.13	20.03
14.x Secondary raw materials; municipal wastes and other wastes	17	22.4	90	116	7.13	20.03

NST2007		IWT		Road		Rail
	TTW	WTW	TTW	WTW	TTW	WTW
15.x Mail, Parcels	17	22.4	69	88	7.13	20.03
16.x Containers and swap bodies in service, empty; Pallets and other packaging in service, empty	108	138.3	354	453	36	100
17.x Goods moved in the course of household and office removals; baggage and articles accompanying travellers; motor vehicles being moved for repair; other non-market goods n.e.c.	17	22.4	136	174	7.13	20.03
18.0 Grouped goods	17	22.4	71	91	7.13	20.03
19 Unidentifiable goods: goods which for any reason cannot be identified and therefore cannot be assigned to groups 01-16.	17	22.4	66	84	7.13	20.03
19.1 Unidentifiable goods in containers or swap bodies	22	27.7	66	84	7.13	20.03
19.2 Other unidentifiable goods	17	21.7	66	84	7.13	20.03
20.0 Other goods n.e.c.	17	22.4	74	95	7.13	20.03

Annex Section 2.1

Figure 45
Destination of goods loaded in Dutch regions and origins of goods unloaded in Dutch regions on basis of tonne-kilometre



Annex Section 4.3

Truck models		
RT	=	Rigid Truck
TR	=	Tractor-trailer
BEV	=	Battery Electric Truck
ICEV	=	Internal Combustion Engine Vehicle
FCEV	=	Fuel Cell Electric Vehicle
RE	=	Range Extender

Table 12
Electric trucks

Make	Model	Type	Driveline	Fuel	GVW (ton)	Battery (kWh)	Range (km)	Fast charging
EMOSS	EMS10, 12, 16 & 18	RT	BEV	-	10 - 18	60 - 240	50 - 250	Yes
EMOSS	EMS 1824	TR	BEV	-	18	240	250	Yes
EMOSS	Ever (chassis-cabine)	RT	BEV + RE	CNG/LPG	≥ 12	120	≥ 350	Yes
EMOSS	Ever (trekker-trailer)	TR	BEV + RE	CNG/LPG	≤ 50	120	≥ 350	Yes
DAF & VDL	CF Electric	TR	BEV	-	37	170	100	Yes
DAF	LF Electric	RT	BEV	-	19	222	220	Yes
DAF	CF Hybrid	TR	BEV	EV/D	37	85	30-50	Yes
Ginaf	eCity	RT	BEV	-	16-50	130-250	150-300	-
Volvo	FL Electric	RT	BEV	-	16	100-300	Tot 300	Yes
Volvo	FE Electric	TR	BEV	-	27	100-300	Tot 200	Yes
Tesla	Semi	TR	BEV	-	40	-	800	Yes
Daimler	eCascadia	TR	BEV	-	-	550	400	Yes
Daimler	Freightliner eM2 106	RT	BEV	-	-	325	370	Yes
MAN	eTruck	RT	BEV	-	18 - 26	-	200	-
MAN	eTruck	TR	BEV	-	18 - 26	-	200	-
Boonstra transport	Ginaf truck	TR	BEV (retrofit)	-	44	173	130	Yes
Etrucks	Retrofit trucks	RT/TR	BEV (retrofit)	-	-	-	-	-

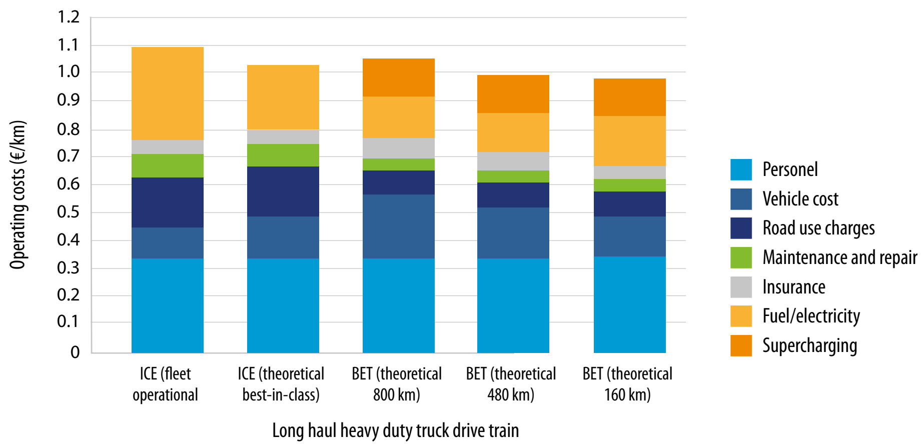
Table 13
Fuel cell trucks

Make	Model	Type	Driveline	Fuel	GVW (ton)	Battery (kWh)	Range (km)	Fast charging
Hyundai	FCET	TR	FCEV	-	34	-	400	-
Toyota	Beta	TR	FCEV	-	40	-	480	-
Nikola	Two (US version)	TR	FCEV	-	40	250	800-1200	Yes
Nikola	Tre (EU version)	TR	FCEV	-	40	250	500-1200	Yes

Table 14
CNG and LNG trucks

Make	Model	Type	Driveline	Fuel	GVW (ton)	Battery (kWh)	Range (km)	Fast charging
Volvo	FE CNG	RT	ICEV	CNG	10 - 17	-	250-400	-
Volvo	FH/FM series	TR	ICEV	LNG	60	-	1000	-
Scania	P/G 280	RT	ICEV	CNG	40	-	425	-
Scania	P/G 280	RT	ICEV	LNG	40	-	1100	-
Scania	P/G 340	RT	ICEV	CNG	50	-	425	-
Scania	P/G 340	RT	ICEV	LNG	50	-	1100	-
Scania	G/R 410	TR	ICEV	LNG	40	-	1600	-
IVECO	Eurocargo	RT	ICEV	CNG	12 - 16	-	250	-
IVECO	Stralis	TR	ICEV	CNG	≤ 50	-	570	-
IVECO	Stralis	TR	ICEV	LNG	≤ 50	-	1500	-
Mercedes	Econic	RT	ICEV	CNG	18	-	-	-
Renault	D-Wide	RT	ICEV	CNG	12 - 18	-	400	-

Figure 46
Total cost of operating (TCO) of BET's in 2020 in the EU, over a period of 5 years (Earl et al., 2018)



Connekt/Topsector Logistiek
Ezelsveldlaan 59
2611 RV Delft
+31 15 251 65 65
info@connekt.nl
www.connekt.nl

Topsector Logistiek