

Preliminary assessment of e-truck operational and economic viability

Drayage operations from and to the Port of Rotterdam

September 2024



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Suggested citation: Smart Freight Centre. Preliminary assessment of e-truck operational and economic viability: Drayage operations from and to the Port of Rotterdam. 2024.

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Acknowledgements

This report was written by Tharsis Teoh.

About Smart Freight Centre

Smart Freight Centre is an international non-profit organization focused on reducing greenhouse gas emissions from freight transportation. Smart Freight Centre's vision is an efficient and zero emission global logistics sector. Smart Freight Centre's mission is to collaborate with the organization's global partners to quantify impacts, identify solutions, and propagate logistics decarbonization strategies. Smart Freight Centre's goal is to guide the global logistics industry in tracking and reducing the industry's greenhouse gas emissions by one billion tonnes by 2030 and to reach zero emissions by 2050 or earlier, consistent with a 1.5°C future.

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Electrification of Drayage Operations at the Port of Rotterdam

Electrification of the operations at the port of Rotterdam represents a critical step towards enhancing sustainability in one of Europe's largest and most pivotal ports. With its substantial truck drayage operations the port stands as an optimal candidate for electrification. The back-to-base nature and short daily distances of the truck movements are ideally suited to the capabilities of current HD electric vehicle technology. The Dutch government's robust support for sustainable transport, including incentives for electric truck deployment, aligns seamlessly with Port of Rotterdam's commitment to reducing air pollution and advancing its sustainability agenda.

The Smart Freight Centre is working with Port of Rotterdam and Maersk to bring together shippers who want to electrify their truck drayage operations. The goal is to create a zero-emission freight hub that connects to other major hubs in Europe using zero-emission corridors. The large amount of cargo moving through Rotterdam can help jumpstart the needed investments in electric trucks and charging infrastructure.

The initiative in Rotterdam is a good start for truck electrification for several reasons. New European rules on truck CO₂ emissions will require 30-45% of new truck sales to be zero-emission by 2030, with strong government support for electric vehicles and charging. Also, studies show electric trucks will be cheaper to own and operate in the Netherlands even before 2030¹. Finally, shippers in the area are very interested in electrification to make their supply chains greener and meet their emission reduction goals.

This report presents context to understand the necessity of conducting this port drayage project.

- Description of the port and road freight activity serving the port area
- Background information on EV and charging services availability
- A preliminary assessment of the total cost of ownership for EV operators and the emissions reduction potential

Port and Road Freight Activity

Rotterdam is the largest port in Europe with total cargo throughput of approximately 438.8 million tonnes in 2023 generating €30.6 billion, 3.2% of the Dutch GDP². 72% of all containers whose first destination is Netherlands arrive in Rotterdam and are later transported to hinterland. The most important types of containerized commodities are presented in Figure 1. 55% of the hinterland transport is transported by trucks³, which results in about 6.8 million TEUs transported annually by road, and about 10,000 total truck movements to and from the port per day.

Top Commodities Shipped by Containers in 2023

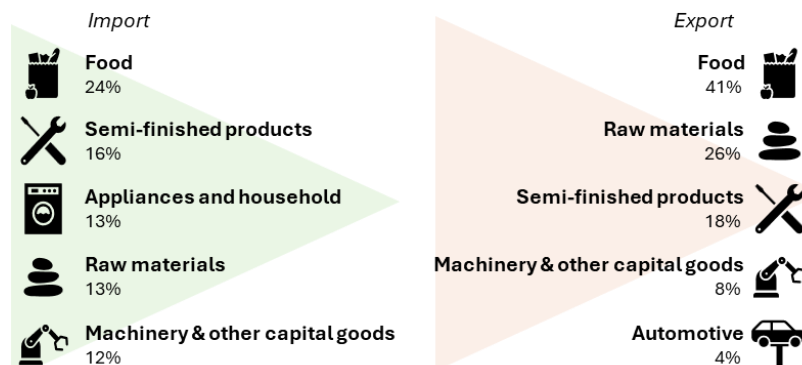


Figure 1 Commodities shipped by containers via the port of Rotterdam (Image source: Own graphic, based on private correspondence with Port of Rotterdam)

¹ ICCT (2023): A total cost of ownership comparison of truck decarbonization pathways in Europe.

² Port of Rotterdam. (2023) *Annual Report 2023: Highlights*. Available at:

https://reporting.portofrotterdam.com/FbContent.ashx/pub_1018/downloads/v240305102746/PoR_AR_2023_Annual_Report_Highlights.pdf

³ Port of Rotterdam (2024) Private communication

The port of Rotterdam and the A15 motorway leading to the port are part of the core TEN-T network, namely North-Sea-Rhein-Mediterranean corridor. Stretching across eight European countries—Ireland, the Netherlands, Belgium, Luxembourg, France, Germany, Switzerland, and Italy—it facilitates the movement of people and goods between major economic hubs and ports.

The port area hosts 14 container terminals and 20 container depots and is served by the N15 and A15 motorways. Figure 2 shows the layout of the port of Rotterdam.

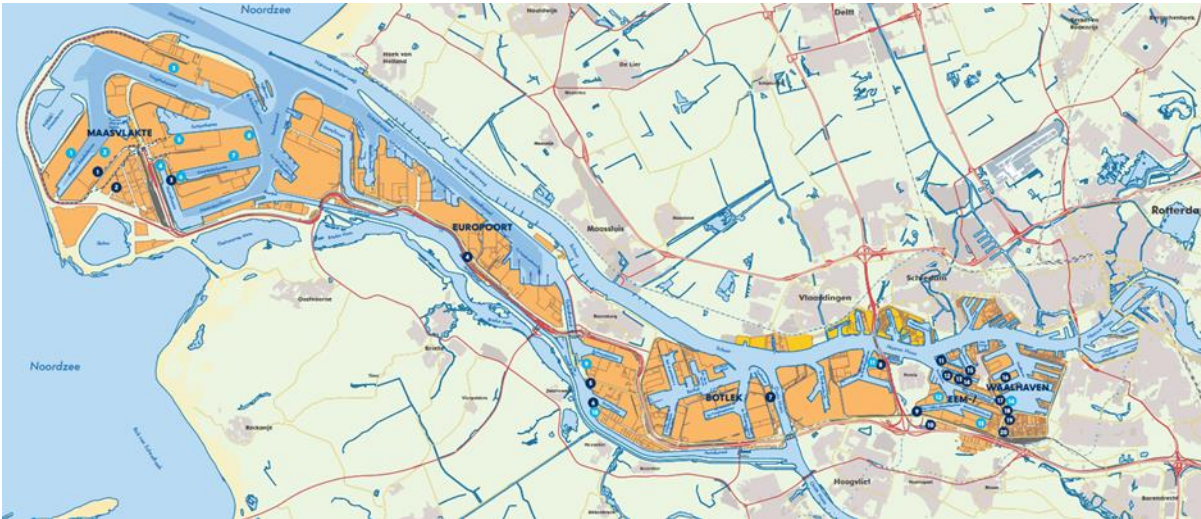


Figure 2 Port of Rotterdam layout (Source: Port of Rotterdam⁴)

Distance and flow analysis

The share of the truck trips carried out from or to the port of Rotterdam is presented in Figure 3. As the figure shows, approximately 74% of the total trips (to and from) are shorter than 250 km, i.e. within the typical range of current BEVs on the market. Drayage operations are typically conducted within 60 km of the port. 18% of the total trips fall under this distance band.

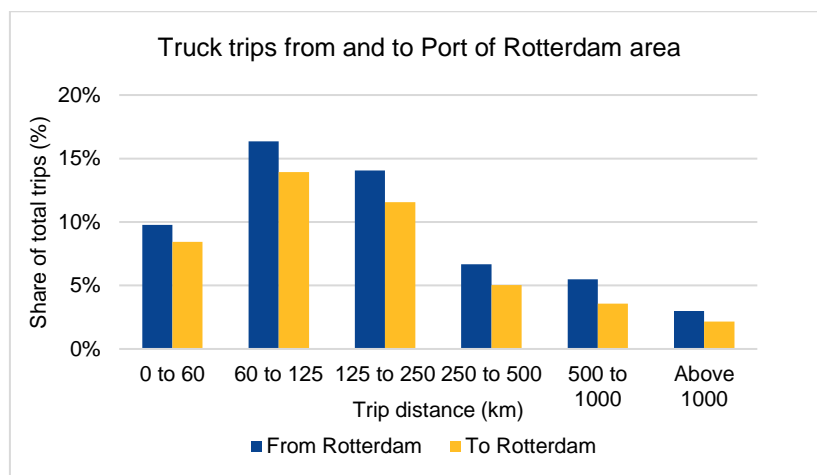


Figure 3 Modelled truck traffic from and to the port of Rotterdam area (Source: Smart Freight Centre)

In estimating the number of trucks that serve each trip distance band, we have taken the following assumptions.

- The loading factor per truck is 1.6 TEUs
- The assumptions on the number of round trips are:

⁴ Port of Rotterdam (2024) "Container Terminal and Depots in the Rotterdam Port Area". <https://www.portofrotterdam.com/sites/default/files/2021-06/container-terminals-and-depots-in-the-rotterdam-port-area.pdf>

- 3 round trips by trucks operating in the 0 to 60 trip distance band.
- 2 round trips by trucks operating in the 60 to 125 trip distance band.
- 1 round trip by trucks operating in the 125 and above trip distance bands.

These assumptions provide us with a conservative number of trucks that serve the whole port of Rotterdam area and are aligned with high-level estimates 10,000 trucks movements per day and 6 million containers per year provided in correspondence with Port of Rotterdam.

The estimate of the number of trucks serving the trip distance bands are presented in Figure 4. We estimate that 623 trucks serve the drayage distance band of up to 60 km. This represents an 8% share of the trucks that visit the port of Rotterdam area and approximately 1 million containers moved per year.

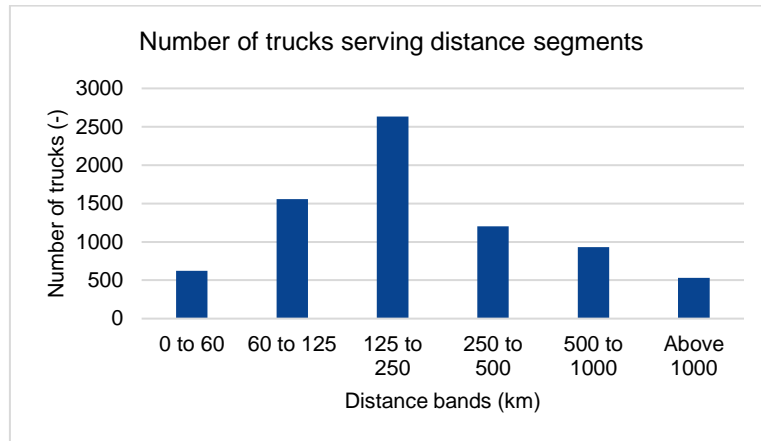


Figure 4 Number of trucks serving each distance band (Source: Smart Freight Centre)

In summary, by focusing on drayage operations alone (i.e. drayage distances up to 60 km), we can expect to put 623 eTrucks on the road and reduce the emissions of shippers associated with 1 million containers.

Types of EVs and Charging Services

This section presents general information about the electric truck market in the Netherlands and public charging infrastructure serving the port of Rotterdam area.

Electric truck market

The number of medium and heavy duty BE trucks on the road has been steadily increasing, leading to 951 trucks on the road in the first half of 2024. On average doubling annually since 2022. In 2023, it had a market share of 7% of newly registered trucks⁵ (EAFO).

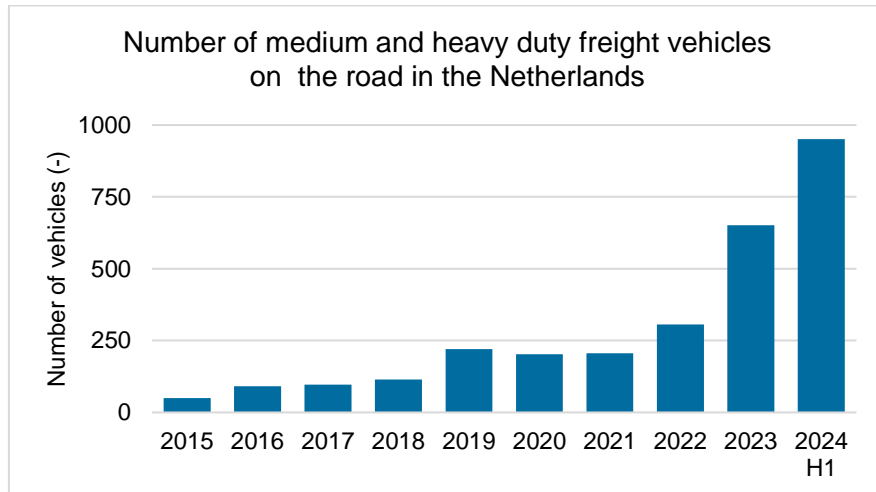


Figure 5 Number of medium and heavy duty freight vehicles in the Netherlands (Source: Smart Freight Centre, based on data from the European Alternative Fuel Observatory)

There are 36 heavy duty battery electric truck models⁶. The battery capacity and range are presented in Figure 6. Most have a battery capacity between 200 to 625 kWh (typical SOC window of 80%) with a range between 250 to 450 km, based on an average energy consumption rate.

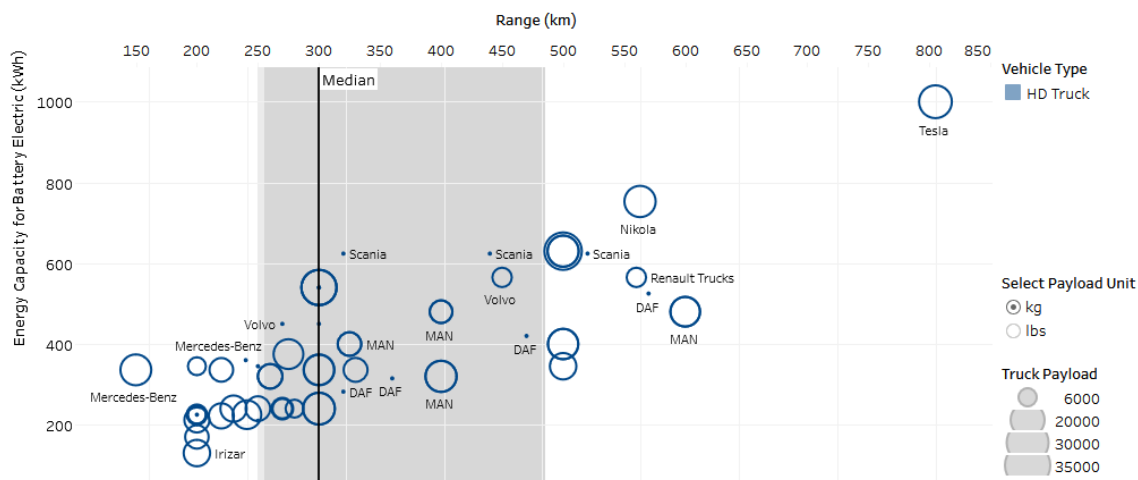


Figure 6 Heavy duty battery electric truck models battery capacity and range (Source: Zero-Emission Technology Inventory)

⁵ European Alternative Fuels Observatory (2024) "Netherlands: Vehicles and fleet". <https://alternative-fuels-observatory.ec.europa.eu/transport-mode/road/netherlands/vehicles-and-fleet>

⁶ CALSTART (2024): Drive to Zero's Zero-Emission Technology Inventory Data Explorer. Version 1.5. Available online at: <https://globaldrivetozero.org/zeti-data-explorer/>

Currently, only one station in the Waalhaven area off the A15 is publicly accessible for drayage operations. The Truckparking Rotterdam Exploitatie opened its first charging station at the Bodaanweg truck park in Waalhaven. This station includes five charging terminals with capacities of 360kW and 180kW, allowing a total of 8 e-trucks to charge simultaneously⁹.



Figure 9 Charging station at Waalhaven operated by Truckparking Rotterdam Exploitatie

Distribution network congestion in the Netherlands is beginning to have an impact on the energy transition. In the port of Rotterdam area, the situation is challenging (see Figure 10), which would mean that waiting times for getting a connection can be long. The upgrade of the grid will be completed between 2027 and 2029. The Dutch government has long recognized the challenge and is supporting the upgrade efforts by the grid operator. The Nationale Agenda Laadinfrastructuur (Dutch for National Charging Infrastructure Agenda) has published guidance for logistics operators and those operating charging stations for the logistics sector to provide for charging demand despite the grid constraints, such as shared charging, smart charging, and on-site energy storage. Fundamentally, this calls for collaboration between actors in the region to coordinate, plan, deploy and operate, charging infrastructure in the area.

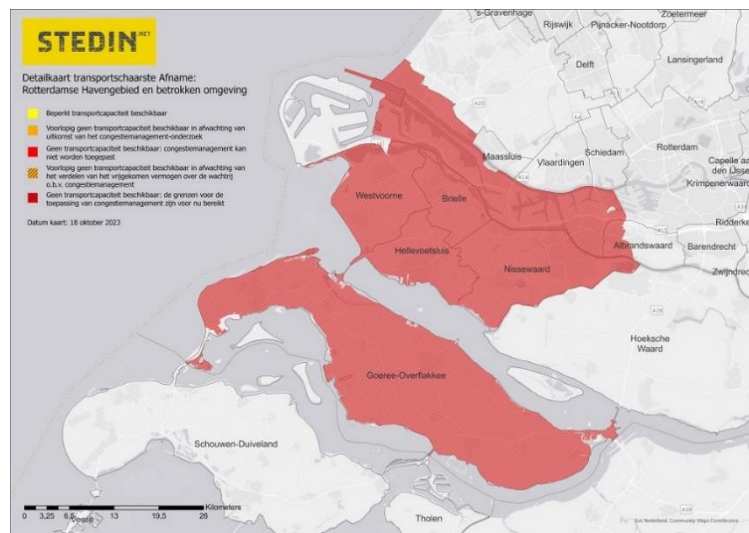


Figure 10 Electricity transport capacity in and surrounding the port of Rotterdam (Source: Stedin¹⁰)

⁹ Port of Rotterdam (2024) *Charging station for electric trucks*. Available at: <https://www.portofrotterdam.com/en/port-future/energy-transition/making-logistics-chains-more-sustainable/charging-station-for>

¹⁰ <https://www.stedin.net/zakelijk/energietransitie/beschikbare-netcapaciteit/congestie-en-congestiemanagement/rotterdams-havengebied>, Accessed 16.09.2024

Assessment of the total cost of ownership and the emissions reduction potential

A preliminary assessment of the total cost of ownership and emission reduction potential based on average and modeled data is provided below. During the course of deployment, operational data will be collected to create a better, more accurate understanding of the situation.

Modelling of e-truck operations

The operations for four drayage distances were modelled to illustrate how key parameters could vary depending on decisions of fleet managers. The number of round trips for each distance was maximized to meet the desired operating window of 9 hours. In each, we found that 3 round trips could be made, based on the average distances (i.e, distances to the middle of each NUTS3 zone).

The tractor-trailer used in the model has a battery size of 540 kWh with an average range of 250, assuming 1.7 kWh/km average energy consumption. The impact of drayage distances on the number of round trips, operating duration, daily and annual mileages, as well as charging needs are presented in the table.

Table 1 Modeled operational data

NUTS3 regions	Average drayage distance* (km)	Operating duration (h)	Daily mileage (km)	Annual mileage (km)	Charging needs		
					Depot charging point (kW)	Additional charging point (kW)	Additional charging (%)
Agglomeratie 's-Gravenhage (AG)	38	8.3	228	59,280	50	-	0%
Delft en Westland (DW)	42	8.7	252	65,520	150	-	0%
Zuidoost-Zuid-Holland (ZZH)	45	9.0	270	70,200	150	22	4%
Oost-Zuid-Holland (OZH)	51	9.6	306	79,560	150	150	15%

* Drayage distance represents the average distance between the NUTS3 zones of Groot-Rijnmond, where the port of Rotterdam is located, and another NUTS3 zone. It represents in the model the distance of a single leg. The distances are based on the synthetic transport flow data based on ETISplus database¹¹.

The operating assumptions are:

- Working window: 0900 to 1800 hours (approximate)
- Working days in a year: 260 days
- Loading time: 45 minutes
- Unloading time: 45 minutes
- Average speed: 60 km/h
- Maximum number of additional charging sessions in a day and duration: 1 session for 1 hour.

There are a few observations to be made:

- Operating duration can vary strongly depending on the drayage distances. In some cases, where drayage distances exceed the average significantly, the transport operator will be under time pressure. Hence, it is imperative that additional charging can be conducted in parallel with the operations and will not add to the time needed for the operations.
- Though the average drayage distances vary little across the NUTS 3 regions, there are big implications on the daily and annual mileage. In the Zuidoost-Zuid-Holland and Oost-Zuid-Holland operations, additional charging during operations is required, even if the average distances are merely 3 and 9 kilometers further than Delft en Westland.
- The minimal specifications for additional charging points are still low, and can be easily conducted on-site, whether during loading or during a short driver break. The charging power is calculated based on a 1 hour session but depending on the available high-powered charging points the charging session can be significantly reduced.

¹¹ Speth, Daniel; Sauter, Verena; Plötz, Patrick; Signer, Tim (2021), "Synthetic European road freight transport flow data based on ETISplus", Mendeley Data, V1, doi: 10.17632/py2zkrb65h.1

Total cost of ownership assessment

To understand the viability of drayage operations in Rotterdam, a total cost of ownership analysis was performed on the modelled scenarios above.

Table 2 Total cost of ownership comparison between diesel and electric truck operations (Source: Smart Freight Centre based on Panteia TCO-ZET-Vracht Model¹²)

NUTS 3 Region	Additional charging (%)	Estimated number of trucks operating between regions	TCO per km (€/km)	
			Diesel	Electric
AG	0%	81	€3.13	€3.24 (+4%)
DW	0%	131	€2.92	€3.14 (+7%)
ZZH	4%	246	€2.79	€3.07 (+10%)
OZH	15%	165	€2.58	€2.80 (+9%)
Total: 623			Average: €2.79	€3.02 (+10%)

The key cost assumptions are:

- Electric truck purchase price: €300,000; Diesel truck purchase price: €115,000;
- Depot charging costs: €0.20/kWh to €0.28/kWh; external charging depending on need: €0.30/kWh to €0.50/kWh; diesel fuel: €1.55/Litre
- No highway toll costs, or renewable energy credits, or purchase subsidies assumed.

A few observations can be made in the analysis:

- Higher truck utilization decreases the TCO differential, as the high investment cost is compensated by lower operational costs. It may also increase reliance on external charging, such as operations from and to ZZH and OZH.
- The reliance on external charging is the key reason for the percentage cost increase for the electric truck, as we have assumed that the additional charging services range from 30 to 50 cents per kWh.
- Another aspect is depot charging utilization, which spreads the purchase, installation, and operating costs of the depot charging system. This is a separate category compared to just the electricity cost. This explains the lower TCO differential between AG and DW.

Breakdown of TCO cost categories of scenario 45 km

Figure 11 shows the breakdown of the costs in the TCO analysis of the ZZH operation scenario with drayage distance of 45 km. In total, the costs increase by about 10 % with the use of the EV.

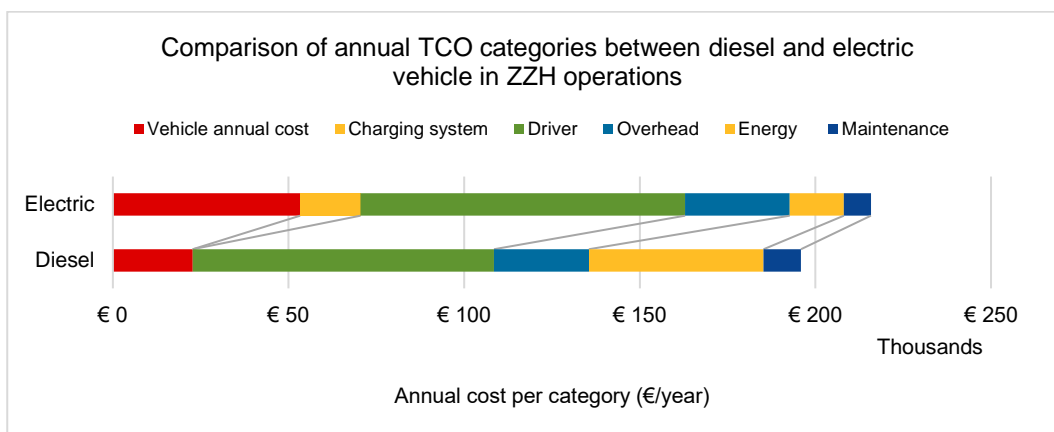


Figure 11 TCO breakdown for ZZH operations (Source: Smart Freight Centre)

The capital costs for the EV and charging system are about 3 times compared to the diesel vehicle. The EV reduces energy costs by 70%. Reliance on additional charging at 30 cents is only a small contribution of about

¹² Panteia's TCO-ZET-Vracht version 6.2 (published 1-3-2024) is an open-access excel-based TCO tool developed within the Dutch Topsector Logistics program. It builds upon Panteia's well-established NEA-Index road freight TCO annual reporting and intensive consultation within the Dutch eTruck ecosystem. Downloaded here: <https://topsectorlogistiek.nl/tco-vracht/>

4% of its charging needs. Maintenance costs are reduced by about 30% but are only a small share of the total costs anyway.

The biggest leverage is to reduce purchase prices through subsidies and reducing energy costs.

A few government initiatives that reduce the energy costs and make the TCO case for electric trucks very attractive are listed below, and a preliminary assessment of how the TCO differential will improve is presented in Figure 12.

- From 2026, a distance-based heavy goods vehicle charge (in Dutch *vrachtwagenheffing*) will incentivize zero-emission trucks and would reduce the TCO differential considerably, and help achieve TCO parity in the AG operations.
- Application for renewable energy credits (in Dutch *Hernieuwbare Brandstof Eenheden* or *HBEs*) will make each operation cheaper by a 1 to 6%, since the sales of the credits would exceed the charging costs.

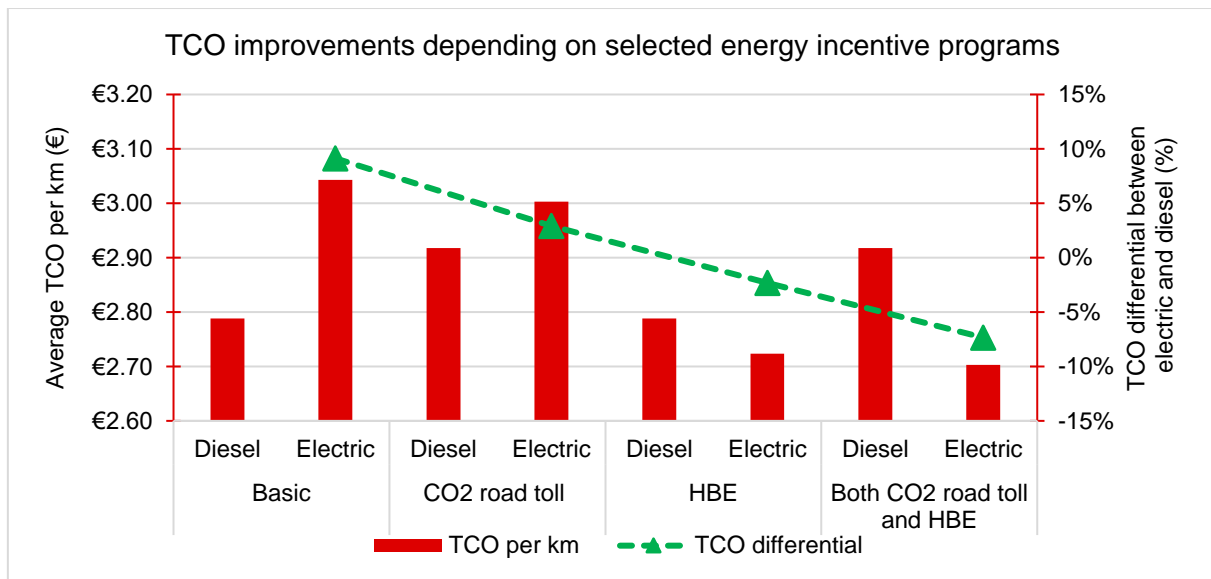


Figure 12 TCO improvements depending on selected energy incentive programs

GHG emissions comparison

Based on the scenario developed in the previous section, the emissions for drayage operations can be estimated. The four main energy and powertrain scenarios to consider are:

- B7 diesel in diesel trucks
- HVO¹³ in diesel trucks
- Grid electricity used in electric trucks
- Renewable electricity used in electric trucks

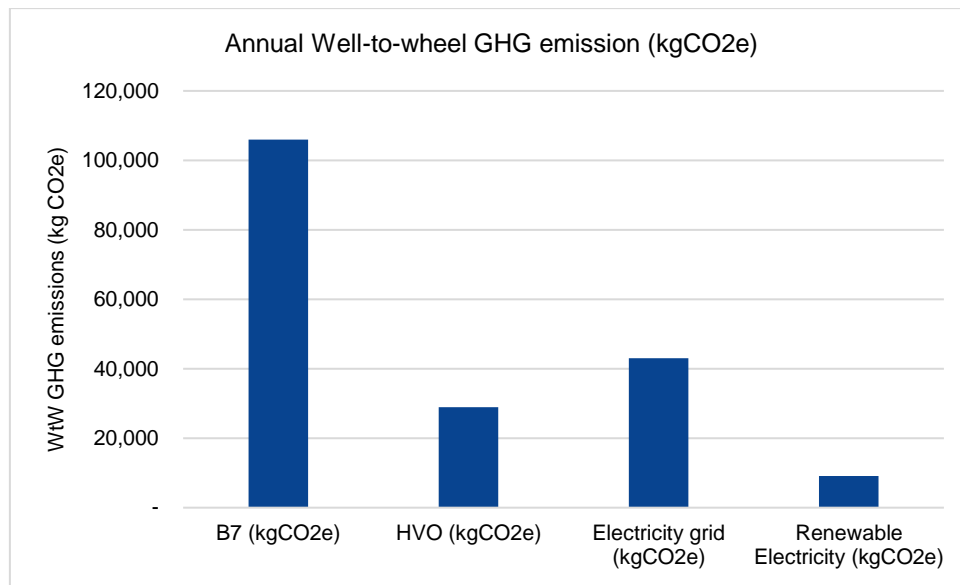


Figure 13 Annual well-to-wheel GHG emissions of an individual truck using different fuel and powertrains (Source: Smart Freight Centre)

The scenario where HVO is used, based on the emission factor from the GLEC Framework¹⁴, provides the emission reduction in the operations of up to 73%.

HVO is one of the most popular low-carbon fuel strategies in the Netherlands. While it is effective in reducing well-to-wheel GHG emissions, it will not provide sufficient scale for road freight decarbonization. It is often viewed as a good solution for long haul decarbonization, where electric trucks are not yet well suited for. On average, the cost of transport using HVO is more or less equal to that of using electric trucks.

The electric trucks provide an emission reduction of 59% using Dutch electricity grid emission factors and 91% for renewable electricity¹⁵. The provision of own renewable electricity using on-site solar and battery energy storage systems is an important strategy to reduce costs and emissions, and it also serves to mitigate the impacts on grid congestion.

In conclusion, this analysis highlights the high potential for reducing GHG emissions in drayage operations through the adoption of electric trucks, even without additional renewable electricity provision. This is significant as having sufficient availability of a low-carbon energy source will allow decarbonization in the operations to quickly scale up once the vehicles and charging infrastructure are in place.

¹³ HVO stands for hydrogenated vegetable oil, which is a drop-in diesel-like biofuel made from both oil crops and waste feedstock, such as used cooking oil.

¹⁴ The HVO/HEFA fuel emission factor is based on a representative fuel produced from 50% rapeseed and 50% used cooking oil feedstocks. Smart Freight Centre. 2023. "GLEC Framework v3.0."

¹⁵ The Dutch electricity grid emission factor is 0.369 kg CO₂e/kWh in 2023. For renewable electricity, a value of 0.078 kg CO₂e/kWh, which is the Switzerland's, is taken.