The use of battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) for retail distribution

Topsector Logistiek

Colophon

The use of battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) for retail distribution

Author
Districon
Simacan

With support of

Hema	Jeroen van Dorp
AS Watson	Gert Tempelman
Cornelissen	Mark van der Drift
Scania	Hans Binnendijk

Anonymous supermarket chain

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1 Introduction

As commissioned by Topsector Logistiek, Districon and Simacan conducted a study on the use of fully electric (BEV) and plug-in hybrid (PHEV) trucks for large retailers.

1.1 Background

Most major retailers supply their stores from a limited number of central distribution centres (DCs), both for the physical stores and for online orders picked up in stores (Click&Collect).
In the future, more and more all-electric and/or hybrid trucks will be used to make these deliveries. PHEV trucks can drive in ZE zones with no emissions, BEV trucks may be able to provide parts of the transportation.

The practical question is whether current distribution patterns for larger retailers, with national or international coverage from central DCs can be carried out by PHEV and BEV trucks. For PHEV trucks, the question is whether they can be used in the zero-emission (ZE) zones, and for BEV trucks, the question is whether their range will be sufficient to make these trips.

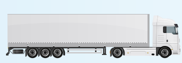
Given the retail density in the major cities (compactness), it is interesting to look beyond the supply of major cities. When supplying medium-sized cities and the hinterland, where stores are at greater distances from each other, the planning is more challenging: is the battery capacity sufficient or does smart routing allow interim charging that fits the planning.

1.2 Logistical principles

The practice of supplying retail has different aspects and assumptions, regardless of whether BEV or PHEV trucks carry out the supply:

- The national network of stores is supplied from one or a limited number of DCs.
- One or more stores are supplied in each trip, with a fully charged vehicle at the start.

  The vehicle types are:

Box truck	
Box truck with trailer	
Tractor-trailer	

- Food products often require refrigeration (conditioning).
- Sometimes the vehicle picks up cargo from a supplier on the way back, and transports this cargo back to the DC to avoid empty miles.

The calculations in the study were done for the 23 zones known at the time; they have since become 28. This increase is not expected to lead to different conclusions.

In addition to PHEV trucks, there are also trucks with hybrid (HEV) drivetrains on the market. Their battery capacity is usually less than PHEV trucks, and they have no plugs. HEV trucks are not included in this study.

Simacan has received trip data from a number of logistics service providers and/or in-house carriers who handle distribution for large retailers. Peak demand and average weekly volume were included to identify the fleet flexibility needed.

This sample based on realization data was used as a reference.

1.3 Expert group

Together with an expert group of carriers, shippers, and a component manufacturer (OEM), the scope and approach were determined.

The expert group identified the recharging of BEV trucks at stores as unrealistic and impractical: the additional grid capacity required for stores is very high and probably not achievable. Also, high-power charging facilities at stores are expensive to purchase and the chargers at the store will have low utilization rates. Nevertheless, this option was included
in the calculations.

On-the-go recharging at public charging facilities was considered a problem by experts, as an activity you do not want to depend on in practice:

- loading time means lost capacity and wage costs;
- it is uncertain whether the charging system is available at the desired time. The truck may have to wait for its turn.

All together, this makes planning the day unpredictable.

1.4 Consumption

There is relatively little publicly available information on the energy consumption of electric trucks in various configurations, conditions and train weights:

- tractor trailer;
- large box truck;
- large box truck with trailer.

The appendix shows the sources and the consumption figures given. Our conservative estimate of average consumption by type was based on that data.

	Energy consumption with average load (kWh per km)		
	Min.	Average	Max.
Tractor-trailer	1.1	1.79	2.8
Large box truck	1.25	1.43	1.8
Large box truck with trailer	1.13	1.85	2.85

For the calculations we used the averages.

If cooling or conditioning is required, the cooling unit will also require power. For BEV and PHEV trucks, the assumption is that the cooling unit is electrically powered by the truck battery. For the calculations, it was assumed that cooling requires an average of 6 kW. In the sensitivity analysis, a variant with 12 kW consumption was also calculated.

2 Scenario's

2.1 Sample trips

The sample of current trips for retail delivery includes 4 different cases.

	Sector	Distribution model	Number of sites in the Netherlands	Percentage of sites in future ZE zones
1	Non-food retailer	Central	+/- 540	8%
2	Non-food retailer	Central	+/- 1,050	8%
3	Transporter food & non-food	Decentralized	+/- 3,000	8%
4	Supermarket	Decentralized	+/- 690	6%

2.2 Scenario's

For the above 4 cases, 3 scenarios were examined:

1. The trips will be all-electric (BEV).
   - With or without option of intermediate recharging at the store.

2. Trips to one/different ZE area(s) with PHEV (electric within ZE zone).

3. Trips to one/different ZE area(s) and changing the tractor (change for BEV) at the edge of the town from where the trip within the ZE zone will be electric.
   - Only possible with tractor trailers (tractor change) or swap bodies.
   - Changing vehicles at a hub and transfering loads is no option.

SCENARIO 1 (CASE 4): BATTERY ELECTRIC VEHICLE (BEV)

Who
Supermarket

How
From 5 different DCs to 690 stores/supermarkets

Vehicle
Tractor-trailer

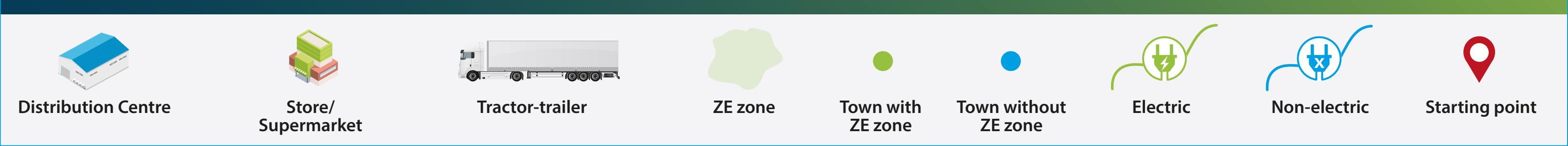
Distribution Model
Region/District

Max. distance
Fully electric driven distance on 1 day is between 150 and 300 km

TOWNS WITH ZE-ZONES IN THE NETHERLANDS*

1. Alphen a/d Rijn
2. Amersfoort
3. Amsterdam
4. Assen
5. Delft
6. Den Bosch
7. Den Haag
8. Deventer
9. Ede
10. Eindhoven
11. Enschede
12. Gouda
13. Groningen
14. Haarlem
15. Hoorn
16. Leiden
17. Maastricht
18. Nijmegen
19. Rotterdam
20. Tilburg
21. Utrecht
22. Zaanstad
23. Zwolle

** Increased after the study to 28 zones.*



SCENARIO 2 (CASE 2): PLUG-IN HYBRID ELECTRIC VEHICLE* (PHEV)

Who
Wholesale goods/non-food

How
From 1 DC to 1,050 stores in the Netherlands

Vehicle
Hybrid tractor-trailer and large box truck

Distribution Model
Regional/Central

Max. distance
Electric driven distance on 1 day is up to 500 km, in ZE zone 25 km electric

TOWNS WITH ZE-ZONES IN THE NETHERLANDS**

1. Alphen a/d Rijn
2. Amersfoort
3. Amsterdam
4. Assen
5. Delft
6. Den Bosch
7. Den Haag
8. Deventer
9. Ede
10. Eindhoven
11. Enschede
12. Gouda
13. Groningen
14. Haarlem
15. Hoorn
16. Leiden
17. Maastricht
18. Nijmegen
19. Rotterdam
20. Tilburg
21. Utrecht
22. Zaanstad
23. Zwolle

* *Plug-in Hybrid: rechargeable batteries (or some other means of energy storage) that can be fully recharged by connecting to an external energy source (e.g., a wall outlet).*
Hybrid: the battery is charged only when driving (or braking).

* * *Increased after the study to 28 zones.*

Distribution Centre | Store/ Supermarket | Tractor-trailer | Box truck | ZE-zone | Town with ZE zone | Town without ZE zone | Electric | Non-electric | Starting point

SCENARIO 3 (CASE 3): PLUG-IN HYBRID ELECTRIC VEHICLE* (PHEV)

Who
Transporter food-nonfood (Logistics Service Provider)

How
From 3 locations in the Netherlands to 3,000 DCs, hubs, stores

Vehicle
Tractor-trailer

Distribution Model
Region/District

Max. distance
Electric driven distance on 1 day is 200-500 km; from hub with BEV into the zone 50 km

TOWNS WITH ZE-ZONES IN THE NETHERLANDS*

1. Alphen a/d Rijn
2. Amersfoort
3. Amsterdam
4. Assen
5. Delft
6. Den Bosch
7. Den Haag
8. Deventer
9. Ede
10. Eindhoven
11. Enschede
12. Gouda
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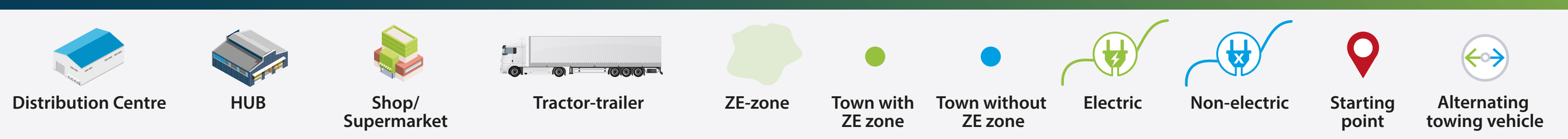
** Increased after the study to 28 zones.*



2.3 Assumptions

The following assumptions were made in the calculations:

- Only 75% of the specified maximum battery capacity can be used.
- Assuming existing battery sizes for PHEV (45/90 kWh).
- Assuming battery sizes now available for trucks (320/500 kWh).
- Truck days are used instead of trips; the total number of trips and kilometers traveled by the vehicle in a day.
- An electric refrigeration system requires 6kW.

2.4 Results

Trips and truck days:

- As expected, there is a big difference between several short trips from a decentralized DC and several long trips from one central DC.
- The peaks in demand (truck days are long and far) are very decisive. That demand is both seasonal (peak delivery) and location-specific (distance from DC). Retail has some peak weeks through the year, which gives a double effect on the required capacity:
  - these weeks are less schedulable, therefore there is a loss of capacity;
  - there is more demand for transportation, more trips, more cargo.

Changing tow vehicles at a hub, which can then be used to take the load into the ZE zone, is relatively expensive and operationally inconvenient for full retail deliveries. It requires a lot more personnel and equipment, and it also makes planning a lot more difficult. Transporting full loads straight into town is much more effective.

Current PHEV trucks can handle all truck days in the sample including peak times, running emission-free in ZE zones.

The current range of BEV trucks can perform some of the truck days. This depends on the structure of the truck days and is different for each case. It is mainly the peak times that require a lot of battery capacity. A fleet with a mix of PHEV and BEV trucks, with the BEV displacing the PHEV due to the expected increase in battery capacity, is operationally effective.

Average consumption

Battery size	Proportion of truck days that can currently be accomplished with all-electric trucks			
	Case 1	Case 2	Case 3*	Case 4**
≤ 350 kWh	43%	9%	46%	81%
≤ 500 kWh	59%	34%	67%	89%

Min. consumption

Battery size	Proportion of truck days that can currently be accomplished with all-electric trucks			
	Case 1	Case 2	Case 3*	Case 4**
≤ 350 kWh	67%	22%	75%	92%
≤ 500 kWh	86%	83%	94%	100%

* *Part truck days conditioned*
** *All truck days conditioned*

BEVs recharging at the store, even if it could be done, will provide fewer additional options than expected. It only makes sense if the recharging time/power is sufficiently high and it has to fit into a trip/truck day that would otherwise not be feasible*.

The impact of the power required by the cooling system is much lower than expected. The sensitivity analysis shows that even with a power demand of 12 kW for cooling, the impact is still limited.

Cooling consumption 6kW
Average consumption

Battery size	Proportion of truck days that can currently be run with all-electric trucks	
	Case 3	Case 4
≤ 350 kWh	46%	81%
≤ 500 kWh	67%	89%

Cooling consumption 12kW
Average consumption

Battery size	Proportion of truck days that can currently be run with all-electric trucks	
	Case 3	Case 4
≤ 350 kWh	45%	74%
≤ 500 kWh	66%	88%

* *Consequences for schedules and related fleet capacity (number of trucks) have not been investigated.*

Appendix

Consumption figures used

	Energy consumption with average load (kWh per km)		
	Min.	Average	Max.
Tractor-trailer	1.1	1.79	2.8
Large box truck	1.25	1.43	1.8
Large box truck + trailer	1.13	1.85	2.85

Results

Average use

Battery size	Proportion of truck days that can currently be accomplished with all-electric trucks			
	Case 1	Case 2	Case 3*	Case 4**
≤ 350 kWh	43%	9%	46%	81%
≤ 500 kWh	59%	34%	67%	89%

Min. use

Battery size	Proportion of truck days that can currently be accomplished with all-electric trucks			
	Case 1	Case 2	Case 3*	Case 4**
≤ 350 kWh	67%	22%	75%	92%
≤ 500 kWh	86%	83%	94%	100%

Max. use

Battery size	Proportion of truck days that can currently be accomplished with all-electric trucks			
	Case 1	Case 2	Case 3*	Case 4**
≤ 350 kWh	30%	3%	28%	30%
≤ 500 kWh	43%	8%	41%	72%

General Assumptions

State of Charge (SoC)	75%
Additional consumption cooling for conditioned	6kW

* *Part truck days conditioned*

** *All truck days conditioned*

Appendix

Source of consumption figures used

Consumption figures of electric vehicles are based on the following sources:

- TNO, 2013: Performance of Battery Electric Buses in Practice: Energy Consumption and Range.
- TNO, AMS Study 2018: Laadinfrastructuur voor elektrische voertuigen in Stadslogistiek.
- TNO, 2021: Towards 100% electric distribution transport: the impact on the energy system.
- www.volvotrucks.com/en-en/news-stories/press-releases/2022/jan/volvos-heavy-duty-electric-truck-isput- to-the-test-excels-in-both-range-and-energy-efficiency.html.
- Panteia, 2022: TCO-ZET-Freight-v2.0.
- Elaad, 2019: Marktverkenning Elektrische trucks Stadslogistiek.
- de Rooy Transport.
- T&E, 2018: Analysis of long haul battery electric trucks in EU.
- California, 2018: Battery Electric Truck and Bus Energy Efficiency Compared to Conventional Diesel Vehicles.

Tractor-trailer consumption

Semi-trailer tractor unit	Energy consumption with average load (kWh per km)			Energy consumption empty (kWh per km)	Sources
GVW/GTW	Min.	Average	Max.		
30 - 40		1.4			Peter de Rooy
32	1.24	1.31	4.35**		California, 2018: Battery Electric Truck and Bus Energy Efficiency Compared to Conventional Diesel Vehicles
37		1.8			TNO, 2021: Naar 100% elektrisch distributievervoer: de impact op het energiesysteem
				1.75	TNO, AMS study 2018: Laadinfrastructuur voor elektrische voertuigen in stadslogistiek
<40		1.39			Panteia, 2022: TCO-ZET-Vracht-v2.0
>40		2.09			Panteia, 2022: TCO-ZET-Vracht-v2.0
40	1.1	1.36	1.6		T&E, 2018: Analysis of long haul battery electric trucks in EU, Elaad, 2019: Marktverkenning Elektrische trucks Stadslogistiek, www.volvotrucks.com

	Energy consumption with average load (kWh per km)		
	Min.	Average	Max.
Tractor-trailer	1.1	1.79	2.8

* *In case of multiple sources figures are based on the min, average and max of a combination of those sources.*

** *= situation uphill, not representative of average.*

Consumption large box truck

Semi-trailer tractor unit	Energy consumption with average load (kWh per km)			Energy consumption empty (kWh per km)	Sources
GVW/GTW	Min.	Gem.	Max.		
>18		1.34			Panteia, 2022: TCO-ZET-Vracht-v2.0
19				0.91	TNO, AMS study 2018: Laadinfrastructuur voor elektrische voertuigen in stadslogistiek.

	Energy consumption with average load (kWh per km)		
	Min.	Average	Max.
Large box truck	1.25	1.43	1.8

Consumption medium box truck

Medium box truck	Energy consumption with average load (kWh per km)			Sources
GVW/GTW	Min.	Average	Max.	
12		0.7		Peter de Rooy
14 - 16		1.15		TNO, 2013: Performance of Battery Electric Buses in Practice: Energy Consumption and Range.
12 - 18		0.95		Panteia, 2022: TCO-ZET-Vracht-v2.0
16	0.8	1.03	1.2	Elaad, 2019: Marktverkenning Elektrische trucks Stadslogistiek.
18		0.9		Peter de Rooy

	Energy consumption with average load (kWh per km)		
	Min.	Average	Max.
Medium box truck	0.7	0.93	1.2

Consumption large box truck + trailer

- No sources were found for the electrical consumption of a large box trucks with trailer.
- However, a study by Panteia (panteia.nl/index.cfm/_api/render/file/?method=inline&fileID= 5B52D01F-D3BA-4170-9179D3CC1C0706B5) showed that the fuel cost for a box truck with trailer is 3% higher than for a tractor trailer.
- The assumption is that at equal weights, a tractor-trailer is more efficient because there is less distance between the tractor and the trailer and the overall length is shorter.
- Following the Panteia study mentioned above, we estimated that the consumption of an electric box truck with trailer is 3% higher than the consumption of the tractor trailer.

	Energy consumption with average load (kWh per km)		
	Min.	Average	Max.
Large box truck + trailer	1.13	1.85	2.85

Topsector Logistiek
Ezelsveldlaan 59
2611 RV Delft
+31 15 251 65 65
www.topsectorlogistiek.nl

Topsector Logistiek